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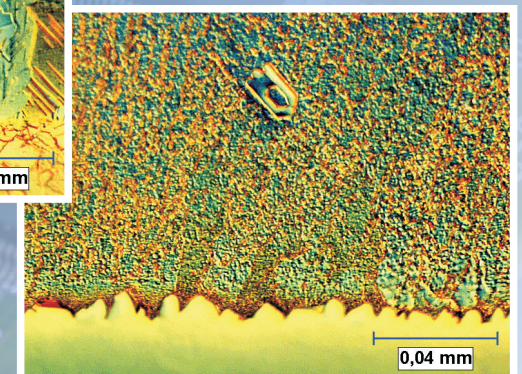
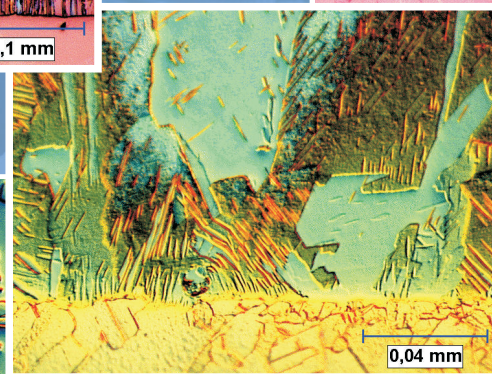
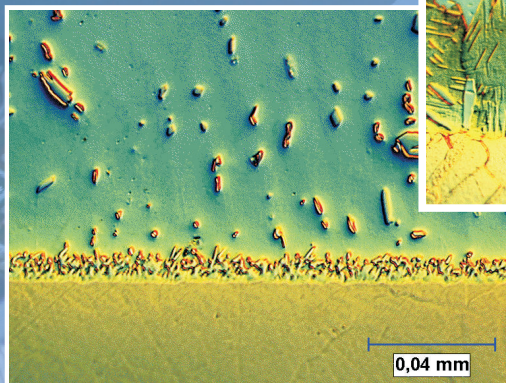
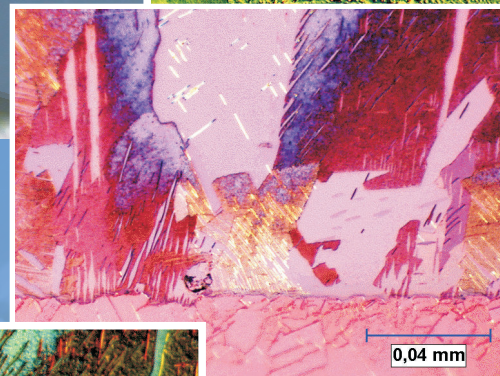
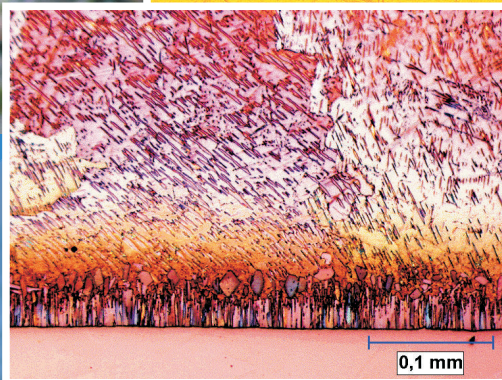
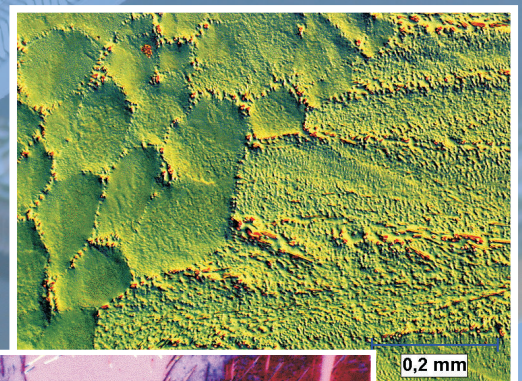
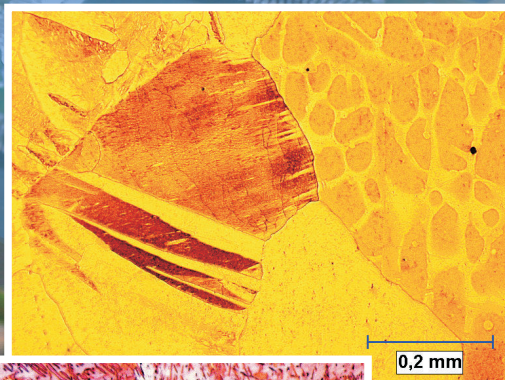
Artur Kudyba
Rafał Nowak

ATLAS

of microstructures

of solder alloys and solder/metal interfaces

Part I: Optical Microscopy



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Under the sponsorship of:

- Ministry of Science and Higher Education of Poland
- Foundry Research Institute - Cracow
- Motor Transport Institute - Warsaw

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Summary

This volume of the Atlas encloses the results of structural characterization of a wide group of lead-free solder alloy candidates and solder joints examined by means of optical color microscopy. The structural features have been distinguished by comparative examination using conventional light, polarized light and phase contrast or using etching in acid solutions.

Main attention is focused on the Sn-based alloys as a key family of lead-free solders for microelectronics. The collection of color micrographs includes the structures of:

- pure Sn and other metals used as base materials of solder alloys, alloying additions or materials to be joined by soldering (Ag, Bi, Cu, In, Zn)
- binary (Sn-X) and ternary (Sn-X-Y) alloys
- interfaces of couples of dissimilar materials (Sn/X, X/Y)
- interfaces of solder joints with Cu and Ni (Sn/Cu, Sn/Ni, Sn-X/Cu)

The effect of type and amount of alloying additions on microstructure of solder itself and on consequent interface structure of solder joint is demonstrated in comparison with phase diagrams corresponding to either alloy or contact systems. For selected solder/substrate couples, the influence of solid particulate reinforcement (composite solders) is also exposed.

The results of structural characterization are compared with experimental data on solderability and shear strength of solder/Cu and solder/Ni couples.

This edition contains a printed collection of microstructures (Atlas of microstructures) and two CDs.

The first CD (ISBN 978-83-60965-08-5) presents a collection of the results of structural characterization by scanning electron microscopy done on polished samples of selected alloys and solder/substrate couples shown in the Atlas. The chemistry of distinguished phases has been estimated by EDS analysis

The second CD (ISBN 978-83-60965-12-2) presents the Synt@ll database containing information on different properties of elements of the periodic table as well as criteria of binary phase diagrams used for selection of alloying additions for the lead-free solder alloys. It contains also experimental data on solderability and shear strength of solder joints in selected systems.

The publication was prepared in frame of COST Action 531 of the European Commission entitled "Lead-free Solder Materials".

Financial support for research and publication was provided from the Ministry of Science and Higher Education of Poland, the Foundry Research Institute in Cracow and the Motor Transport Institute in Warsaw.

Foreword

Lead and lead-containing compounds are among the most toxic substances and thus global economics forces the development of new generation solder materials to replace widely used Pb-containing ones.

In order to solve this problem, the widespread studies are undertaken all over the world, accompanied with different actions involving many research groups and industrial companies at national and international levels. One of them was COST Action 531 entitled "Lead-free Solder Materials" that presented intergovernmental cooperation network organized and financed in frame of European Cooperation in the field of Scientific and Technical Research as one of the longest-running European instruments supporting cooperation among scientists and researchers across Europe.

COST Action 531 was coordinated by Professor Herbert Ipser from the Department of Inorganic Chemistry at University of Vienna, Austria. The objective, defined goals and deliverables of COST Action 531 are presented in details at <http://www.univie.ac.at/cost531> and <http://www.cost.esf.org> websites.

45 research institutions from 19 countries were involved in different activities of this Action in frame of 4 Working Groups. Among others, the activity coordinated by W.J. Plumbridge and Milton Keynes (UK) as well as N. Sobczak (Krakow, Poland), was focused on characterization of physical and chemical properties of both solder alloy candidates and solder joints.

This publication summarizes the authors' contribution to the COST Action 531 and particularly to structural characterization of a wide group of selected alloys and solder joints as one of the tasks of Working Group 3-4.

In this volume of the ATLAS, the authors have placed together an impressive systematic collection of the color optical microscopy microstructures of both Sn-based alloys as well as the alloys of miscellaneous systems that are important from the viewpoint of synthesis of Pb-free solders and of understanding the formation of solder joints with different materials.

Besides the role of the type and amount of alloying additions, the photomicrographs also emphasize and compare the effects of sample preparation (unetched and etched) and of conditions for structural observations (conventional light, polarized light or phase contrast) that present an important and useful value for the researchers and practicing engineers in distinguishing the essential features of materials structure under different optical microscopy magnifications.

June 2009

Professor Wojciech Aleksander Przetakiewicz
Motor Transport Institute
Warsaw, Poland

1. Preface

This volume of the Atlas contains the results obtained by the authors working for two collaborating Polish institutions, Foundry Research Institute in Cracow and Motor Transport Institute in Warsaw that took part in COST Action 531 "Lead-free Solder Materials". One of the activities of Working Group 3-4 was focused on detailed structural characterization of the Pb-free solder alloy candidates.

The structural analysis was made by different procedures of color optical microscopy in order to distinguish essential features of materials microstructure under a wide range of optical microscopy magnifications from 25x to 500x.

The collected photomicrographs are divided in three main groups. The first group includes pure metals used either as solder base material (Sn, Ag), solder alloying elements (Ag, Bi, Cu, In, Zn), or as materials to be soldered (Cu, Ni). The second group corresponds to binary systems, while the third group collects the data on selected ternary systems. Its analysis starts from a comparison of phase diagrams known from the literature and calculated by the partners of COST Action 531 in frame of activities of Working Group 1. Next, the results of structural characterization are compared with experimental data on solderability and shear strength of solder/Cu and solder/Ni couples.

Experimental data on structural characterization are presented separately for bulk alloys and model solder joints. Bulk alloys are binary (e.g. Sn-Ag, Sn-Bi) and ternary (Sn-Ag-Cu, Sn-Bi-Cu, Sn-In-Cu, Sn-Pb-Cu, Sn-Zn-Cu) alloys. Model solder joints present the couples of two materials corresponding to binary systems (e.g. Sn/Ag, Sn/Bi) and to ternary systems formed with binary alloys (Sn-Ag/Cu, Sn-Bi/Cu, Sn-In/Cu, Sn-Pb/Cu, Sn-Zn/Cu) or with ternary alloys (e.g. Sn-Ag-Cu/Cu).

The effect of the type and amount of alloying additions on the structure and morphology of binary and ternary alloys and on the interfacial structure formed with selected alloys and Cu or Ni substrates is evidenced. Additionally, a few photomicrographs of the couples produced with composite solders with SAC paste containing different amounts of Cu particles are also presented (e.g. SAC-10%Cu/Cu couple).

Besides the printed collection of color optical microscopy microstructures (ATLAS of microstructures), this edition contains also two CDs.

The first CD (ISBN 978-83-60965-08-5) presents a collection of the results of structural characterization by scanning electron microscopy done on polished samples of selected alloys and solder/substrate couples shown in the Atlas. The chemistry of distinguished phases has been estimated by EDS analysis

The second CD (ISBN 978-83-60965-12-2) presents the Synt@ll database containing information on different properties of elements of the periodic table as well as criteria of binary phase diagrams used for selection of alloying additions for the lead-free solder alloys. It contains also experimental data on solderability and shear strength of solder joints in selected systems.

Actually, the authors are continuing their systematic microstructure characterization of Pb-free solder alloy candidates at different structural levels by various testing methods. Those results are planned to be published in the next volumes of the ATLAS by extending the number of alloy systems and combinations with materials to be joined.

Acknowledgements

The authors wish to acknowledge the following Polish organizations for their financial support of the authors' participation in the COST Action 531 and corresponding execution of the research, the results of which are presented in this edition:

- Ministry of Science and Higher Education of Poland
- Foundry Research Institute in Cracow
- Motor Transport Institute in Warsaw.

Special thanks are directed to the authors of COST 531 Binary Database, Version I.I, 2004 (A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal) for their permission to use in this volume their data on phase diagrams calculated in frame of COST Action 531.

The authors also thank ASM International for the permission to reproduce the experimental phase diagrams from ASM Handbook Vol. 3: Alloy Phase Diagrams published by ASM International, Materials Park, Ohio in 1992.

2. Experimental Procedure

Materials

The ATLAS presents the collection of photomicrographs of four main groups of materials, divided as follows:

- I. Pure metals (Ag, Bi, Cu, In, Ni, Sn, Zn) in deformed (D) or as-cast (AC) state.
- II. Binary and ternary Sn-based alloys containing different additions of Cu, Ag, In, Bi, Zn and Pb (given in wt.%), prepared from pure metals of 99.9% purity by melting and casting under protective atmosphere.
- III. Interfaces formed between pure liquid metals and selected solid substrates (pure metals only) that represent contact systems, e.g. Sn/Ag, Sn/Cu, Sn/Bi.
- IV. Interfaces formed between liquid binary or ternary alloys and pure Cu substrates that correspond to contact systems named as Sn-X/Cu and Sn-X-Y/Cu (where X, Y are alloying additions).

Interfaces were examined on the solidified sessile drop samples produced during wettability tests. For comparison, similar tests were also made on Cu substrates with industrially available SAC paste (SnAg3Cu0.5) and composite paste prepared from SAC matrix and 10 vol% Cu particles of average size of 10 microns.

Sessile Drop Test

The solderability of selected metals and alloys was characterized by estimation of wetting properties applying the sessile drop method that makes possible the direct measurements of contact angle (θ) values. The contact angle presents a key technological parameter in selecting solder materials and corresponding soldering processes because a good wetting ($\theta < 90^\circ$) is required in order to produce high quality solder joints whereas solderability is optimized when θ is minimized.

Directly before wettability tests, the substrate samples were polished up to an average roughness of $R_a < 20$ nm, while the alloy samples to be melted (mainly Sn and its alloys) were cleaned mechanically. Next, both the substrate and the alloy samples were cleaned ultrasonically in acetone.

The wettability tests were carried out in experimental setup shown in Fig. 1a in different environments (dynamic vacuum, flux) using contact heating (Fig. 1b) at a rate of $\sim 20^\circ\text{C}.\text{min}^{-1}$ by introducing the solder/Cu couple into the furnace preheated to the experimental temperature T_{exp} . This procedure is more suitable for investigation of reactive systems, such as solder ones, since it allows to reduce the time of contact during heating a couple to T_{exp} , contrary to the widely-used procedure of slow *contact heating* when a couple of materials being in contact is first placed in the furnace and then long-time heated from room temperature to the test temperature.

The measurements of contact angles were done at T_{exp} from the image of a liquid solder drop placed on a solid substrate, as it is shown in Fig. 1c. For wettability tests with flux, the contact angles were measured on solidified samples at room temperature after removal of remaining amount of flux.

The measured values of contact angles θ together with corresponding testing conditions are collected in the tables for each examined system.

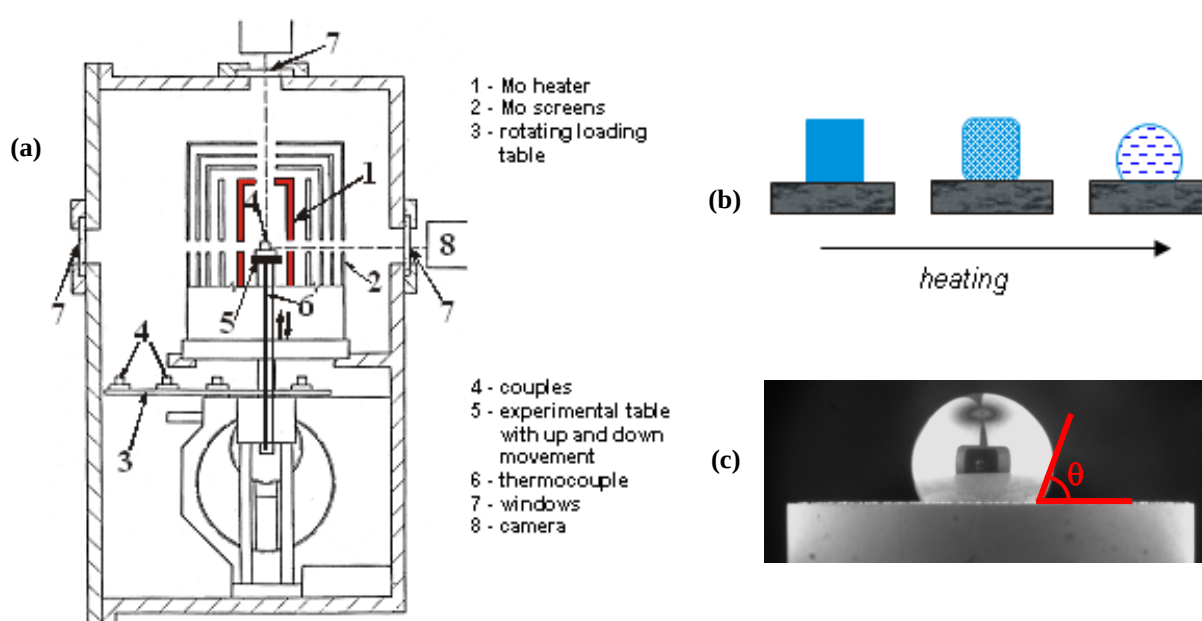


Fig. 1. Schematics of testing methods and procedures: (a) design of equipment for wettability tests by the sessile drop method; b) CH - contact heating procedure; c) estimation of a contact angle θ .

After wettability tests, depending on environmental used, the couples were cooled either in air by removing them from the furnace or under vacuum by moving the couples to a cold part of experimental chamber. The solidified sessile drop samples were bisected (Fig. 2a). One half of each sample was used for structural characterization of the interfaces, while the second half – for measurements of mechanical properties of interfaces by droplet push-off shear test (Fig. 2b).

Droplet Push-off Shear Test

Improved *droplet push-off shear tests* were used for characterization of bonding properties of model alloy/substrate joints by measurement of shear strength (τ) on the solidified sessile drop samples as described in details by Sobczak et al¹.

The tests were done on INSTRON 8802 machine using a special holder of own design. A load was applied to the flat end of the bisected couple (Fig. 2b) at a constant rate of $1 \text{ mm} \cdot \text{min}^{-1}$ and the load versus displacement data were digitally recorded until failure under shear occurred.

Assuming uniform distribution of shear stress along the line during the push-off test, the shear stress was calculated by dividing the maximum load by lateral interface area estimated from geometry of the drop/substrate contact under $\times 10$ magnification. Thus the value of shear strength (τ) of model solder joints corresponded to the value of maximum stress extracted from a stress-displacement curve recorded during testing of solidified drop/substrate couples.

The results of shear strength measurements (τ) together with corresponding processing conditions and contact angle measurements (θ) are collected in the tables for each examined system.

¹ N. Sobczak, J. Sobczak, B. Mikulowski, A. Wojciechowski, R. Nowak, A. Kudyba, P. Darlak, Application of push-off shear test for evaluation of wetting-interface structure-bonding relationship of solder joints, *Journal of Materials Science*, 2005, 40, 9/10, pp. 2547- 2552.

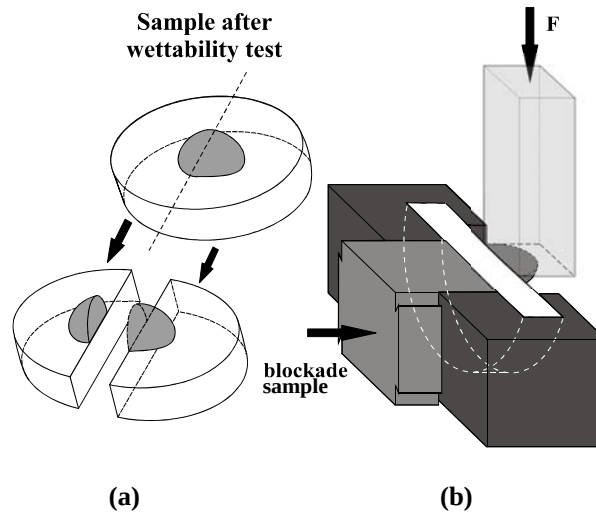


Fig. 2. Schematic of improved push-off shear test of solidified sessile drop samples including cutting of a sample after wettability test (a) and push-off shear test on a half of the sample (b).

Microstructure characterization

For structural examinations, the samples were grinded and next polished on automatic ROTOPOL 21 machine (Struers) using automatic dosing of diamond suspensions in the following order 9, 6, 3 and 1 μm . At the final stage of samples' polishing, the OPS lubricant was used. For selected samples, chemical etching was performed in order to distinguish the details of microstructure.

Structural examination was conducted on optical OLYMPUS PMG3 microscope under magnifications of 25-500 $\times$. In order to distinguish the details of microstructures, particularly interfaces of joints of dissimilar materials, the ATLAS contains the collection of color photomicrographs taken from both non-etched and etched samples. Additionally, the comparison of microstructures observed using conventional light (CL), polarized light (PL) or phase contrast (PC) is presented.

Photomicrographs of interfaces were taken from cross-sectioned samples (Fig. 3a) in such a way that a solidified drop is located on the top, while a solid substrate – on the bottom of each photomicrograph.

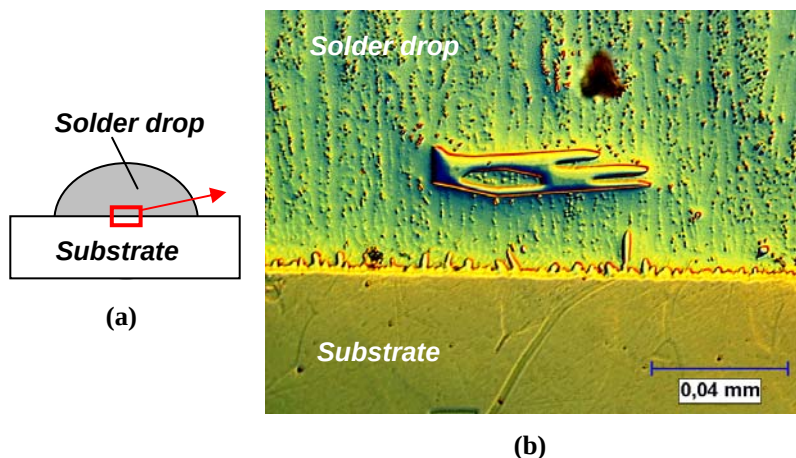


Fig. 3. Schematic of structural examination of cross-sectioned sessile drop sample (a) in selected area of interface observation (b).

Abbreviations

D – deformed metal (metal delivered after plastic deformation)

AC – as-cast metal

E – etched sample

NE – non-etched sample

mag. – magnification

CL – conventional light

PL – polarized light

PC – phase contrast

θ – contact angle (deg.)

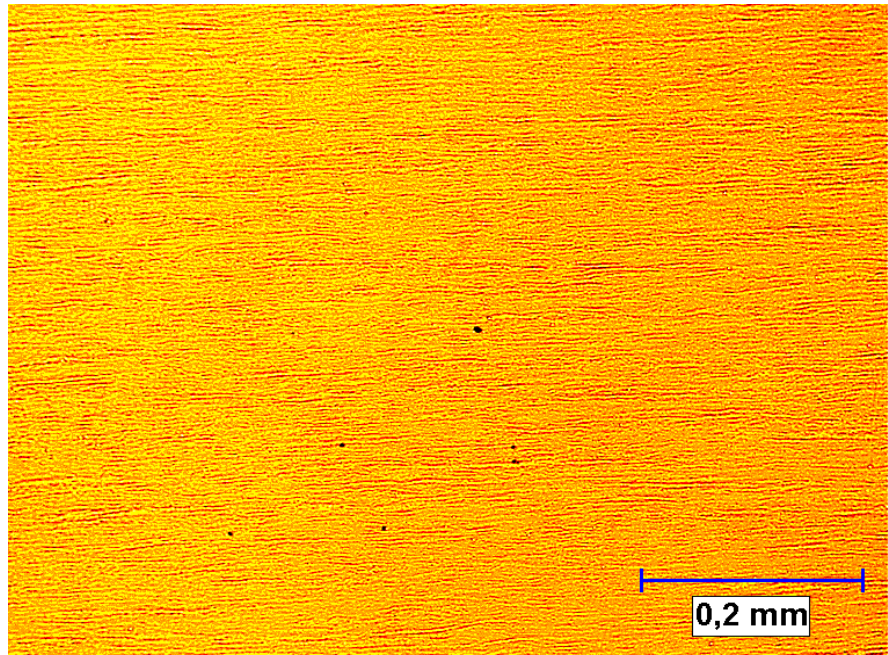
τ – shear strength (MPa)

Abbreviation of alloys: Sn-X, Sn-X-Y (X, Y – alloying elements)

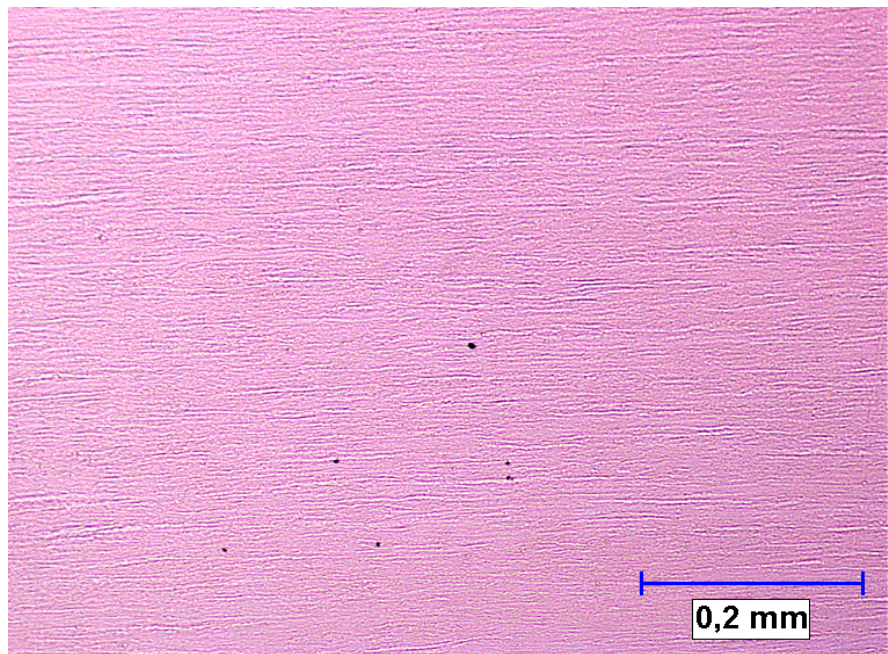
Abbreviation of couples: Sn/X (X – substrate)

3. Pure Metals

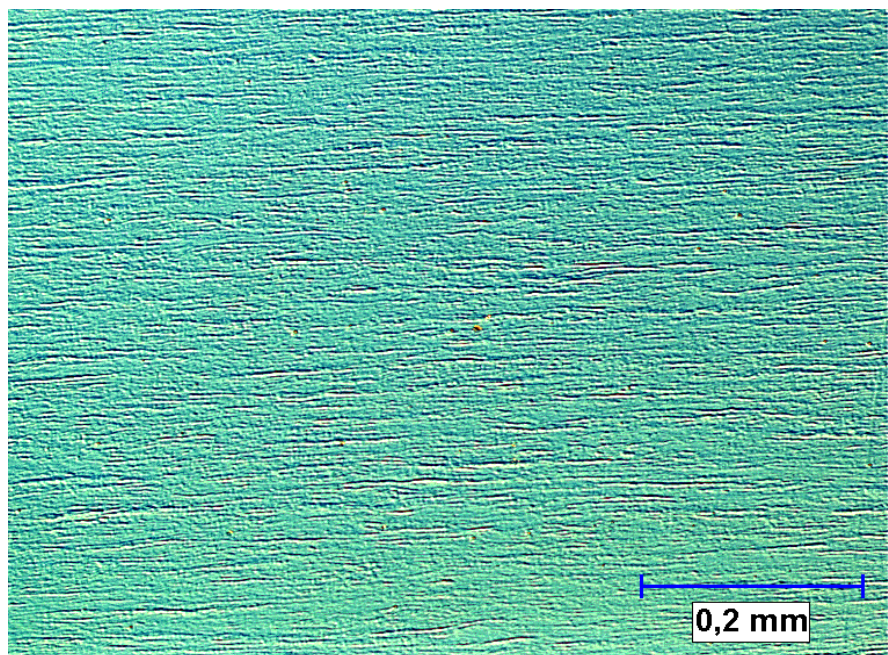
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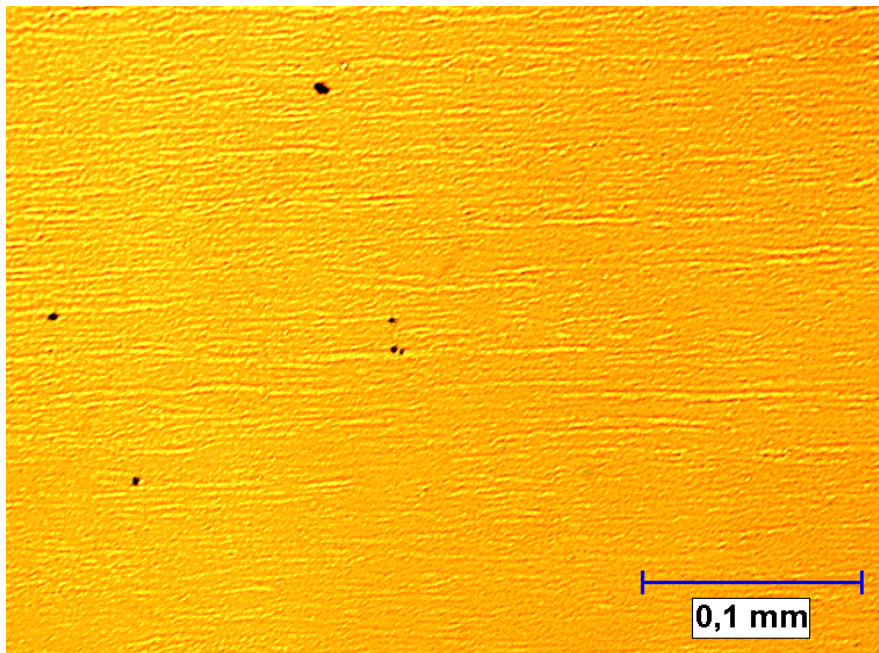


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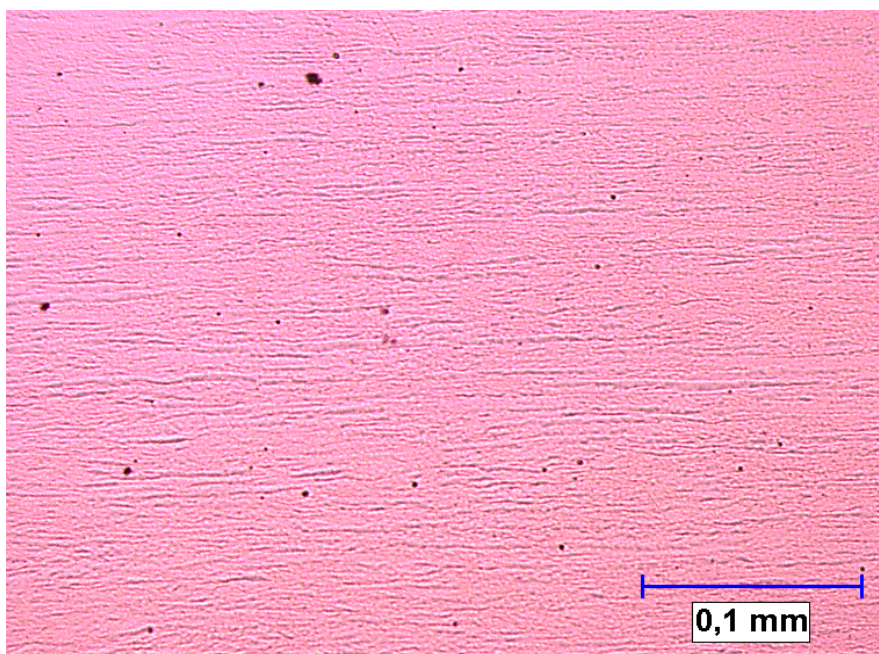


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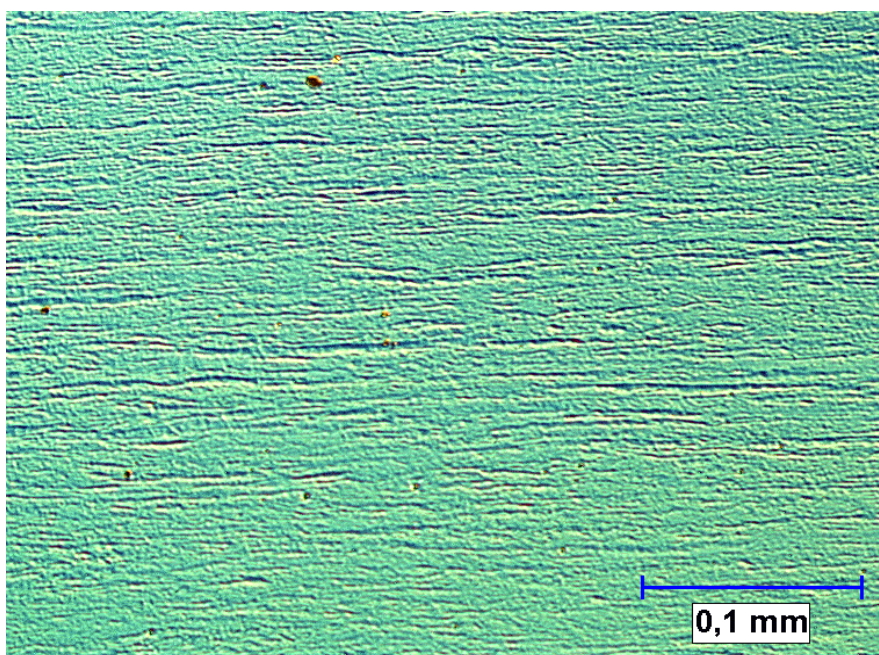




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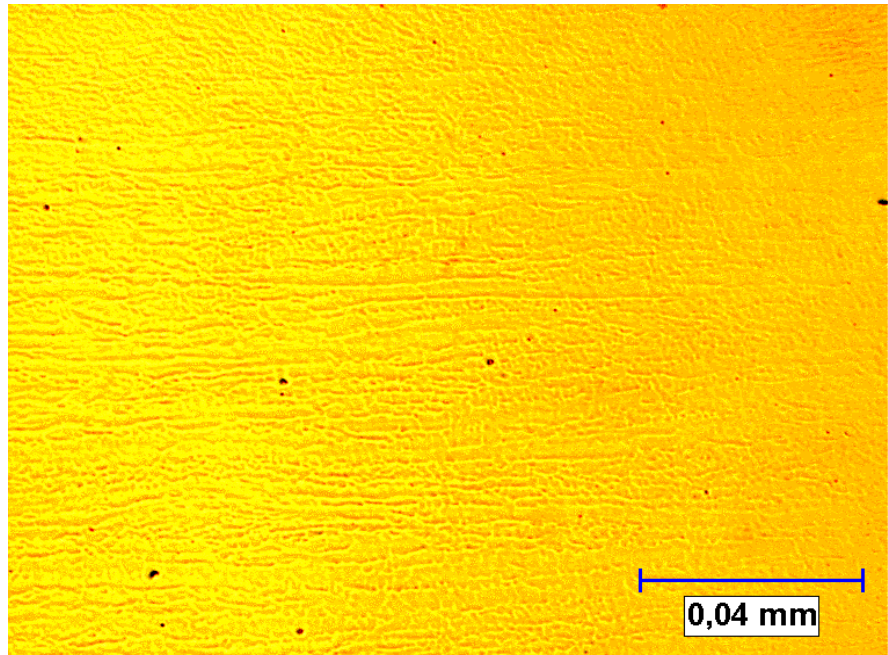


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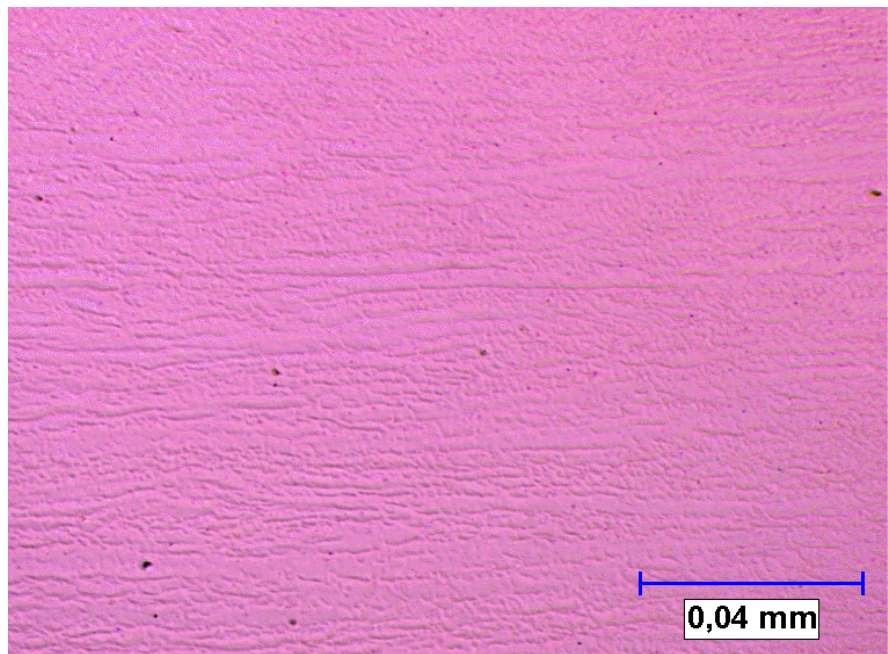


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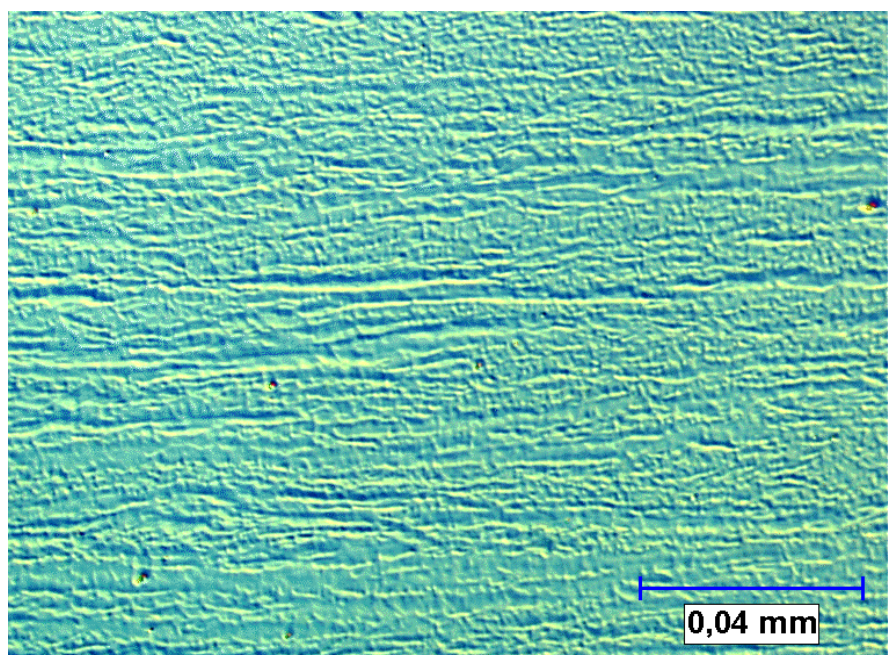
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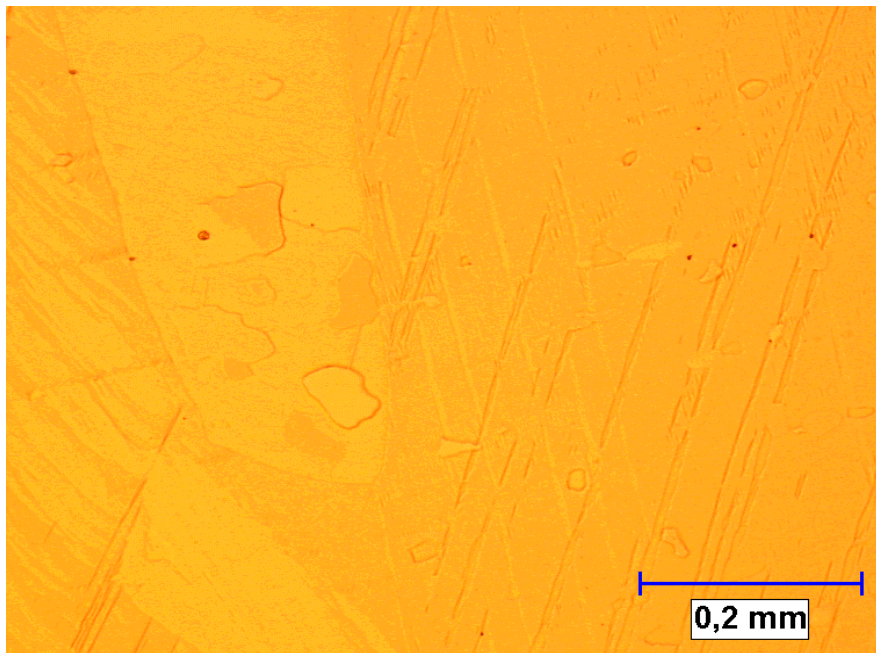


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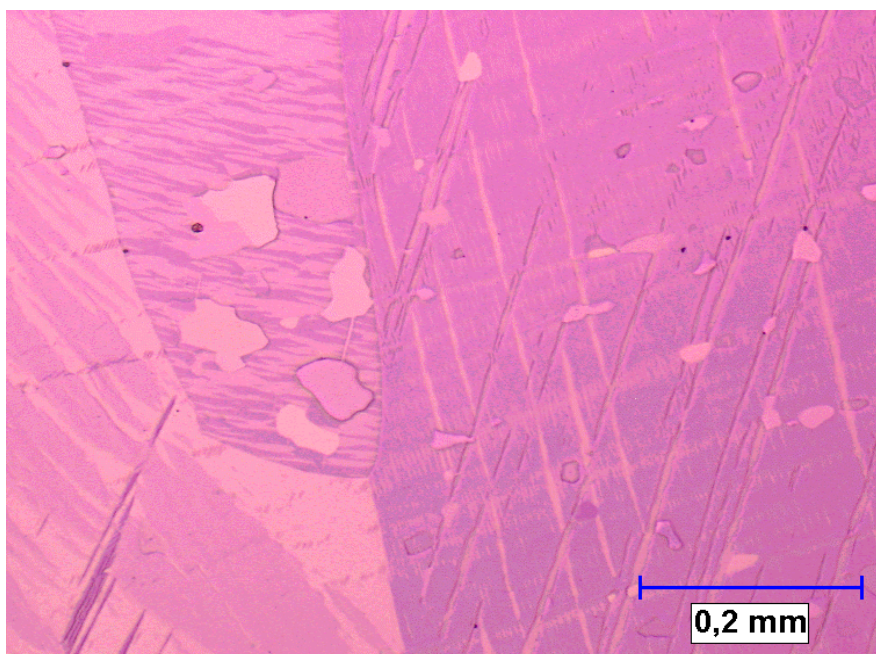


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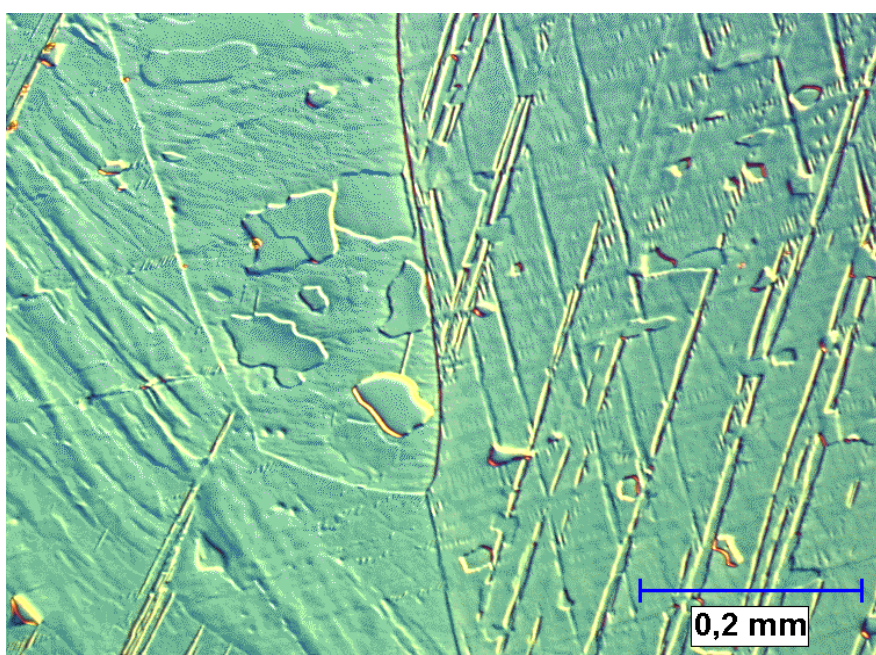




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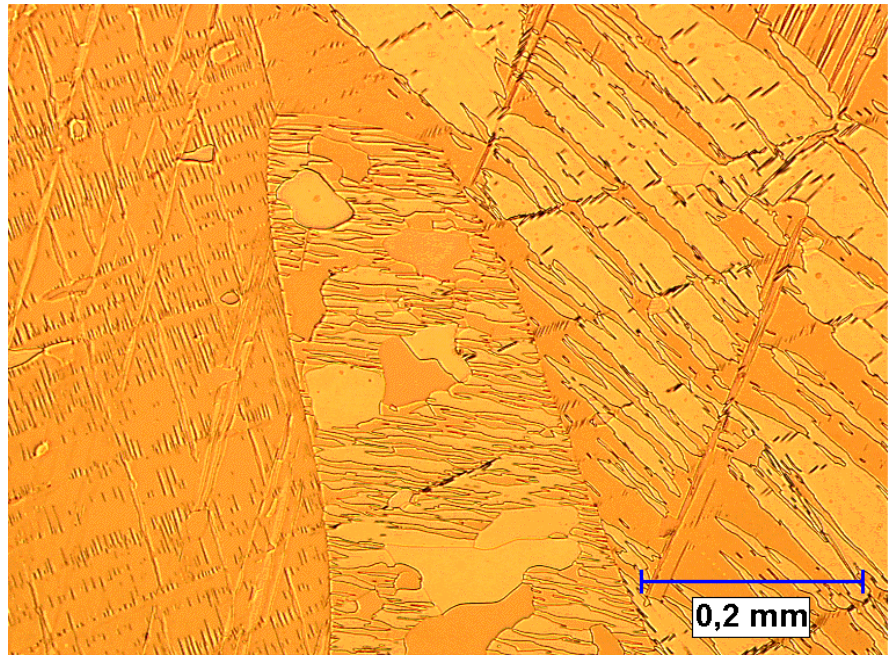


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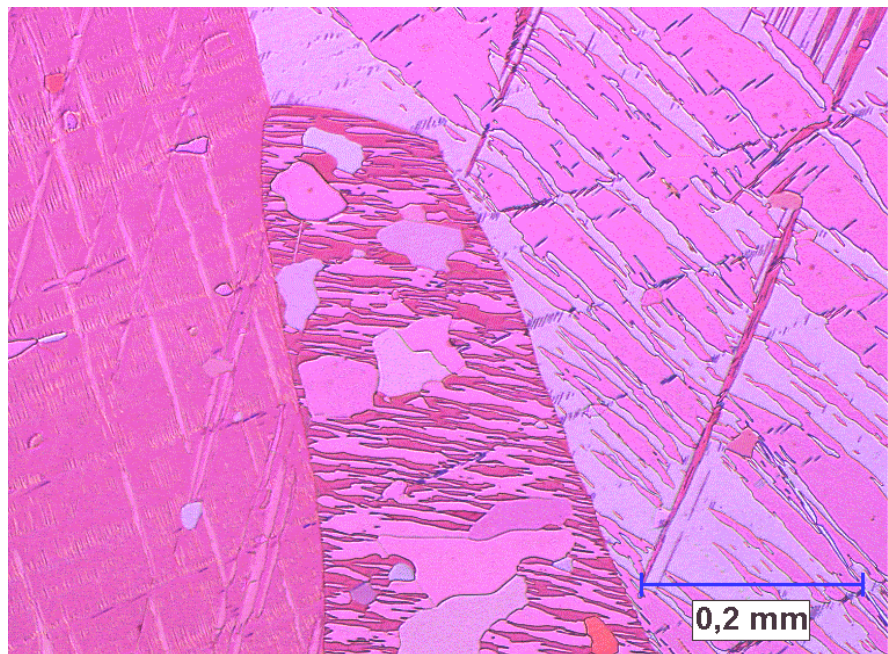


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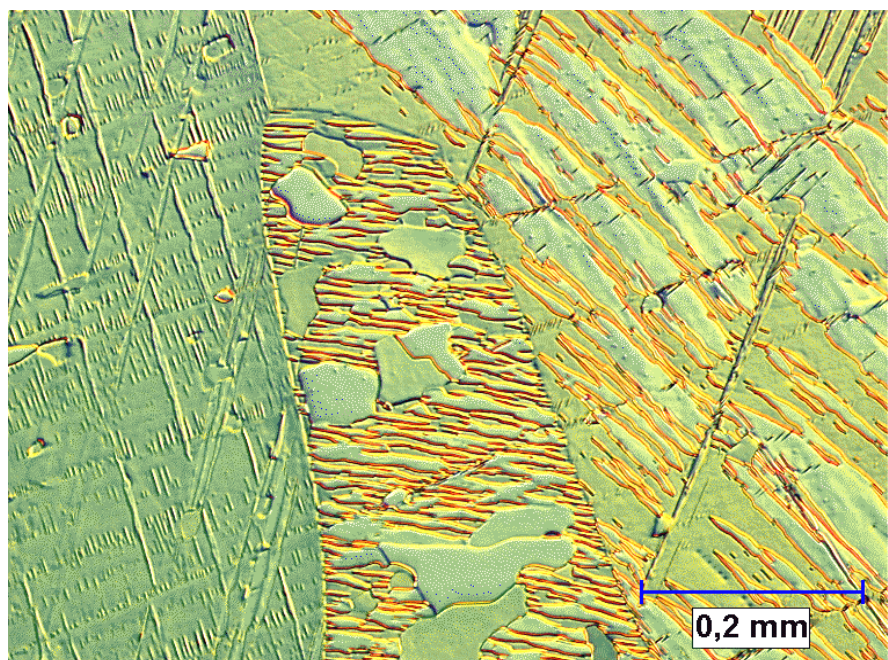
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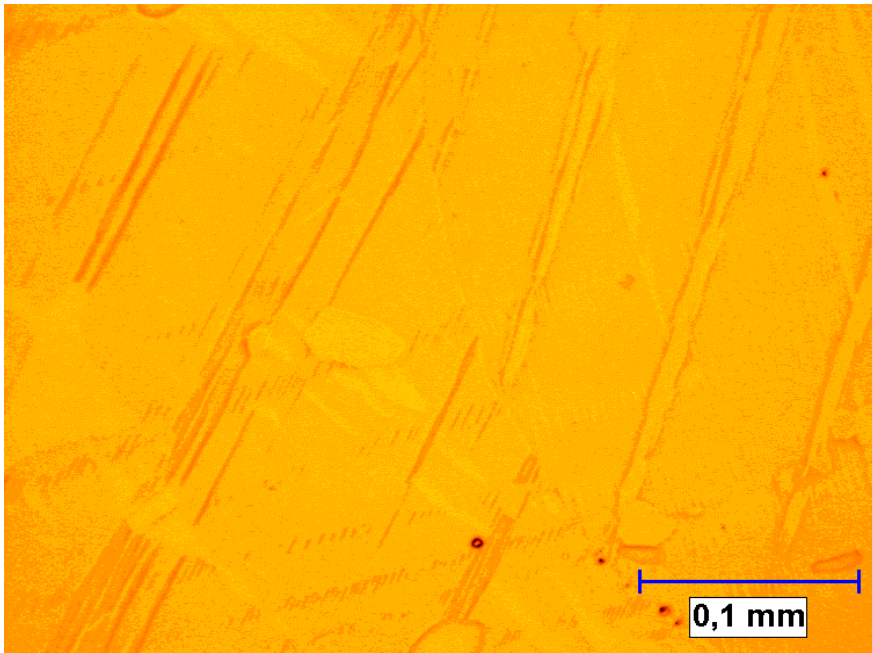


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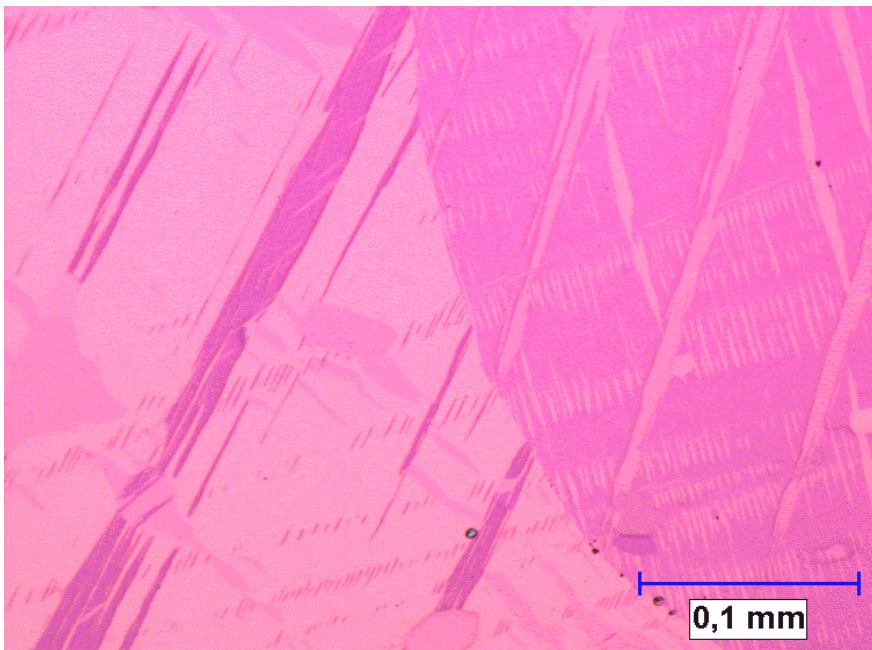


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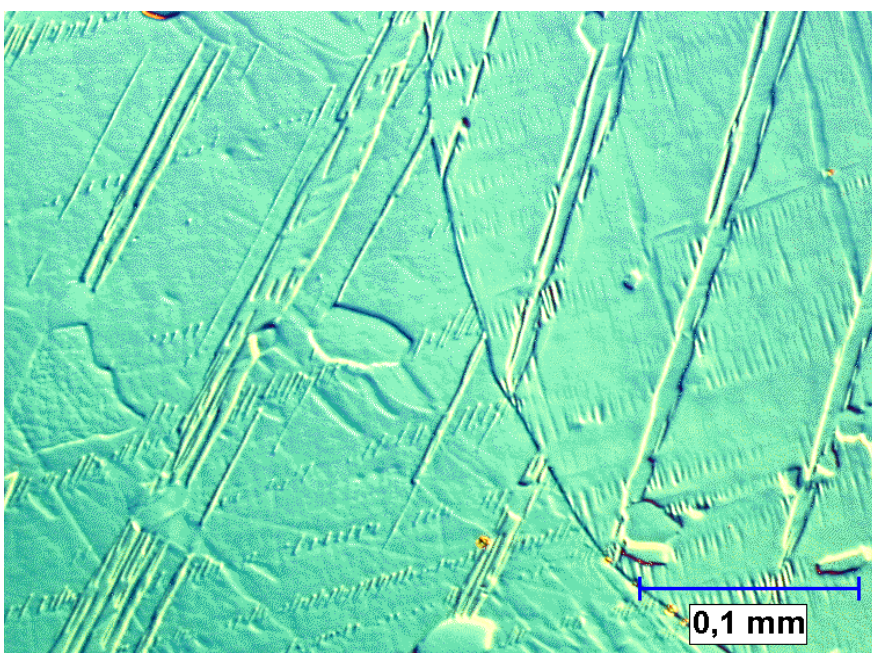




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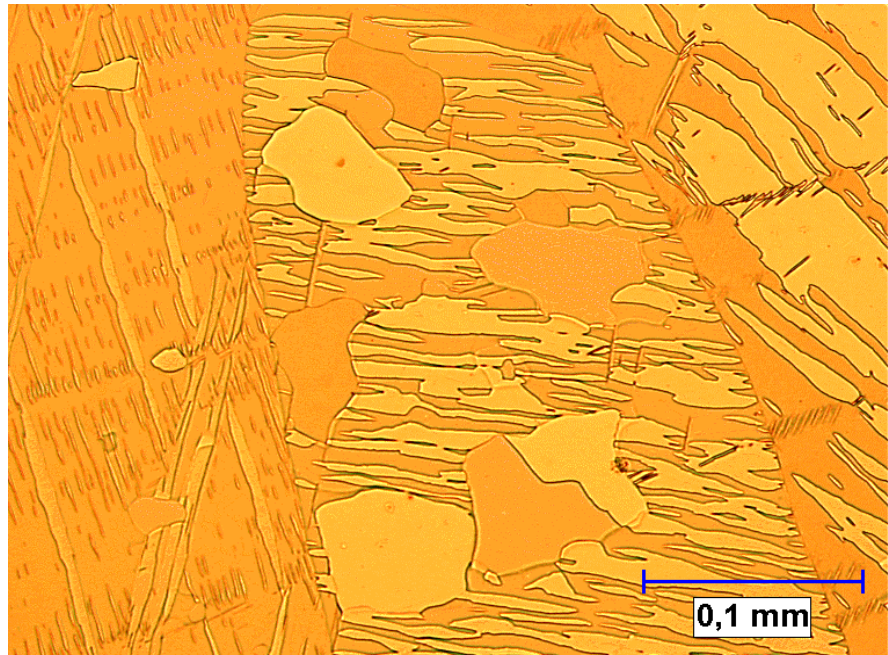


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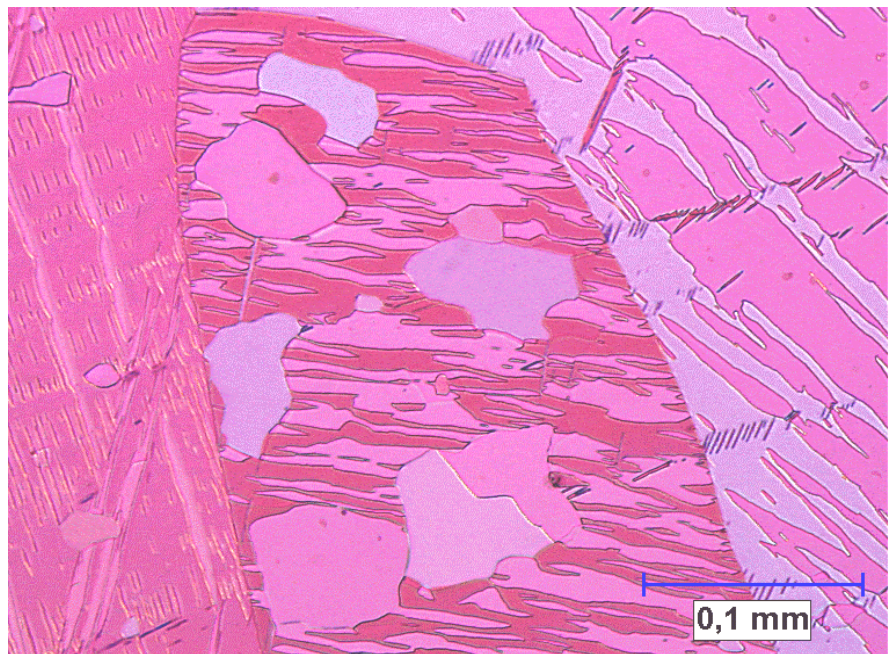


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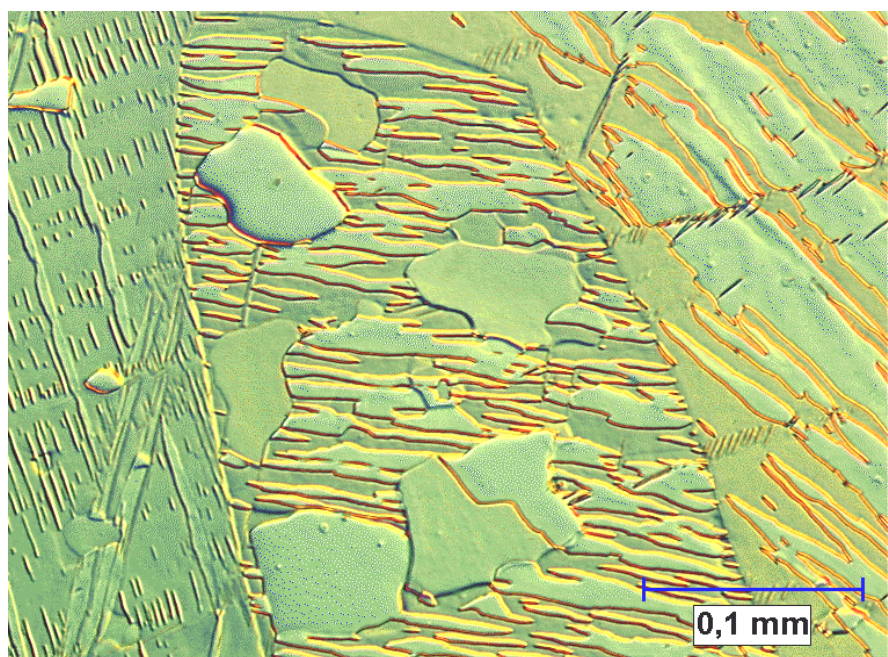
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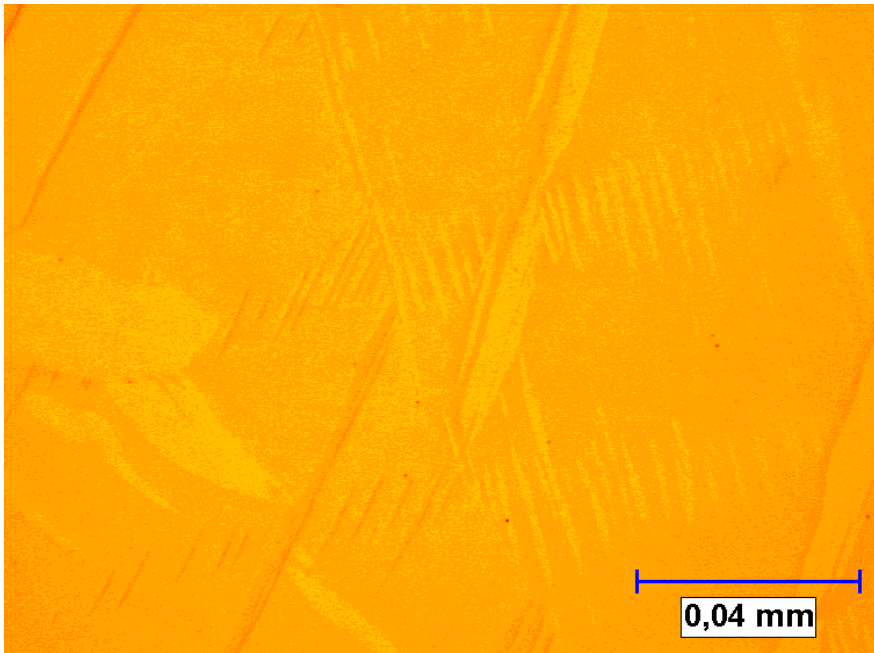


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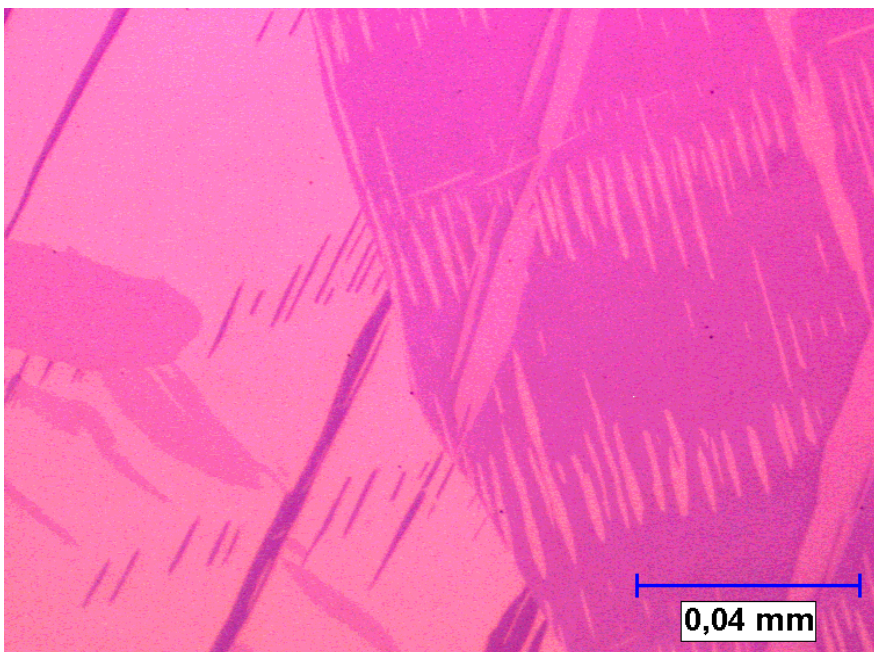


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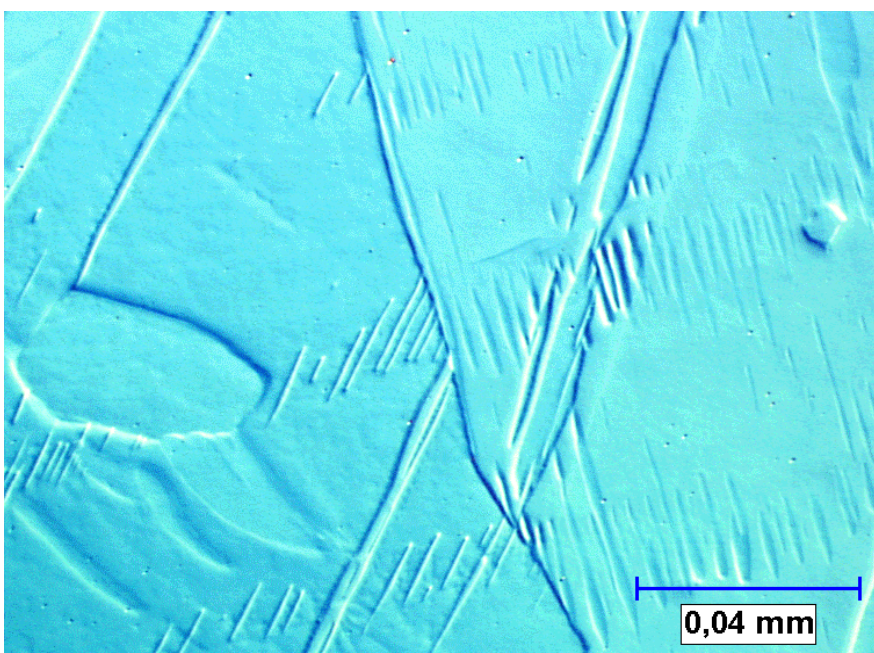




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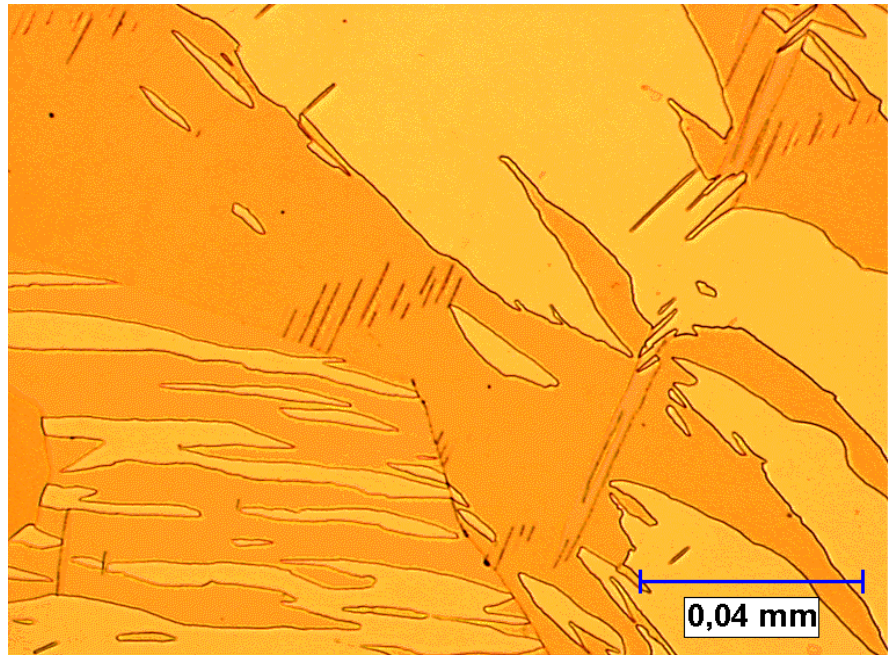


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PL

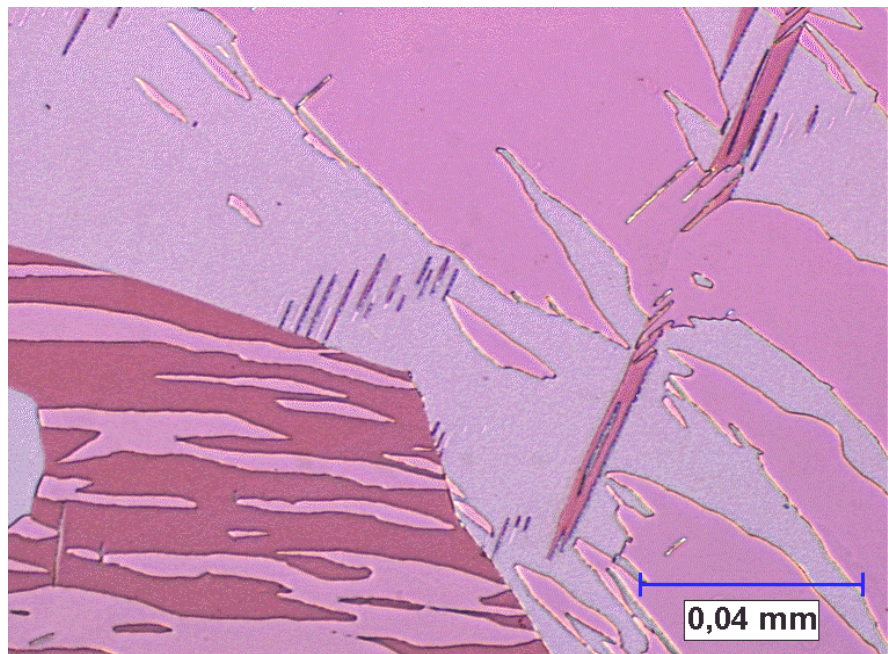


Bi (AC)
NE: mag. 500×
PC

Bi (AC)
E: mag. 500×
CL

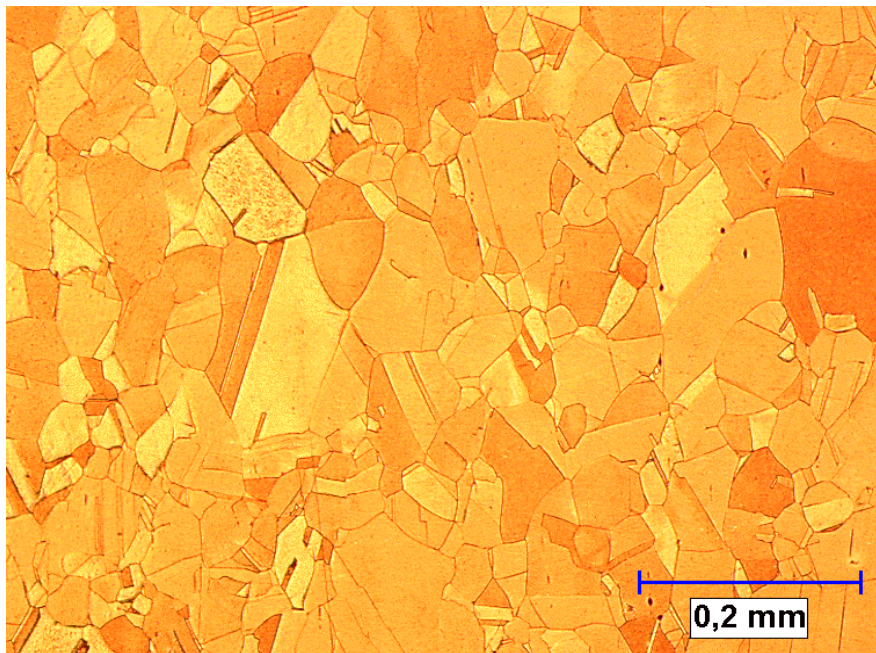


Bi (AC)
E: mag. 500×
PL

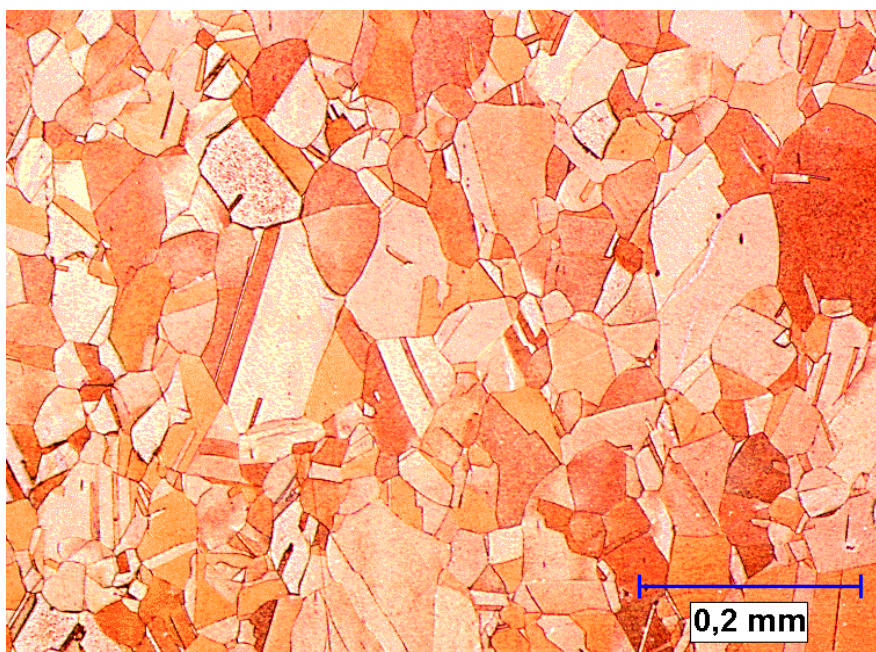


Bi
E: mag. 500×
PC

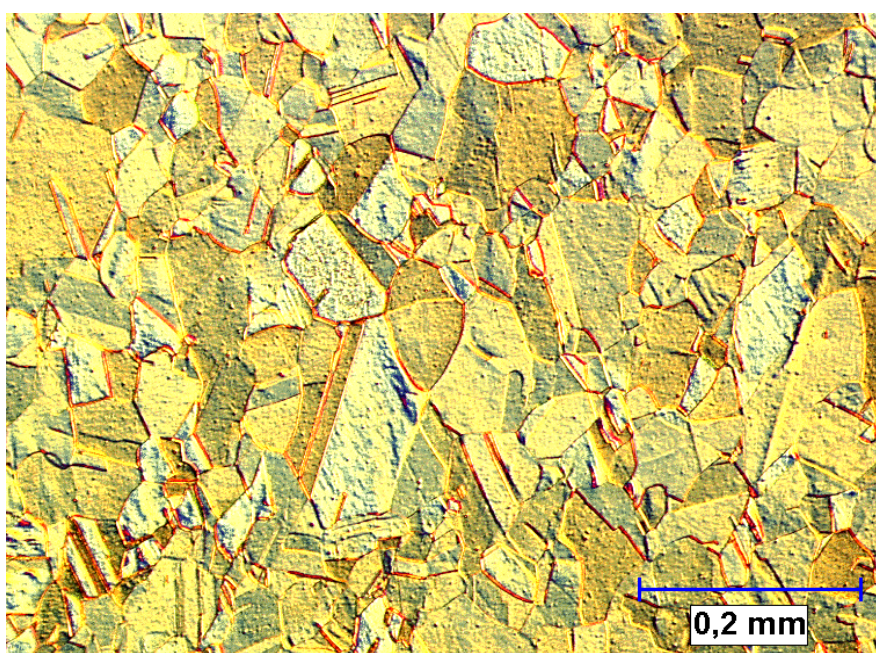




Cu (AC)
E: mag. 100×
CL

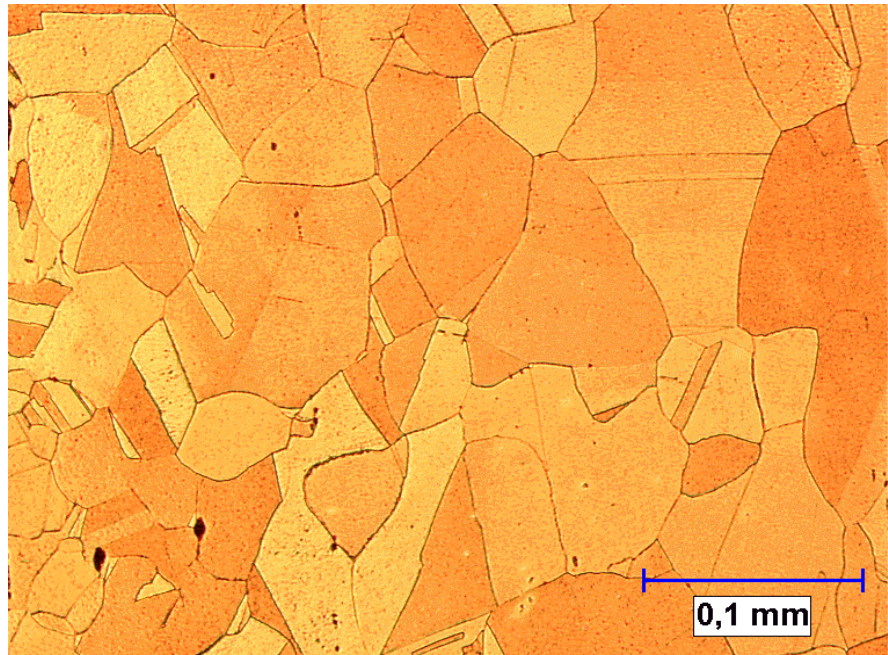


Cu (AC)
E: mag. 100×
PL

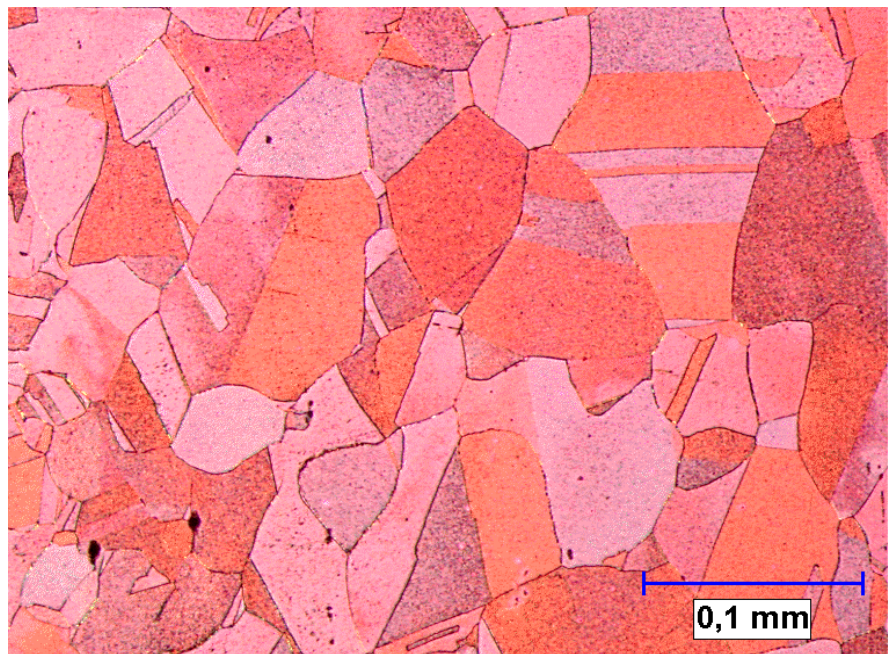


Cu (AC)
E: mag. 100×
PC

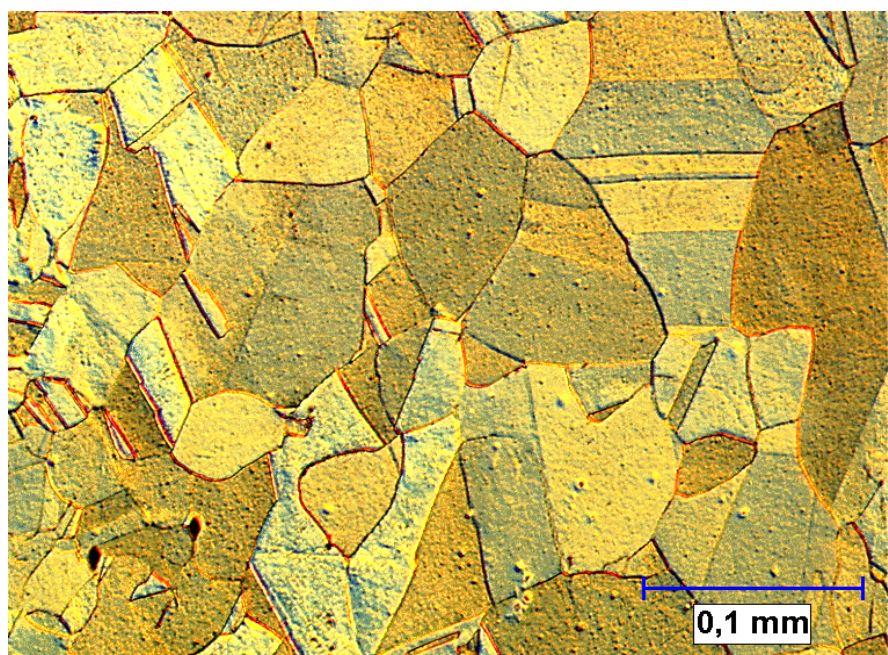
Cu (AC)
E: mag. 200×
CL

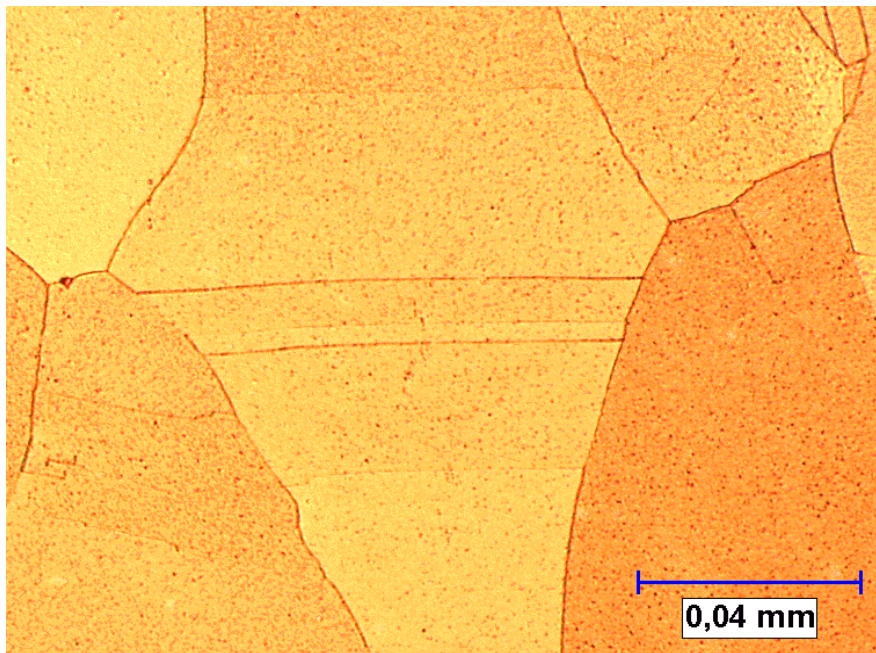


Cu (AC)
E: mag. 200×
PL

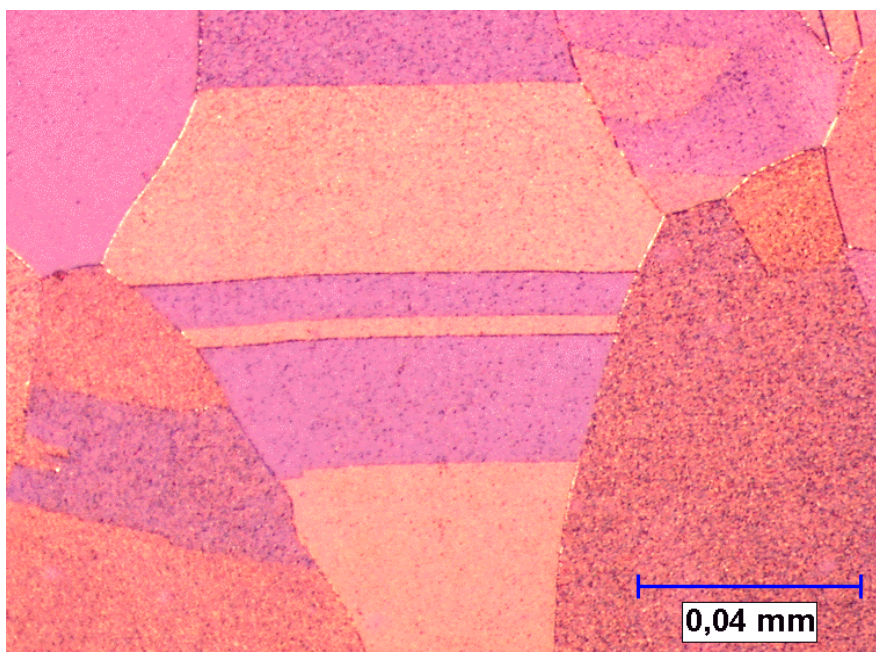


Cu (AC)
E: mag. 200×
PC

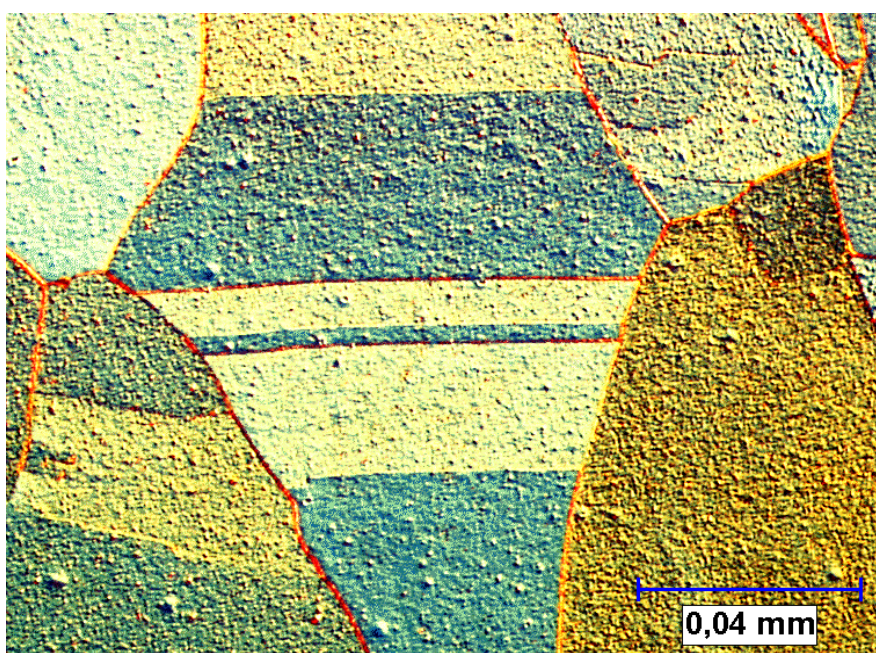




Cu (AC)
E: mag. 500×
CL

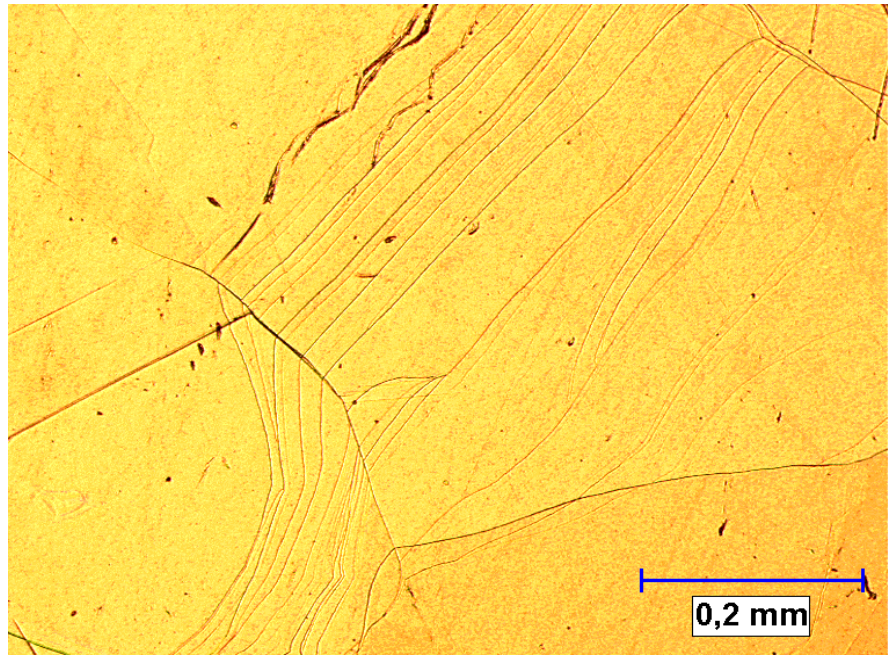


Cu (AC)
E: mag. 500×
PL

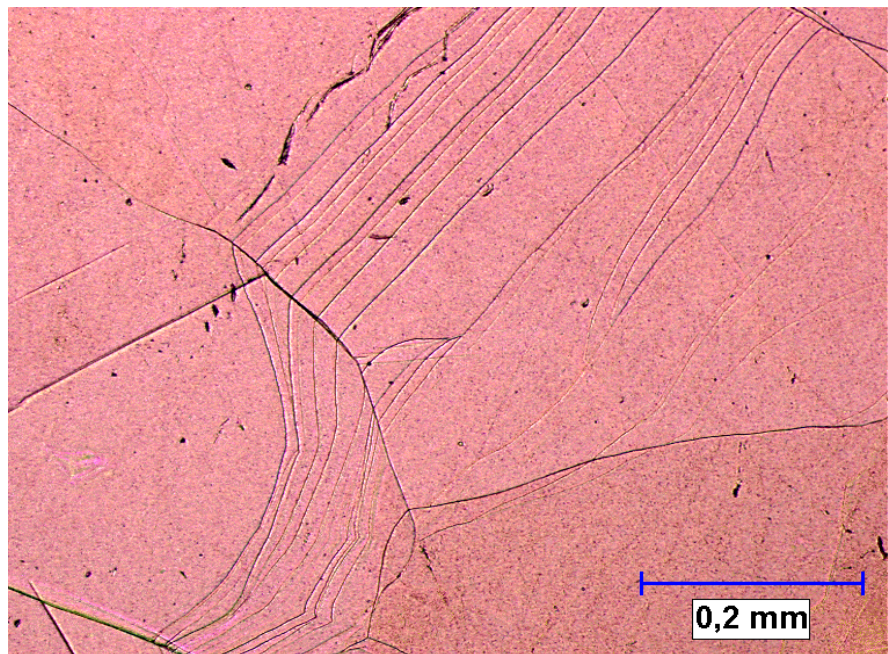


Cu (AC)
E: mag. 500×
PC

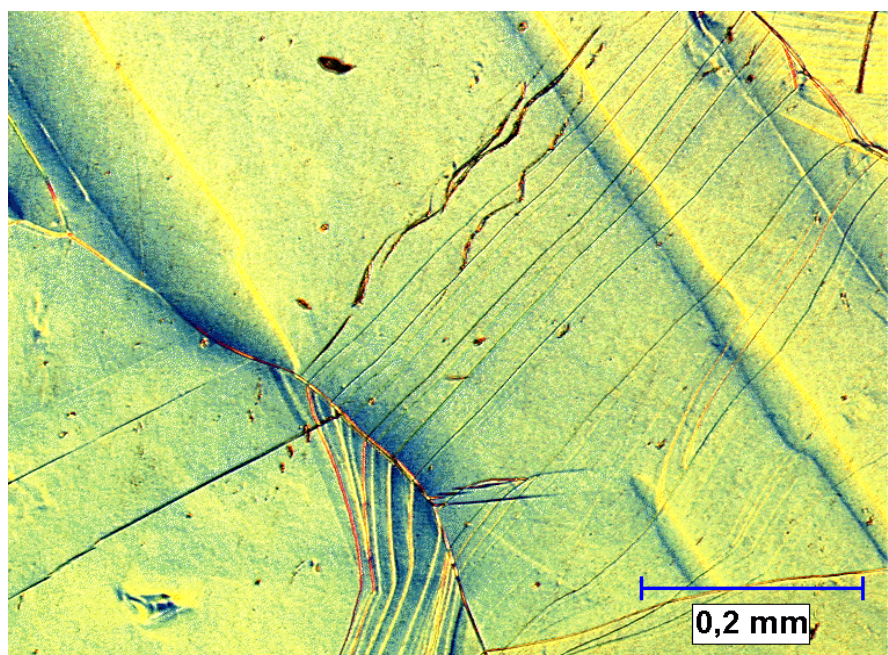
In (AC)
E: mag. 100×
CL

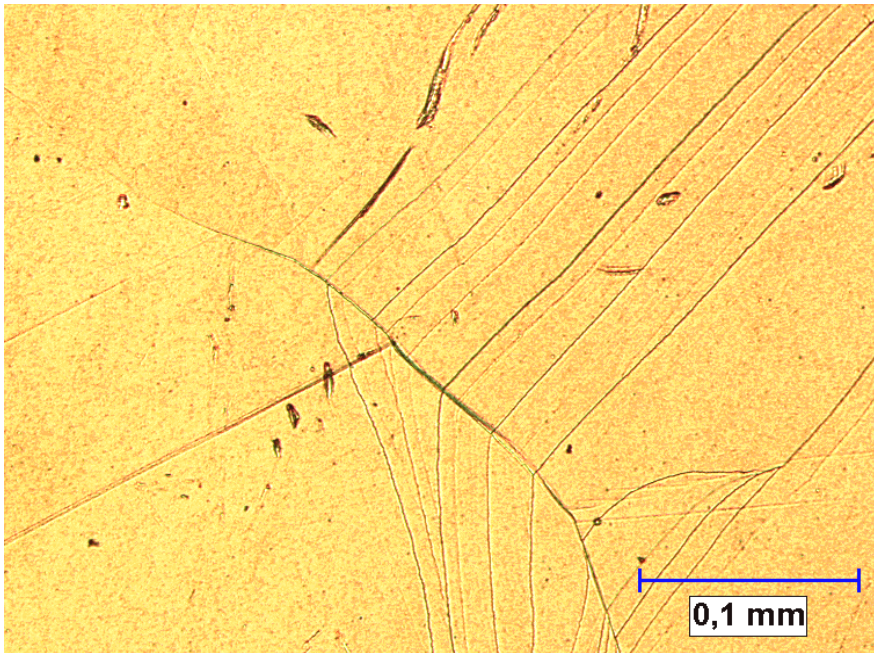


In (AC)
E: mag. 100×
PL

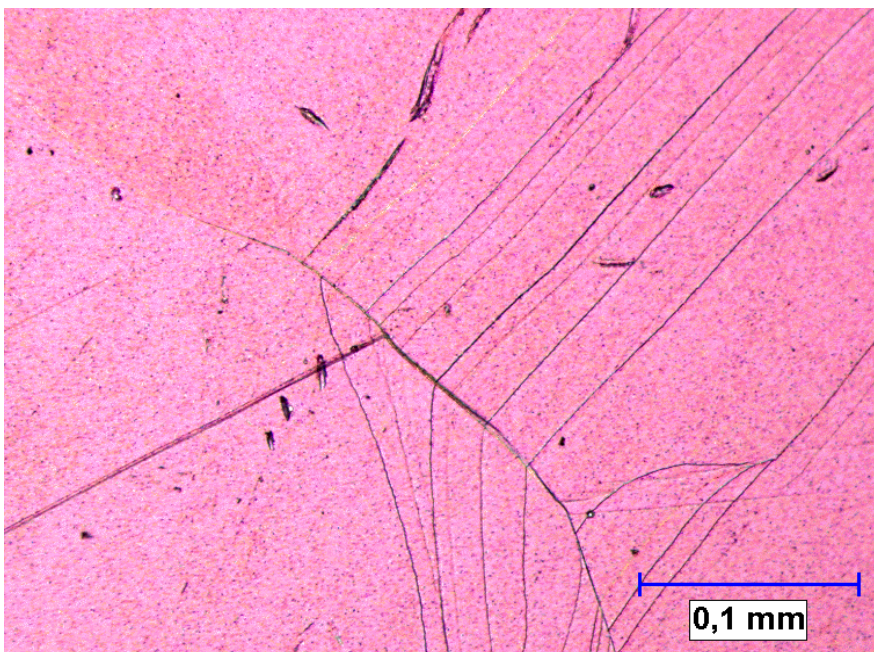


In (AC)
E: mag. 100×
PC

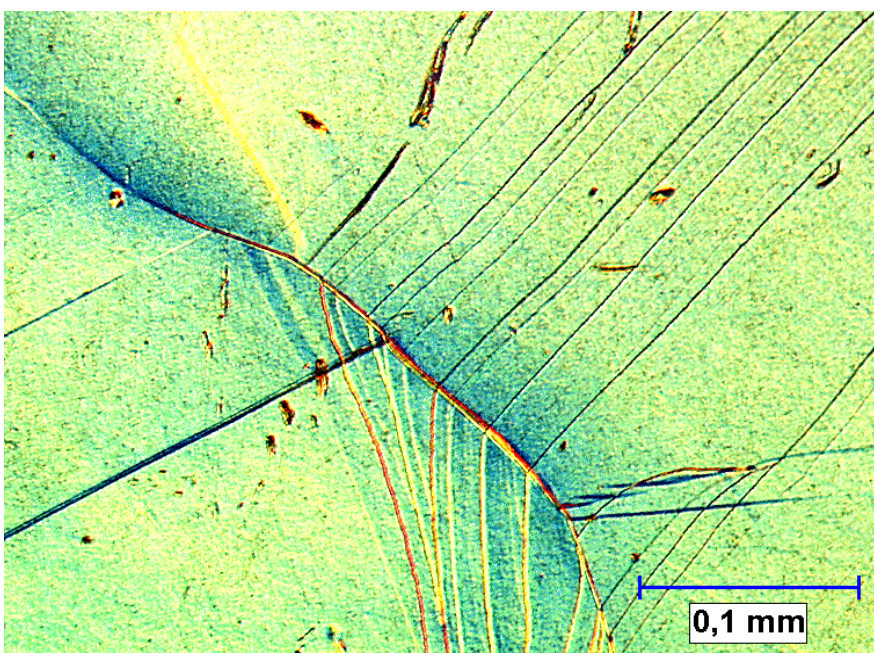




In (AC)
E: mag. 200×
CL

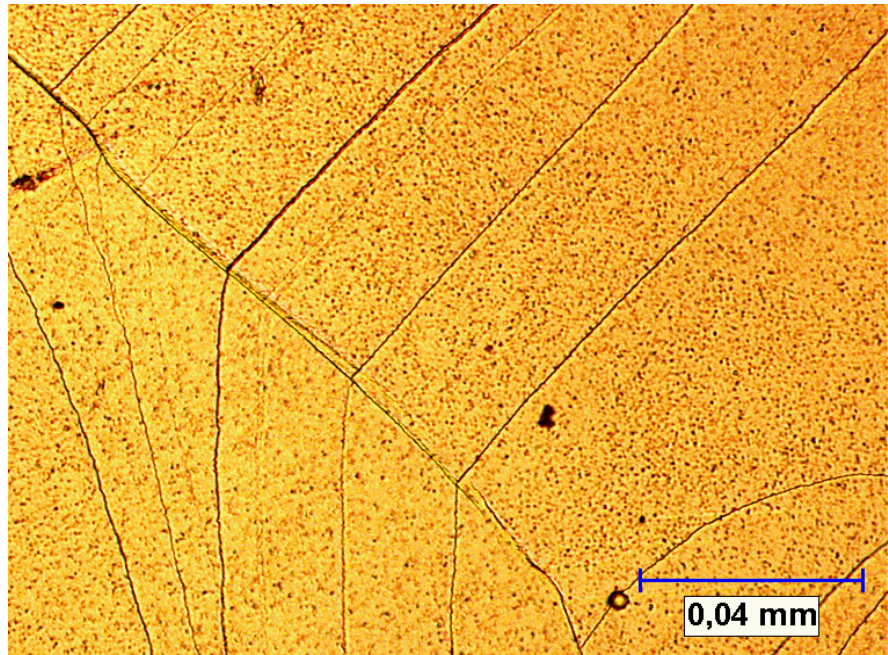


In (AC)
E: mag. 200×
PL

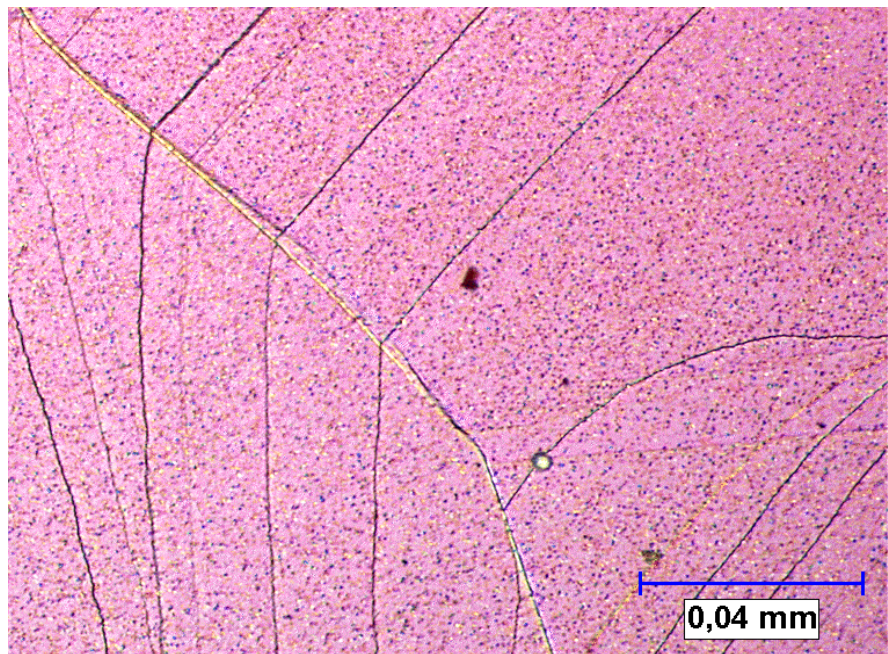


In (AC)
E: mag. 200×
PC

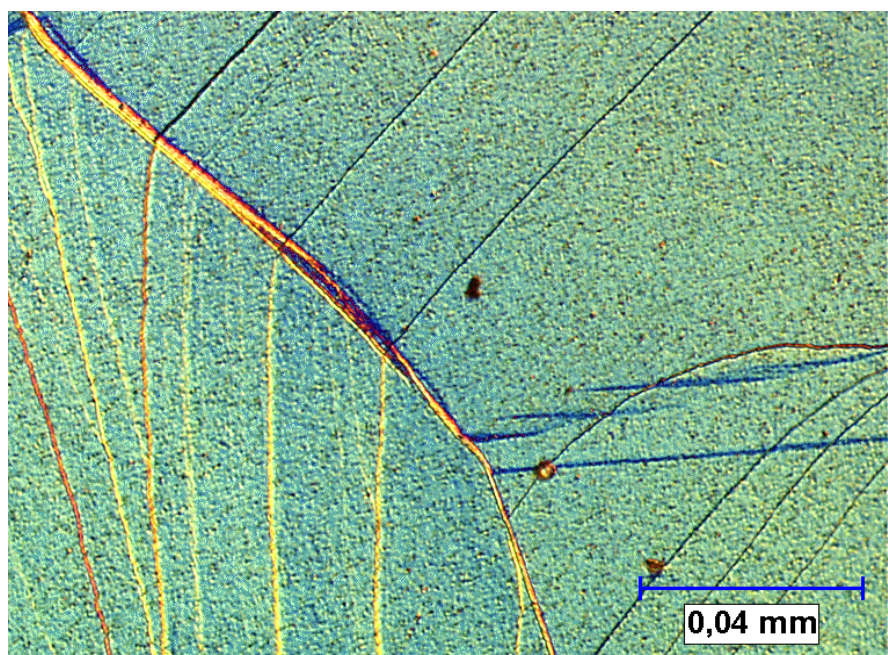
In (AC)
E: mag. 500×
CL

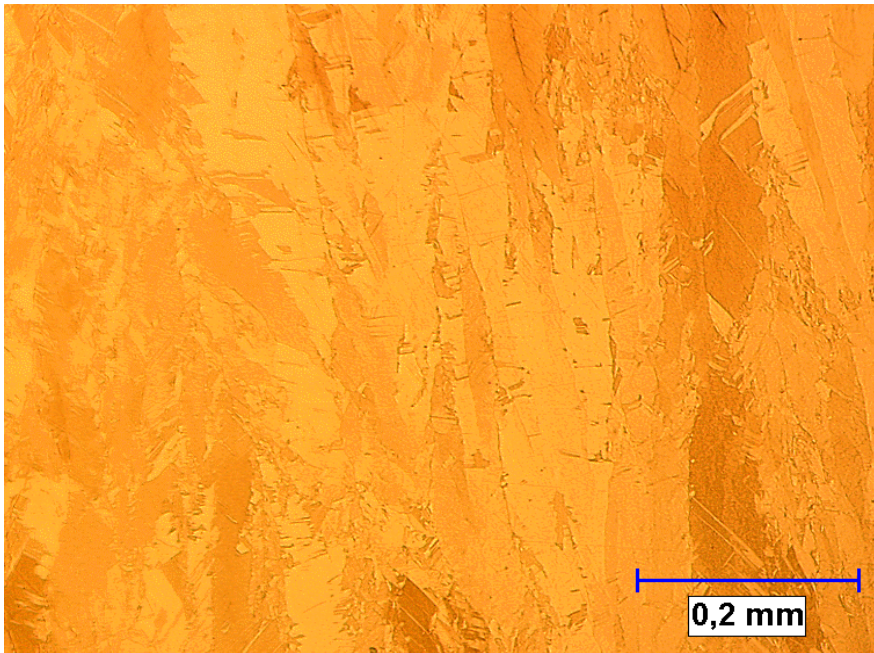


In (AC)
E: mag. 500×
PL

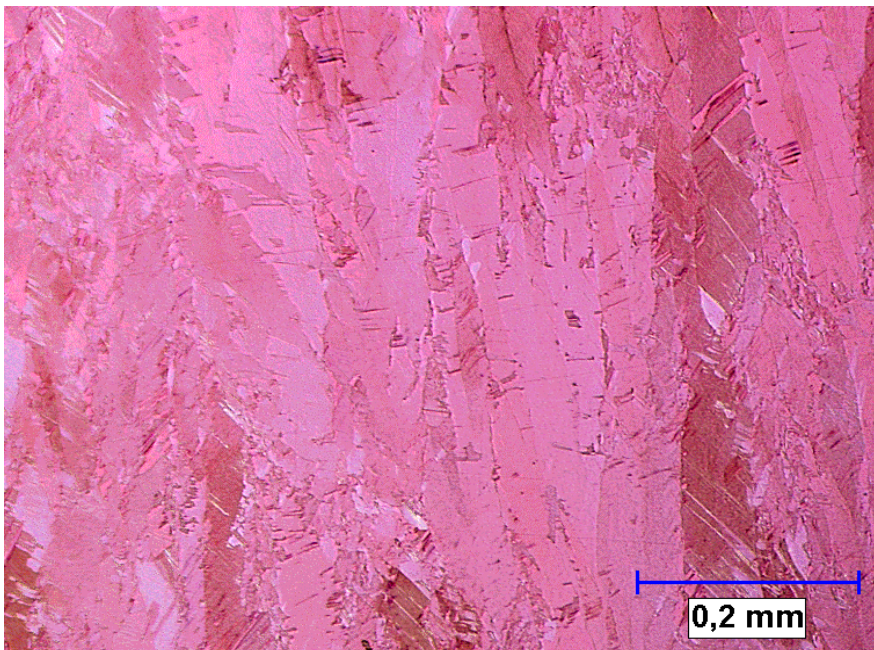


In (AC)
E: mag. 500×
PC

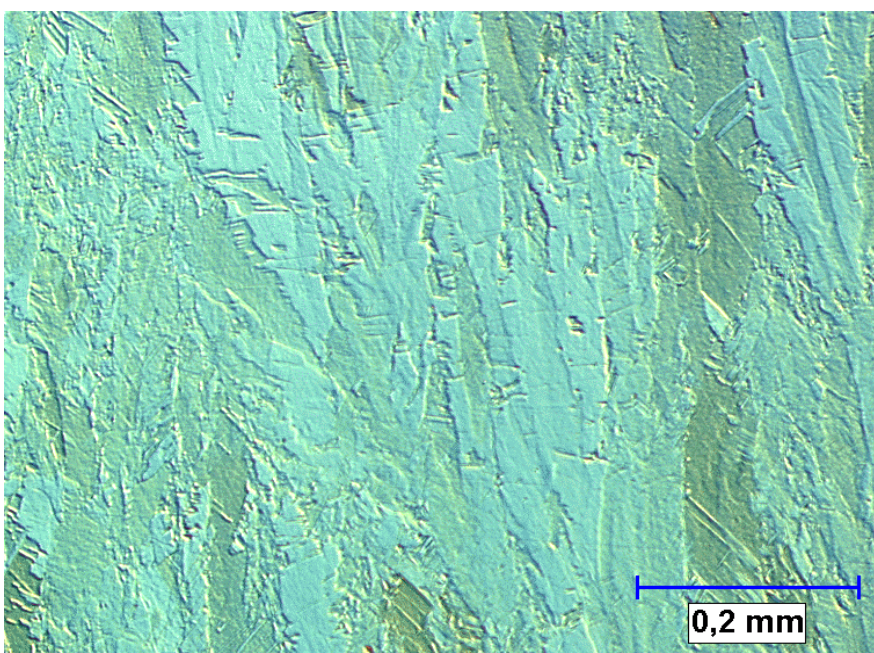




Ni (AC)
E: mag. 100×
CL

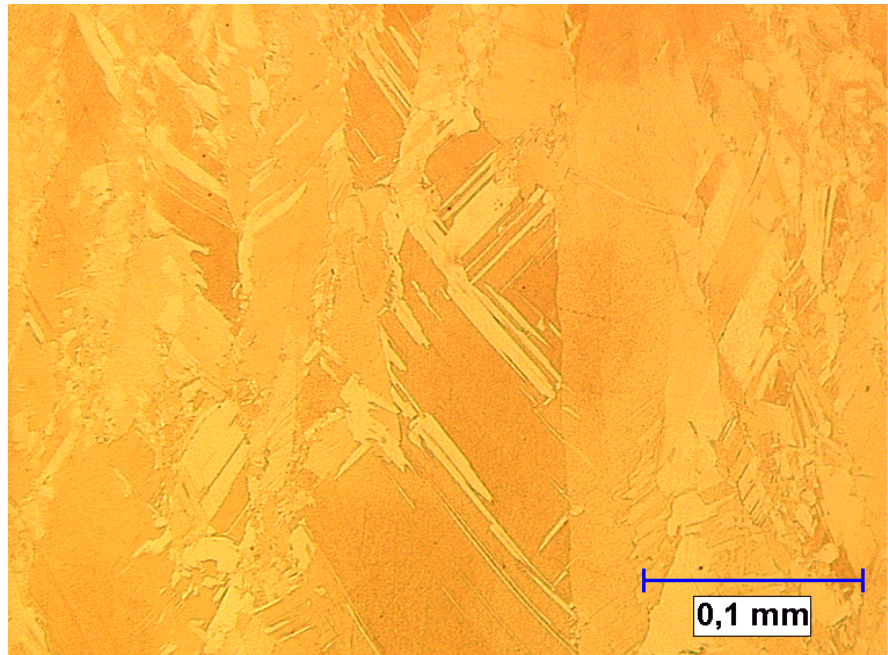


Ni (AC)
E: mag. 100×
PL

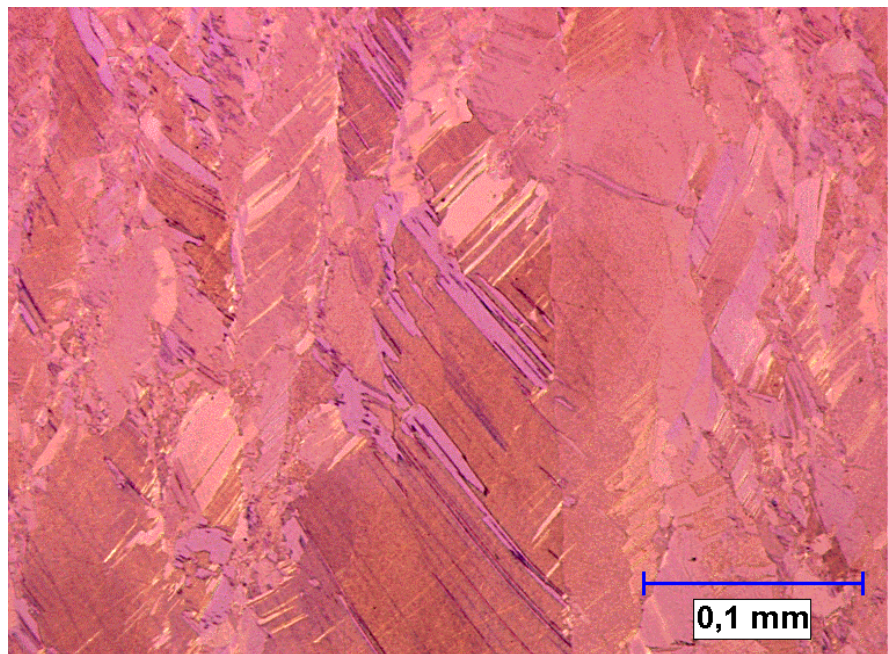


Ni (AC)
E: mag. 100×
PC

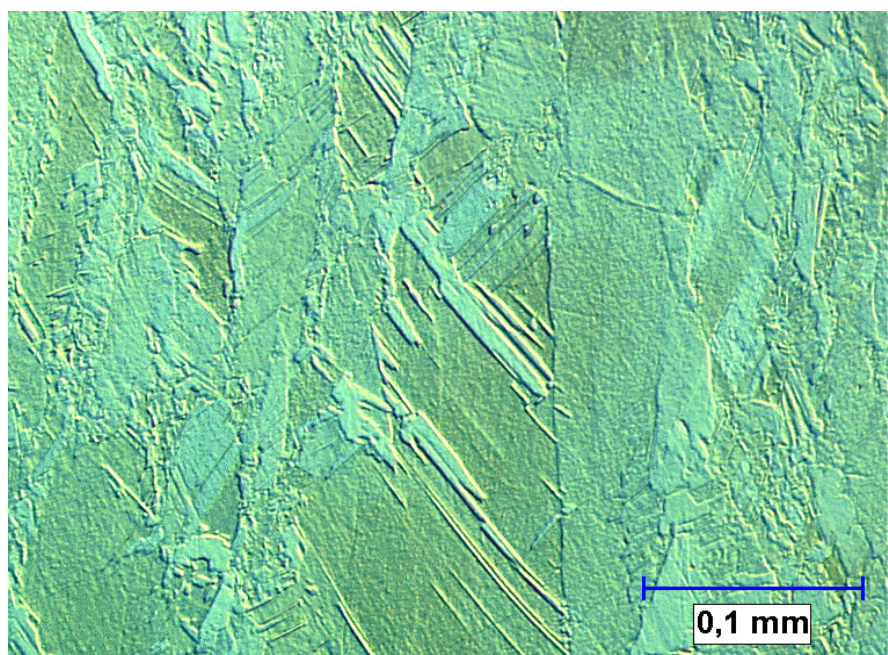
Ni (AC)
E: mag. 200×
CL

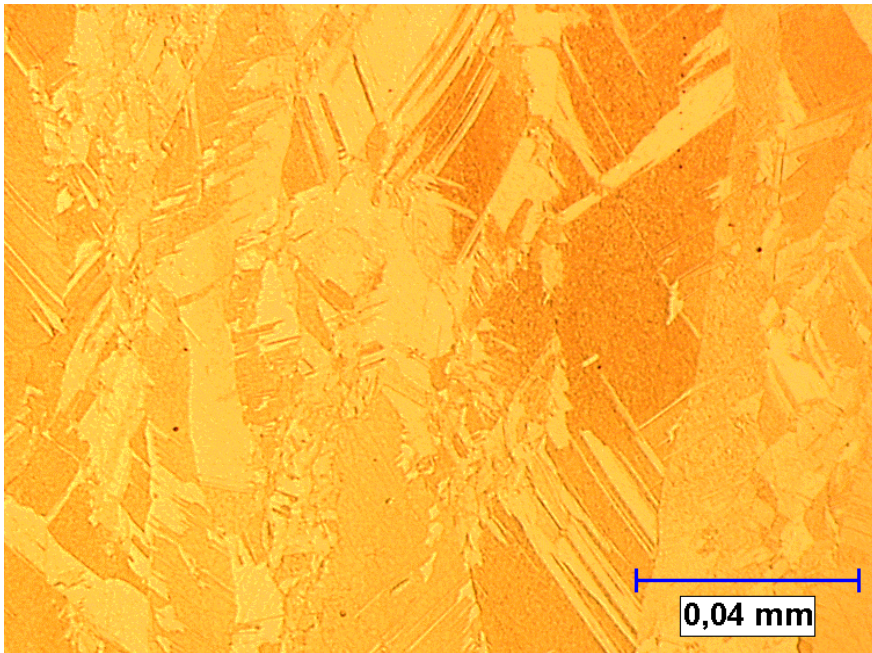


Ni (AC)
E: mag. 200×
PL

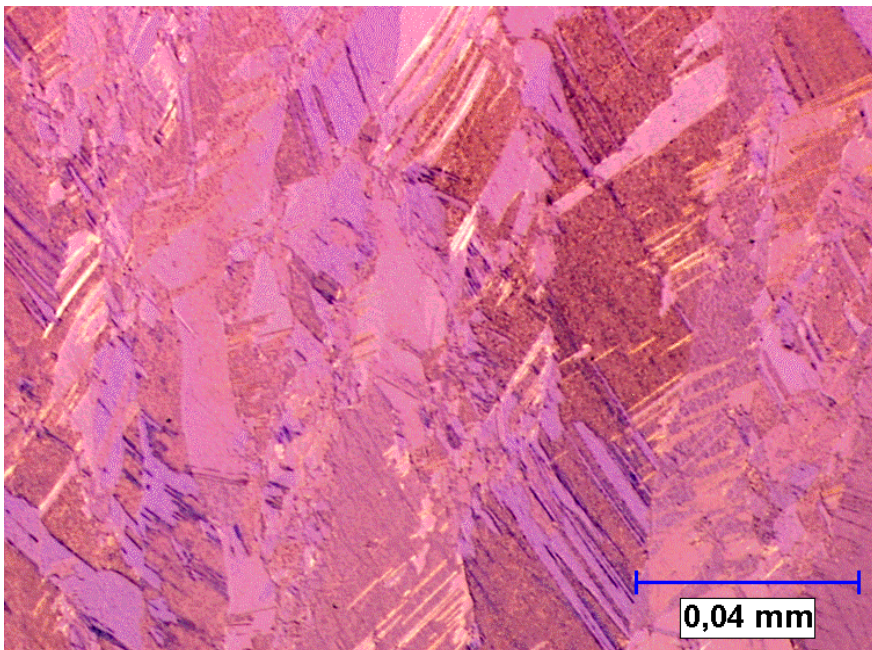


Ni (AC)
E: mag. 200×
PC

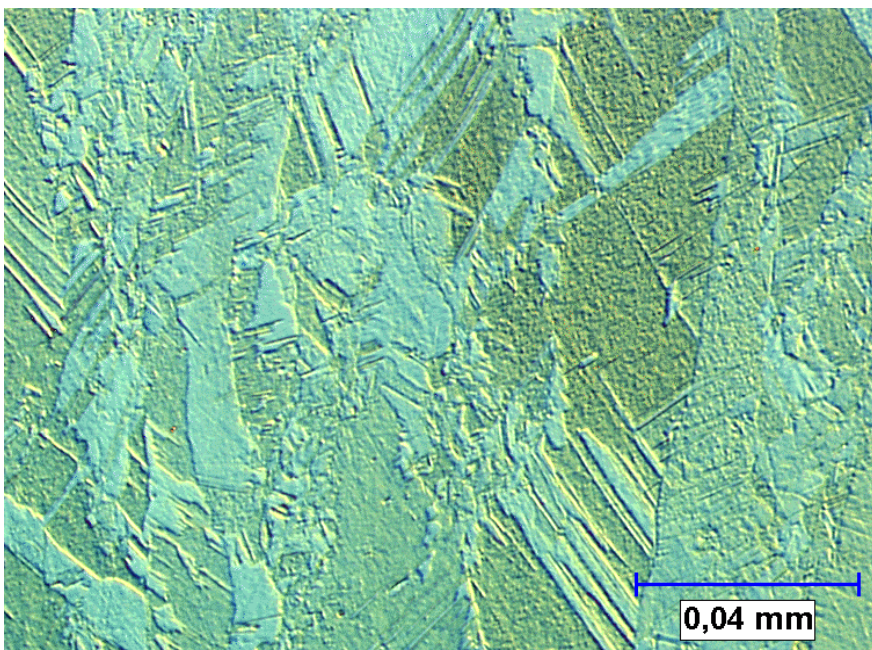




Ni (AC)
E: mag. 500×
CL

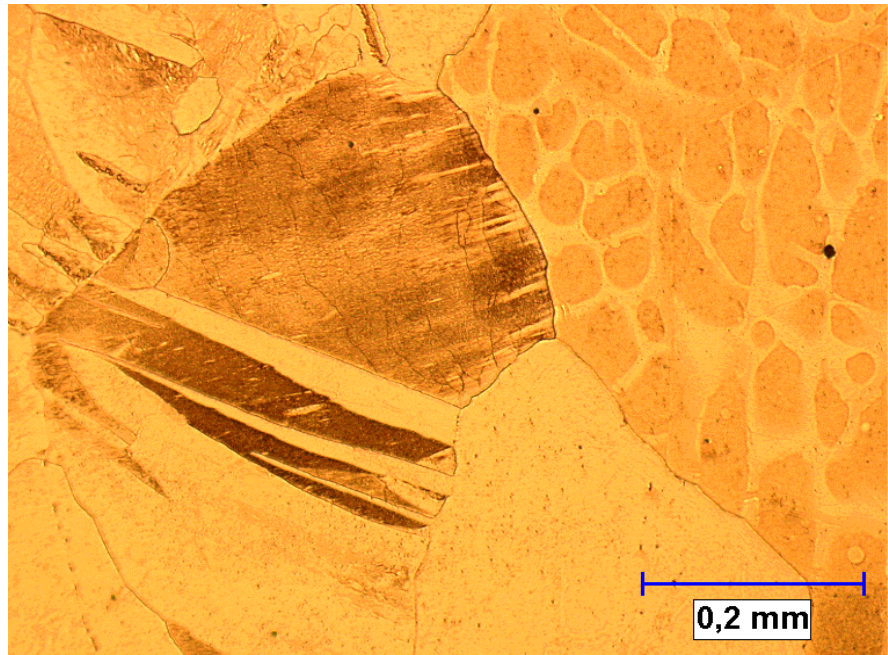


Ni (AC)
E: mag. 500×
PL

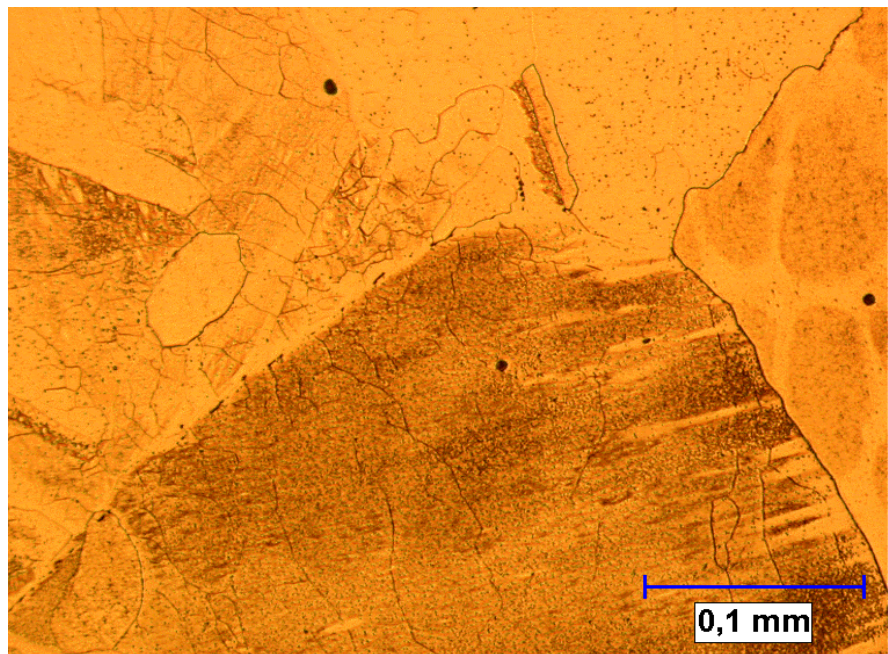


Ni (AC)
E: mag. 500×
PC

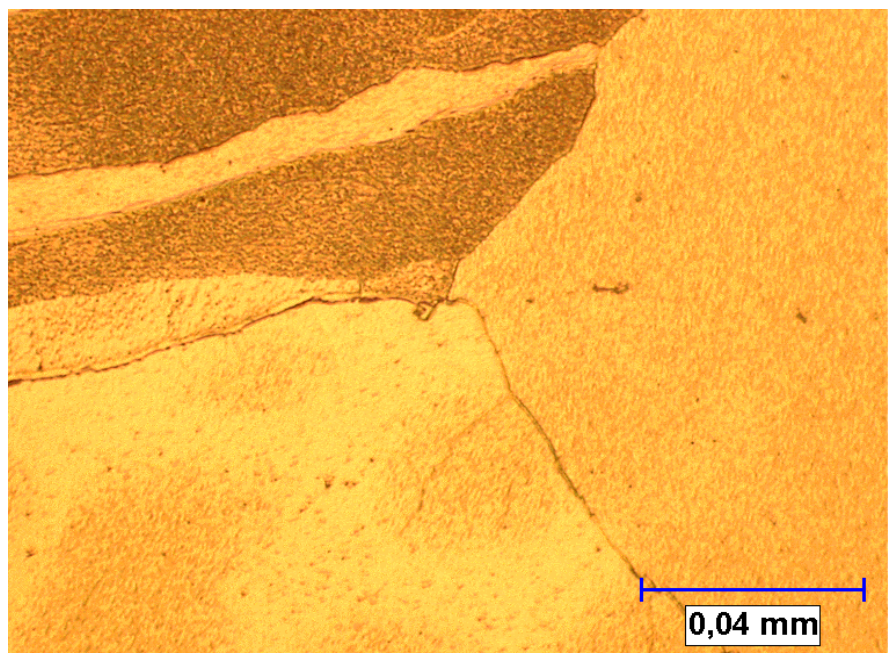
Sn (AC)
E: mag. 100×
CL

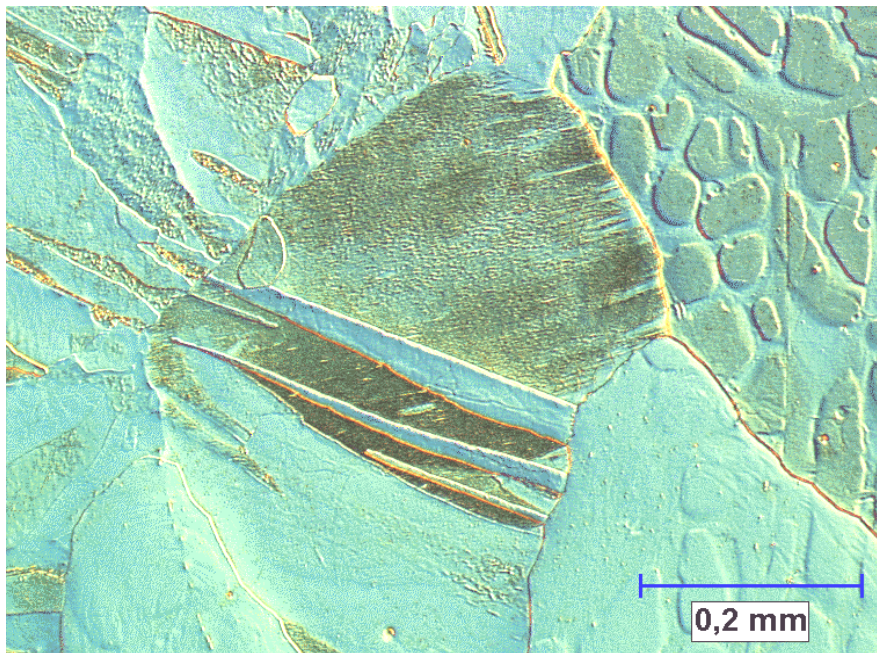


Sn (AC)
E: mag. 200×
CL

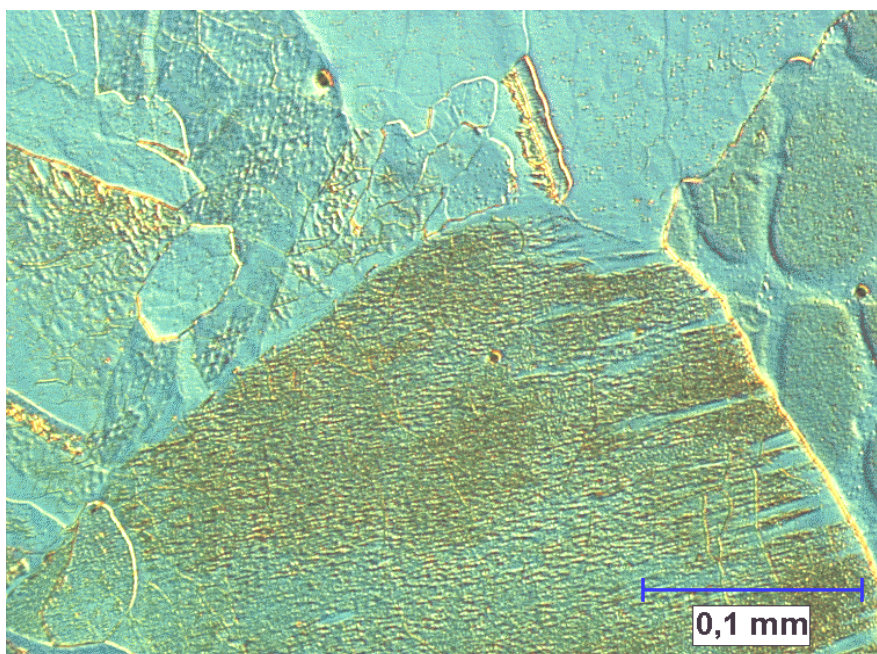


Sn (AC)
E: mag. 500×
CL

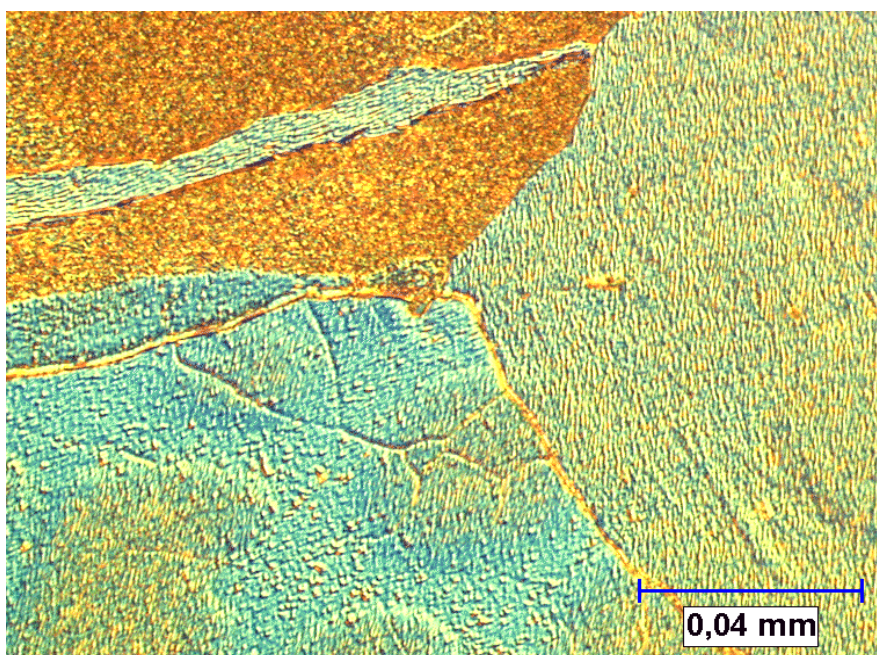




Sn (AC)
E: mag. 100×
PC

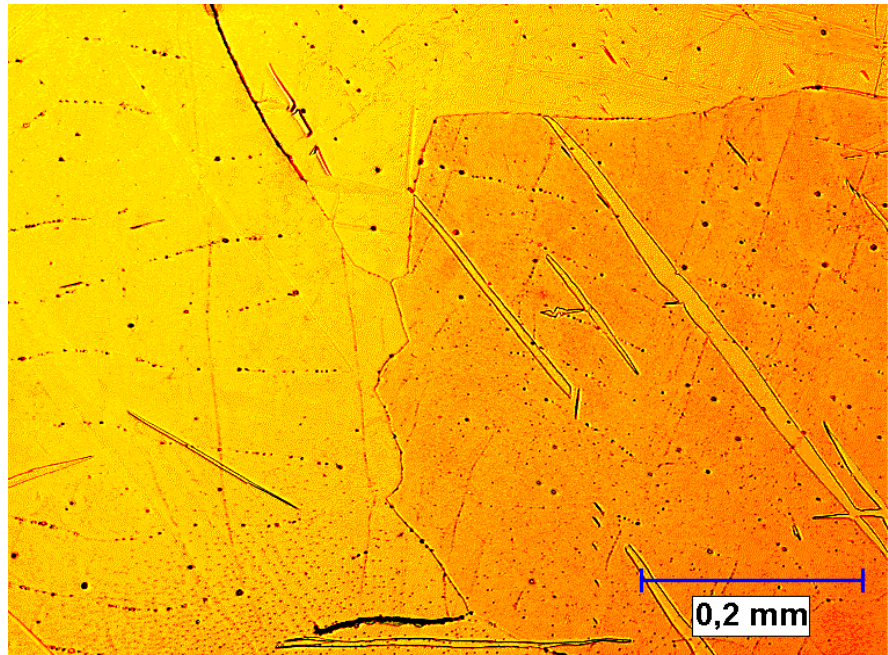


Sn (AC)
E: mag. 200×
PC

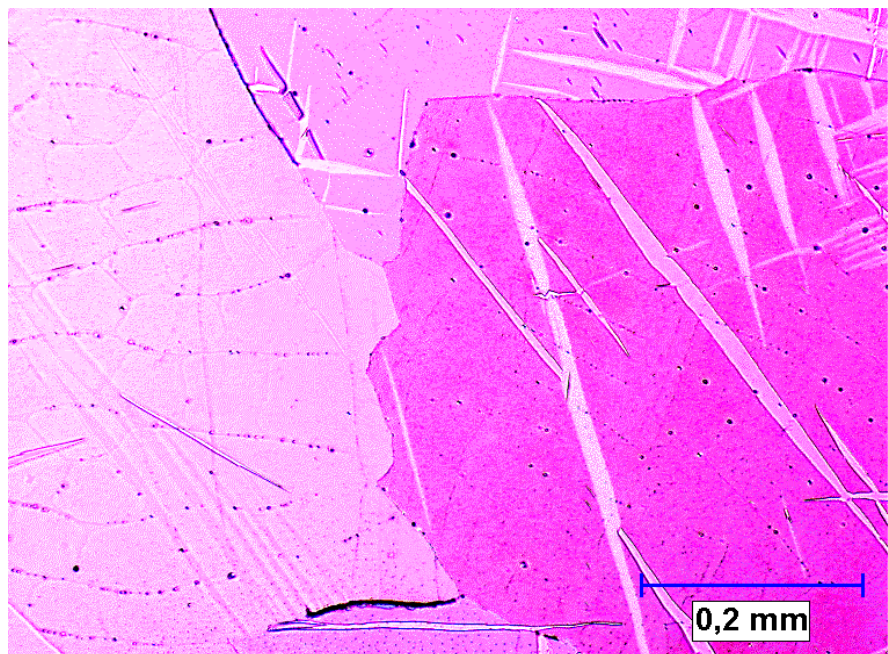


Sn (AC)
E: mag. 500×
PC

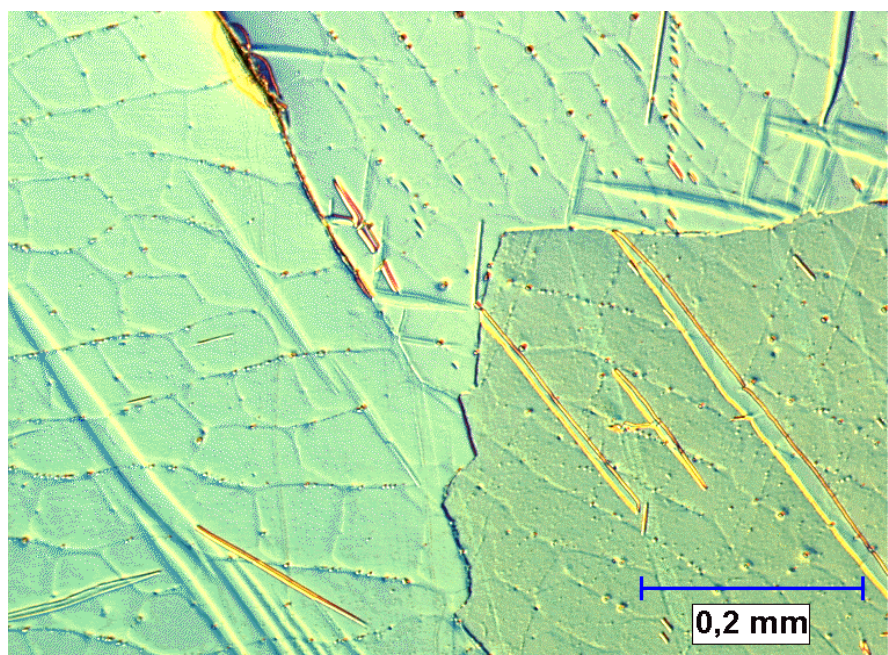
Zn (AC)
E: mag. 100×
CL

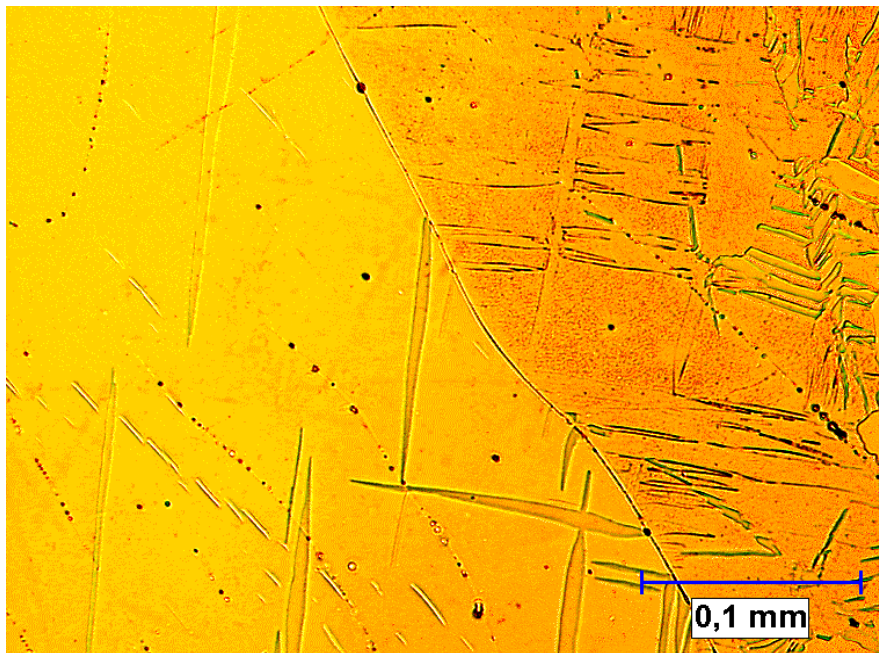


Zn (AC)
E: mag. 100×
PL

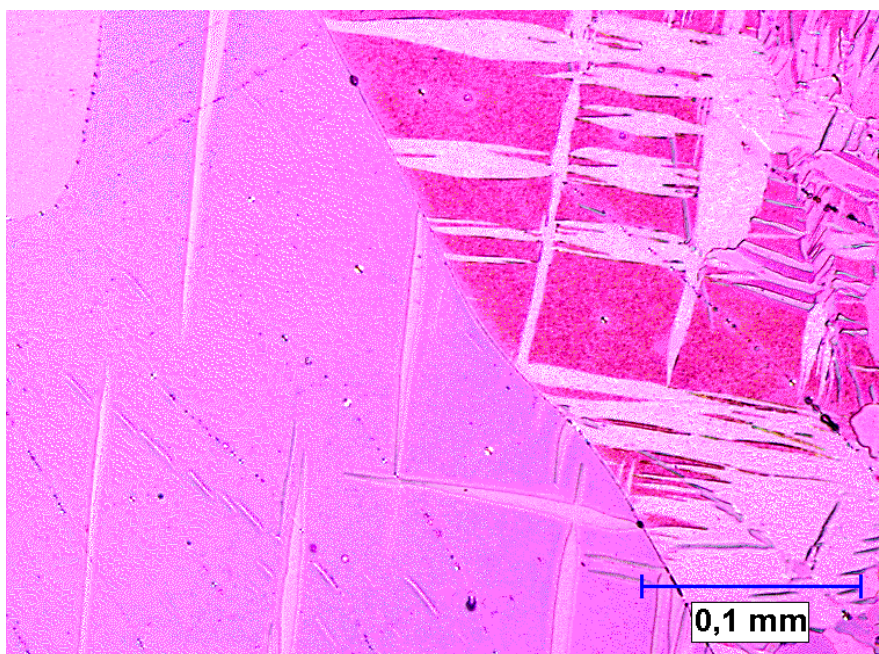


Zn (AC)
E: mag. 100×
PC

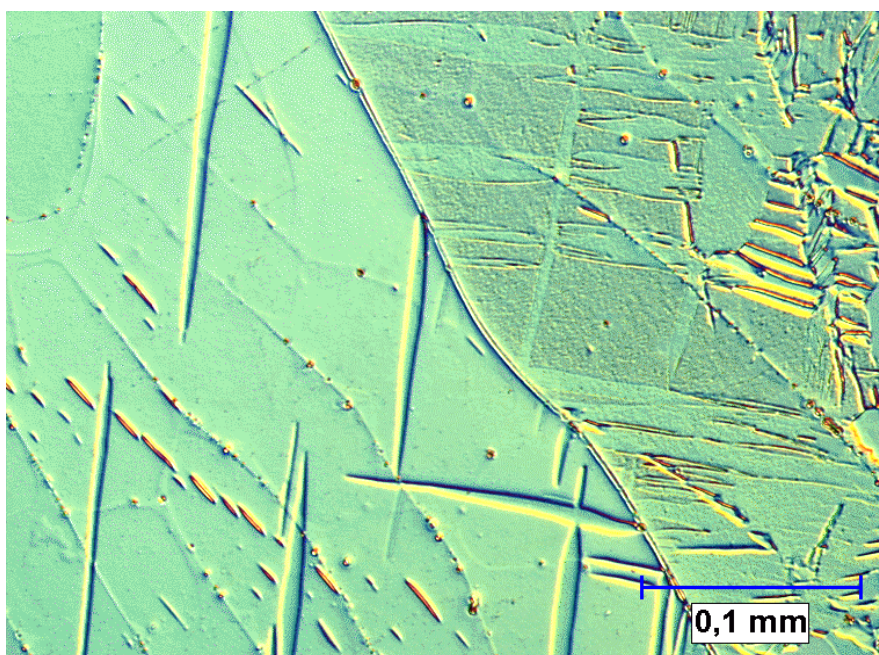




Zn (AC)
E: mag. 200×
CL

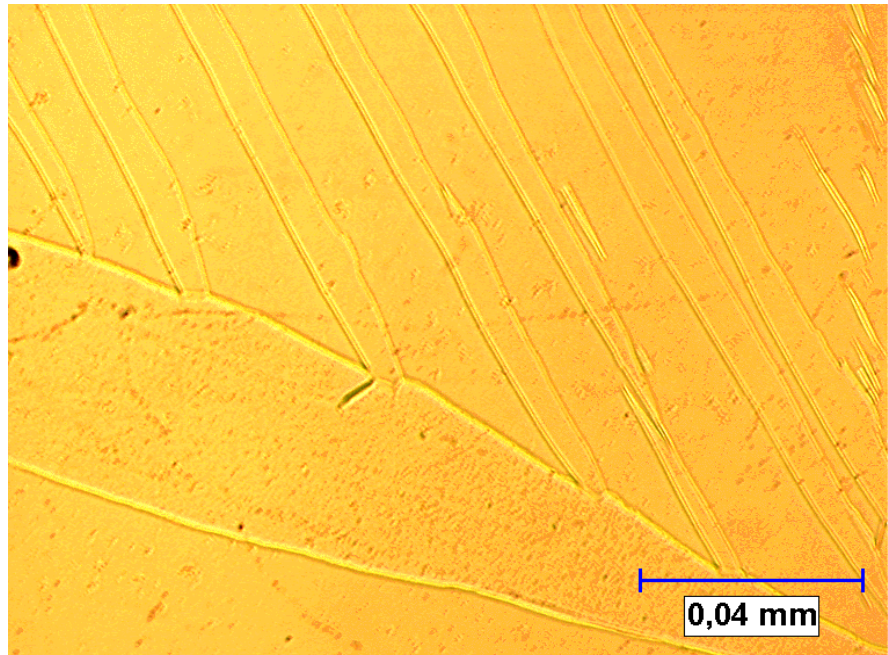


Zn (AC)
E: mag. 200×
PL

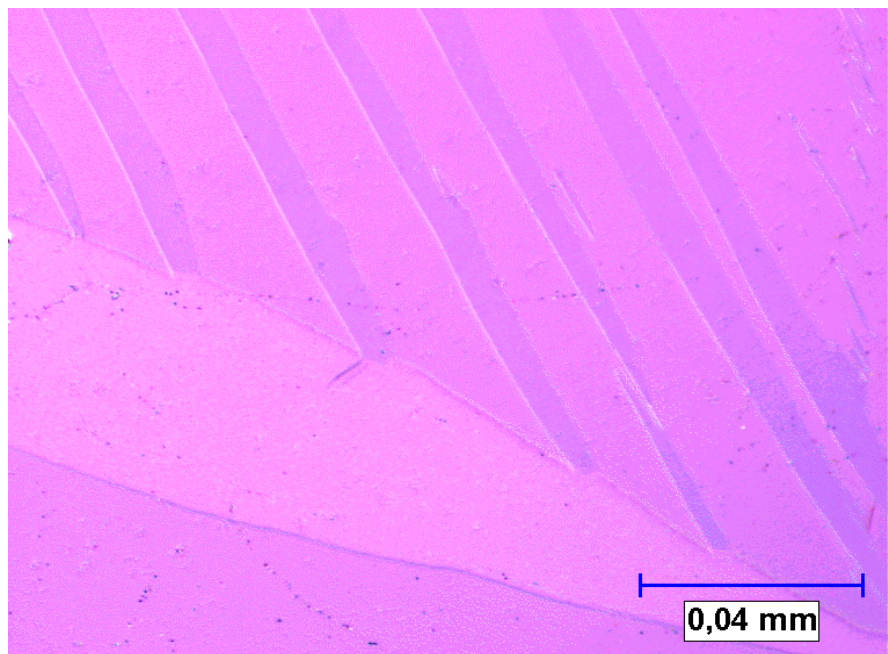


Zn (AC)
E: mag. 200×
PC

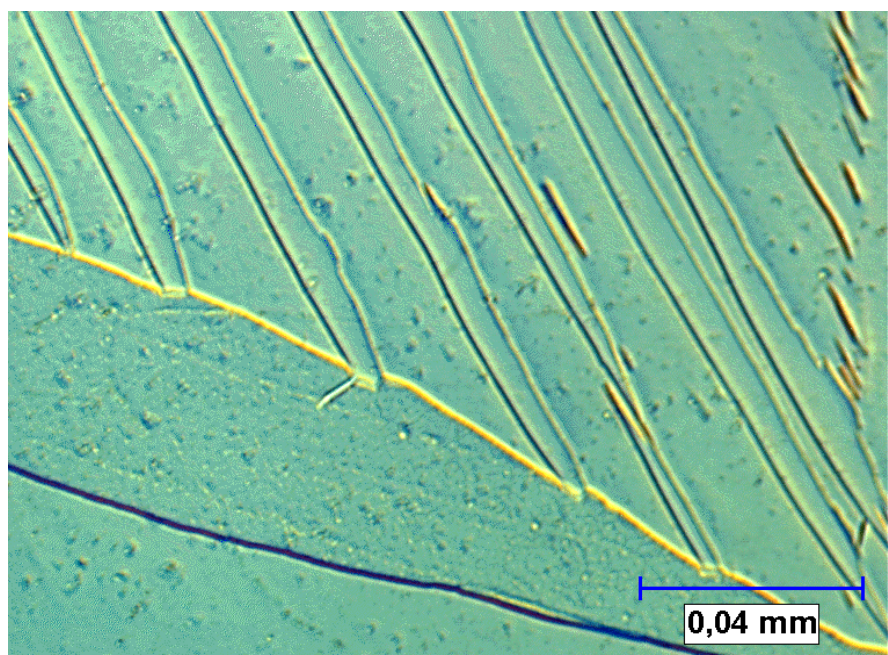
Zn (AC)
E: mag. 500×
CL



Zn (AC)
E: mag. 500×
PL

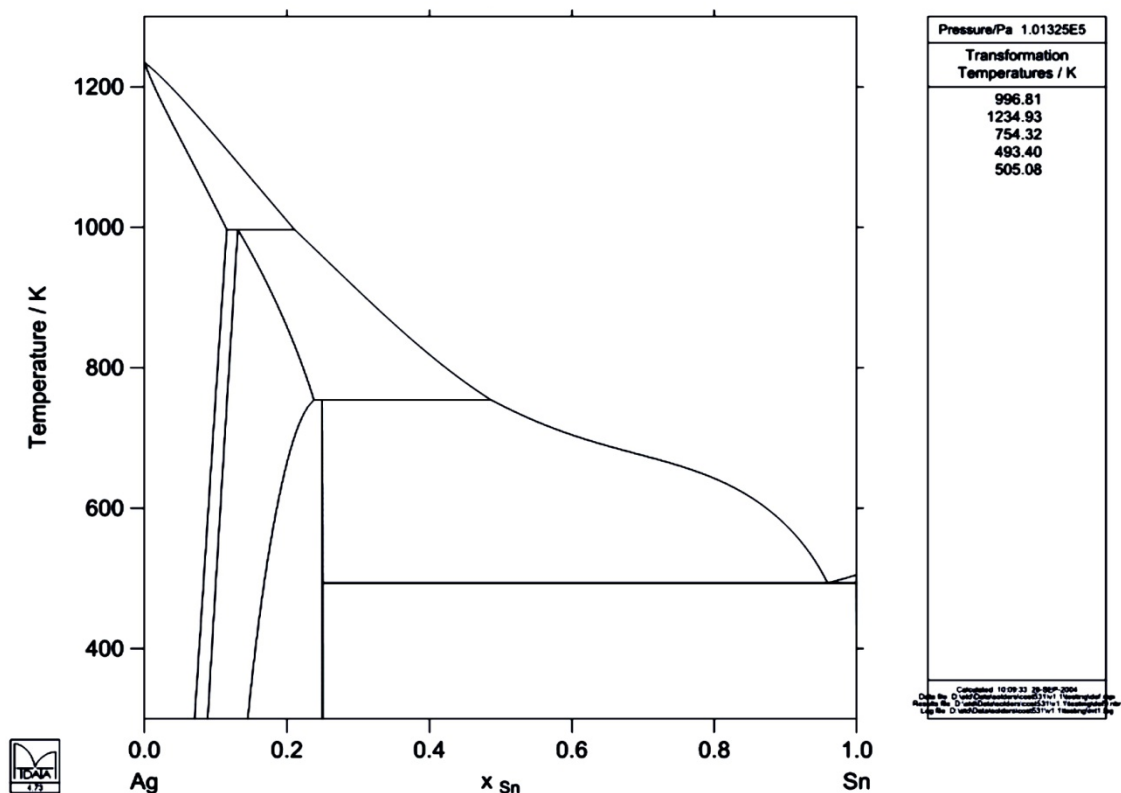


Zn (AC)
E: mag. 500×
PC

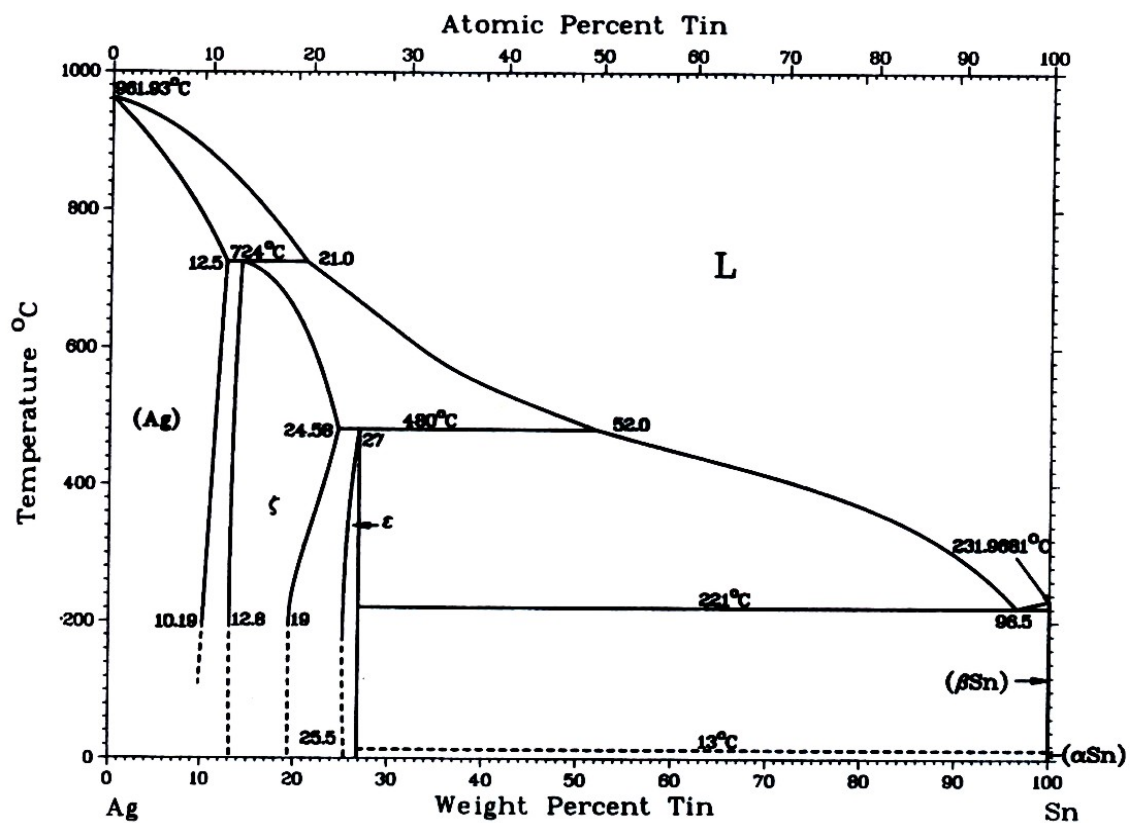


4. Binary Systems

Sn – Ag



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•37)

I. Karakaya and W.T. Thompson, 1987

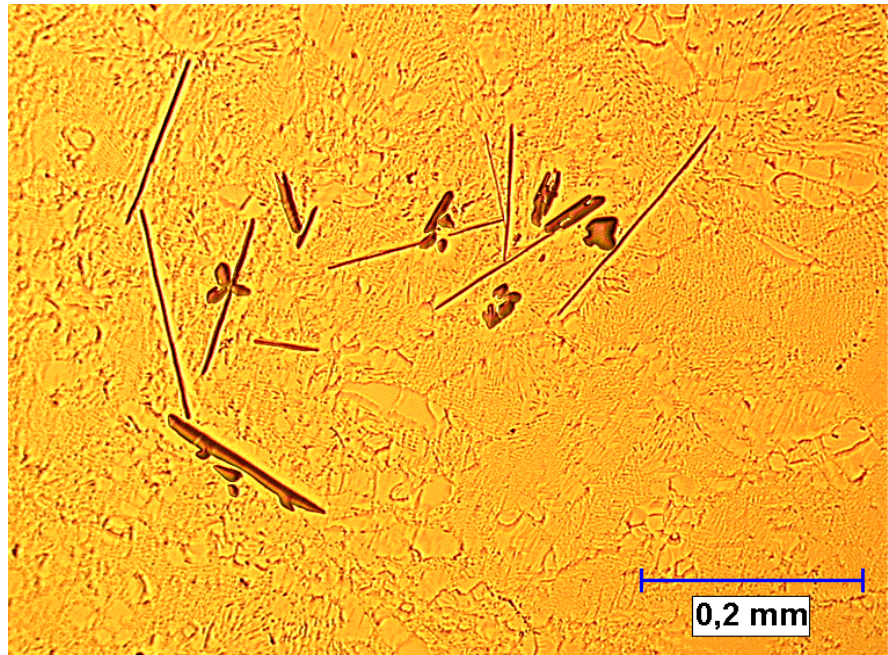
Phase	Composition, wt% Sn	Pearson symbol	Space group
(Ag)	0 to 12.5	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
ζ	12.8 to 24.58	<i>hP2</i>	<i>P6₃/mmc</i>
ϵ	25.5 to 27	<i>oP8</i>	<i>Pmmn</i>
(β Sn)	99.92 to 100	<i>tI4</i>	<i>I4₁/amd</i>
(α Sn)	100	<i>cF8</i>	<i>Fd$\bar{3}m$</i>

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•37)

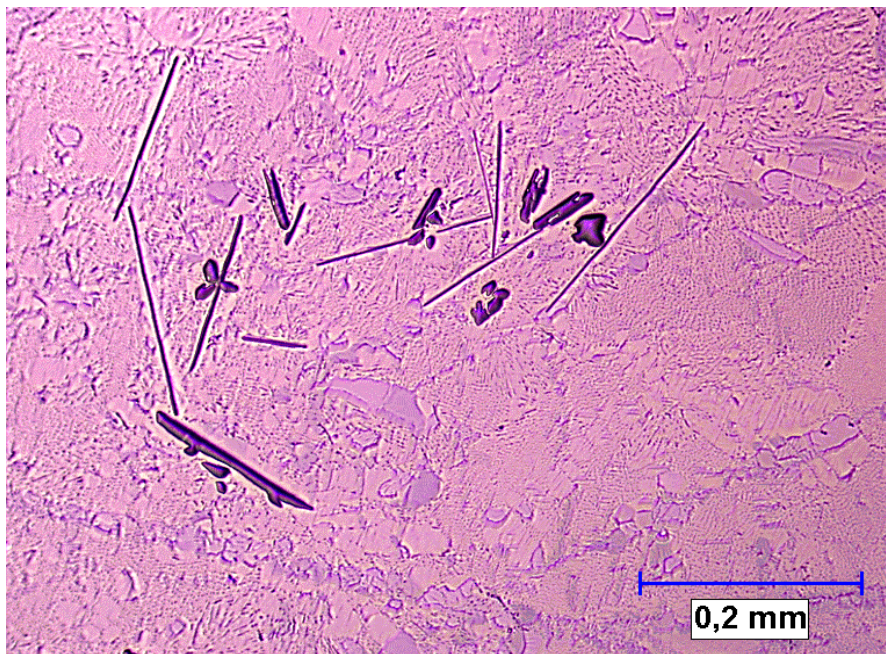
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
Sn/Ag	230°C, 5 min, flux	38°	27
Sn/Ag	230°C, 30 min, flux	41°	—

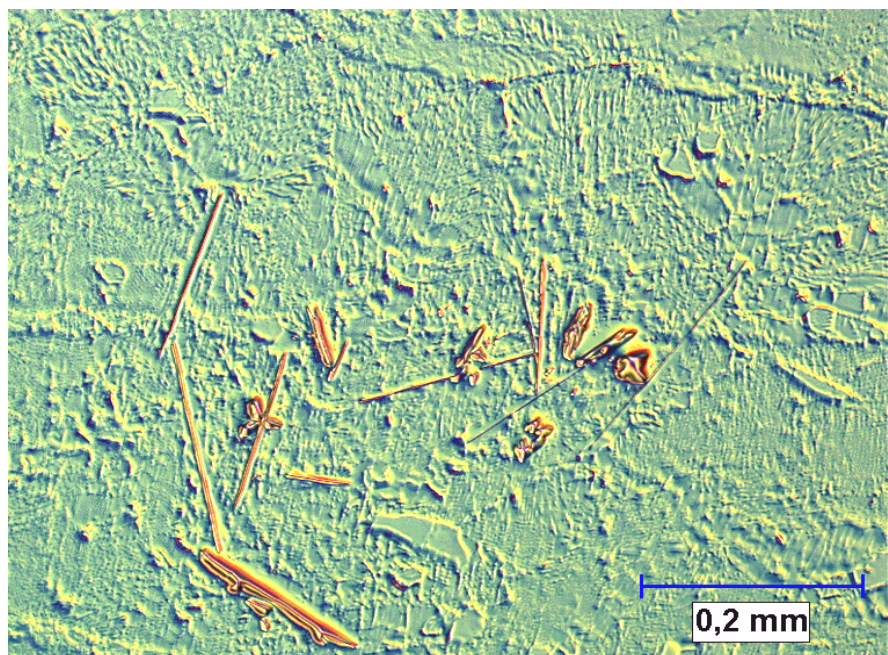
SnAg4 alloy (AC)
E: mag. 100×
CL

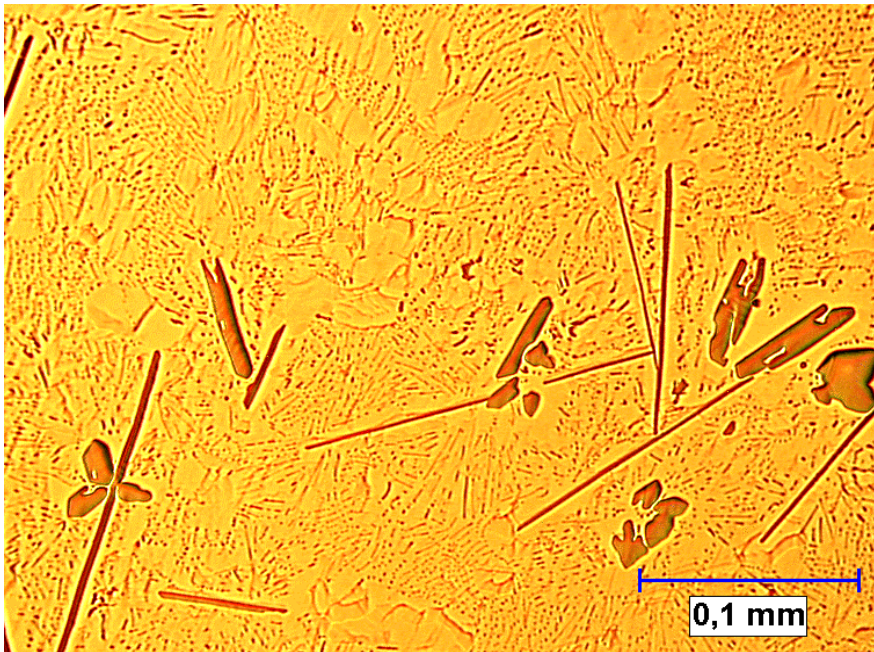
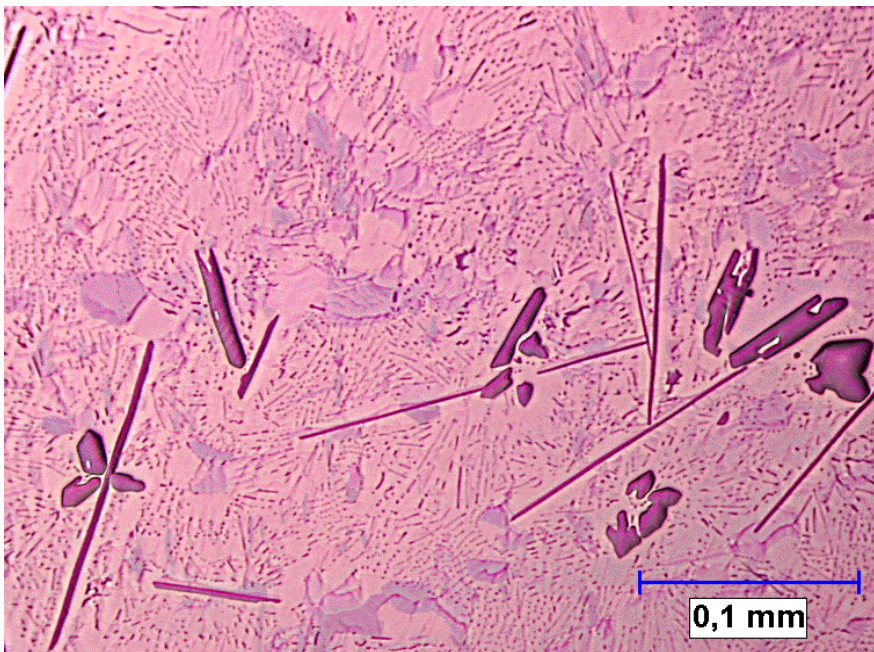
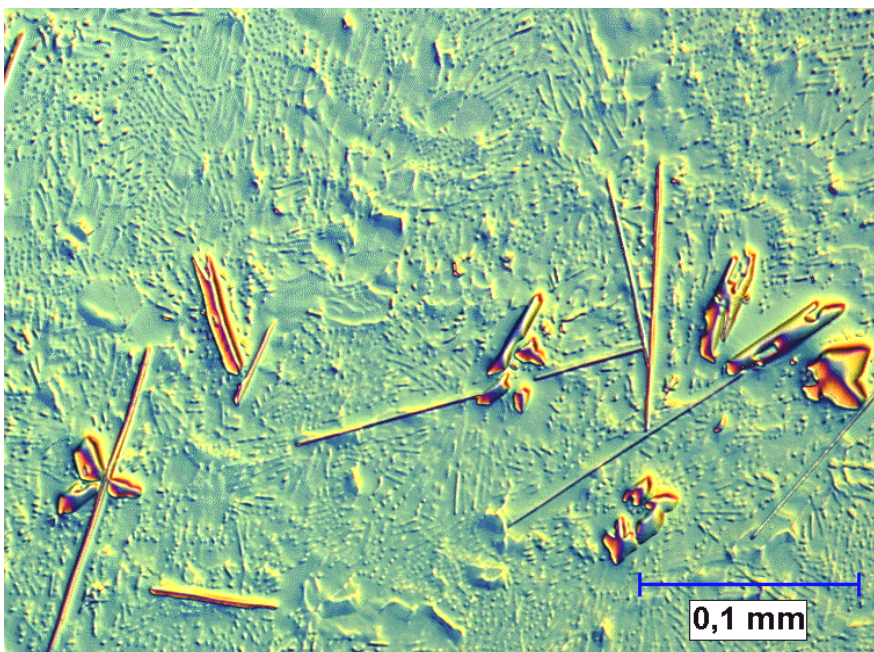


SnAg4 alloy (AC)
E: mag. 100×
PL

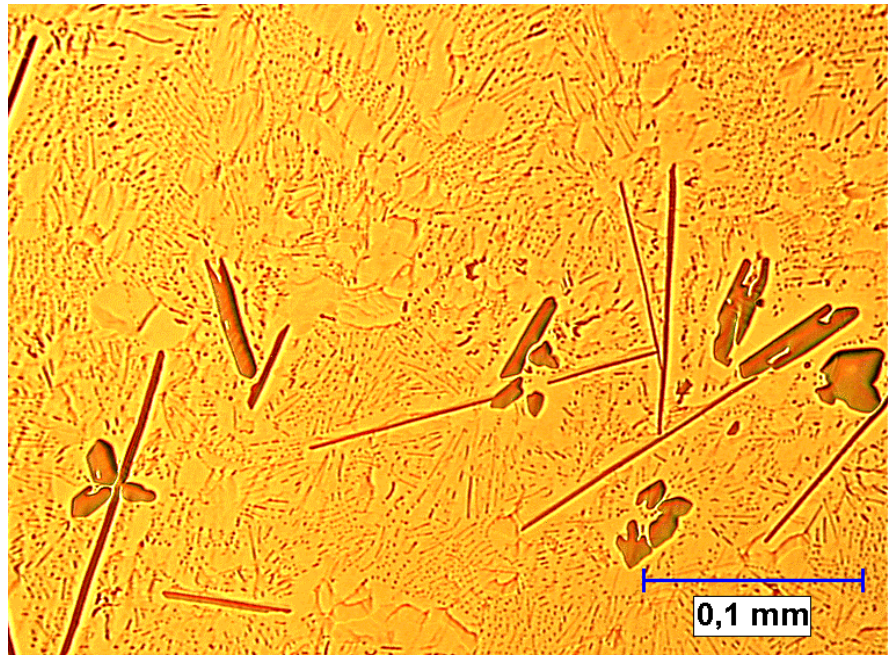


SnAg4 alloy (AC)
E: mag. 100×
PC

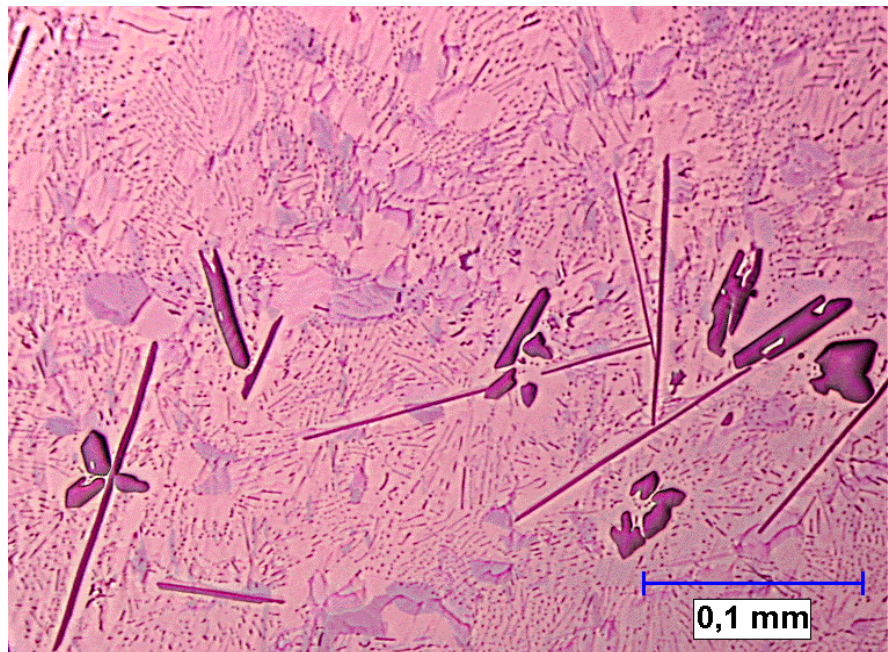


**SnAg4 alloy (AC)****E: mag. 200×****CL****SnAg4 alloy (AC)****E: mag. 200×****PL****SnAg4 alloy (AC)****E: mag. 200×****PC**

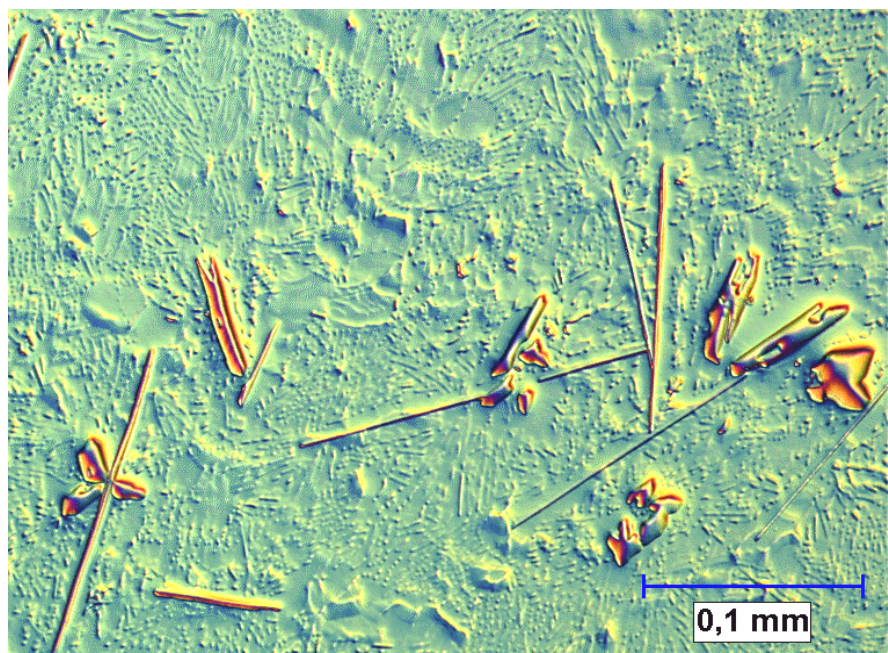
SnAg4 alloy (AC)
E: mag. 200×
CL

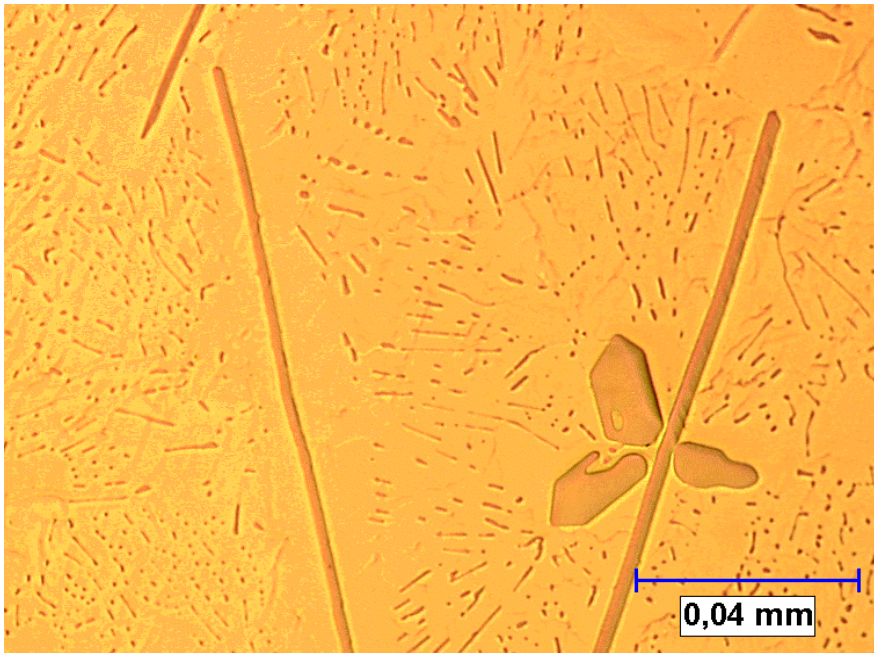
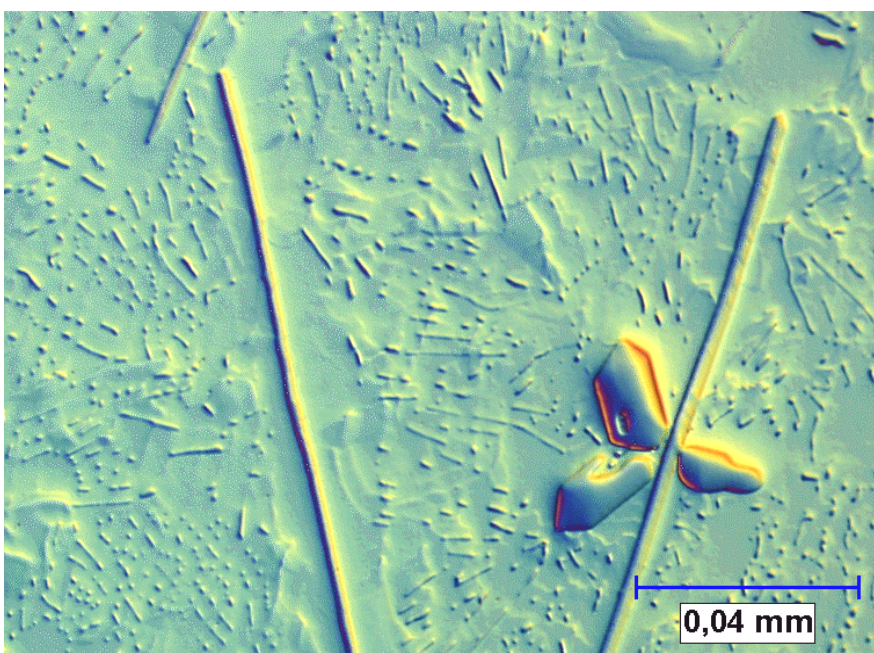


SnAg4 alloy (AC)
E: mag. 200×
PL

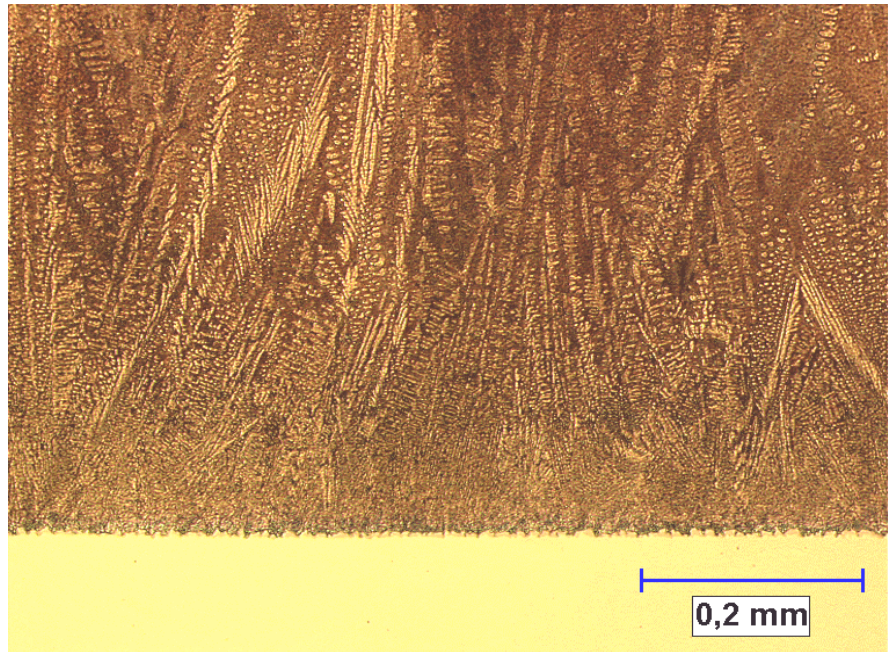


SnAg4 alloy (AC)
E: mag. 200×
PC

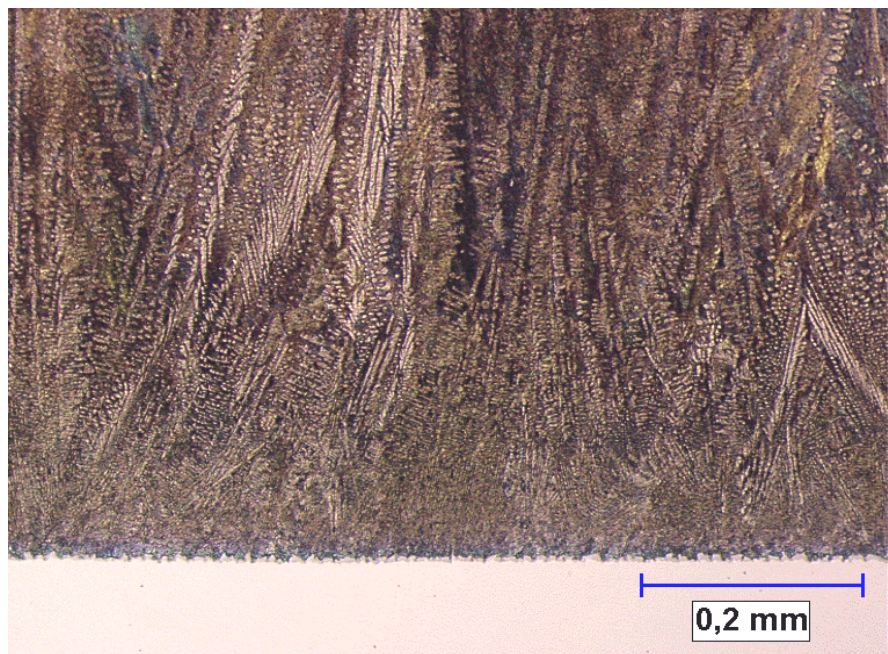


**SnAg4 alloy (AC)****E: mag. 500×****CL****SnAg4 alloy (AC)****E: mag. 500×****PL****SnAg4 alloy (AC)****E: mag. 500×****PC**

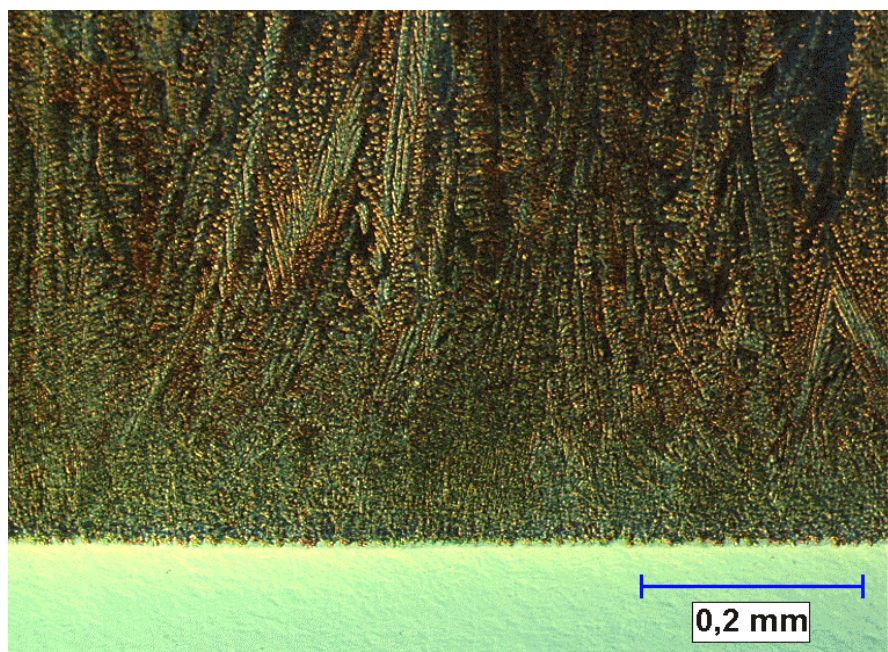
Sn/Ag couple
230°C; 5 min
E: mag. 100×
CL

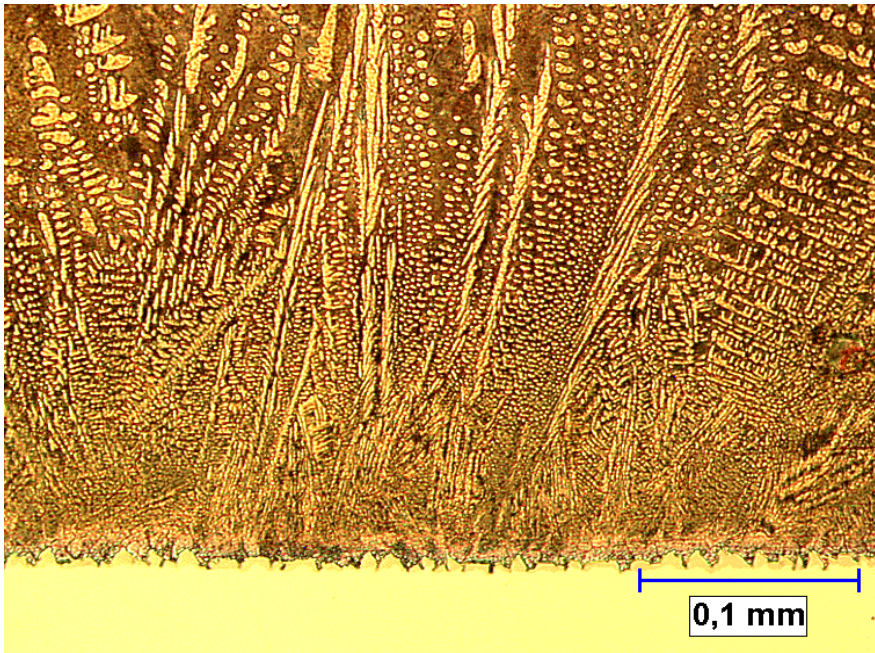


Sn/Ag couple
230°C; 5 min
E: mag. 100×
PL

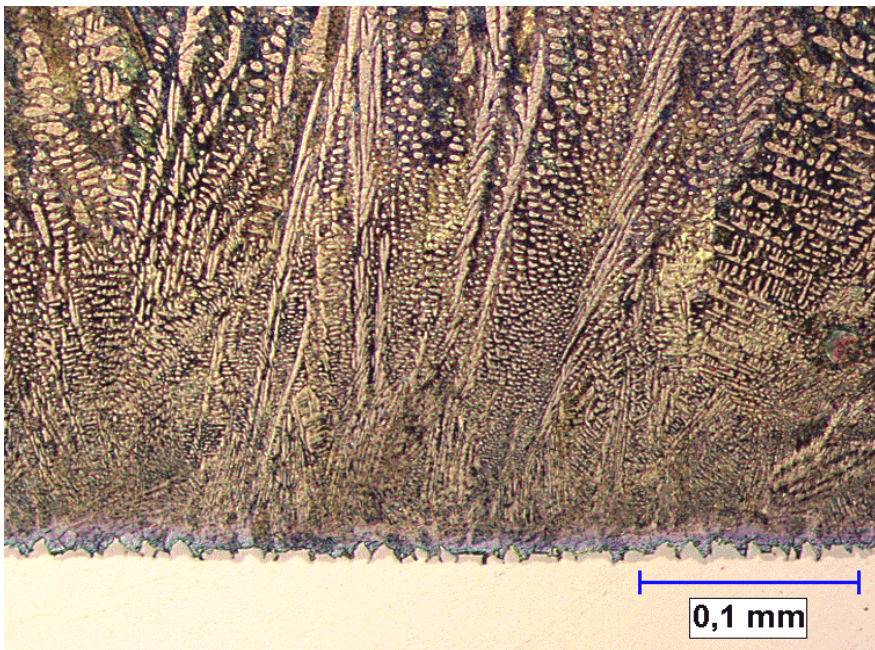


Sn/Ag couple
230°C; 5 min
E: mag. 100×
PC

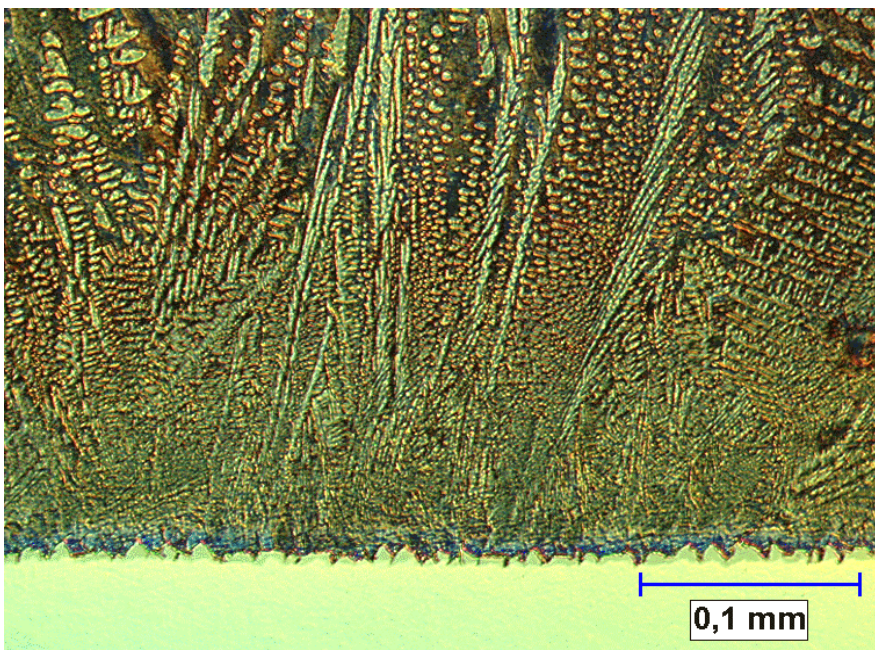




Sn/Ag couple
230°C; 5 min
E: mag. 200×
CL

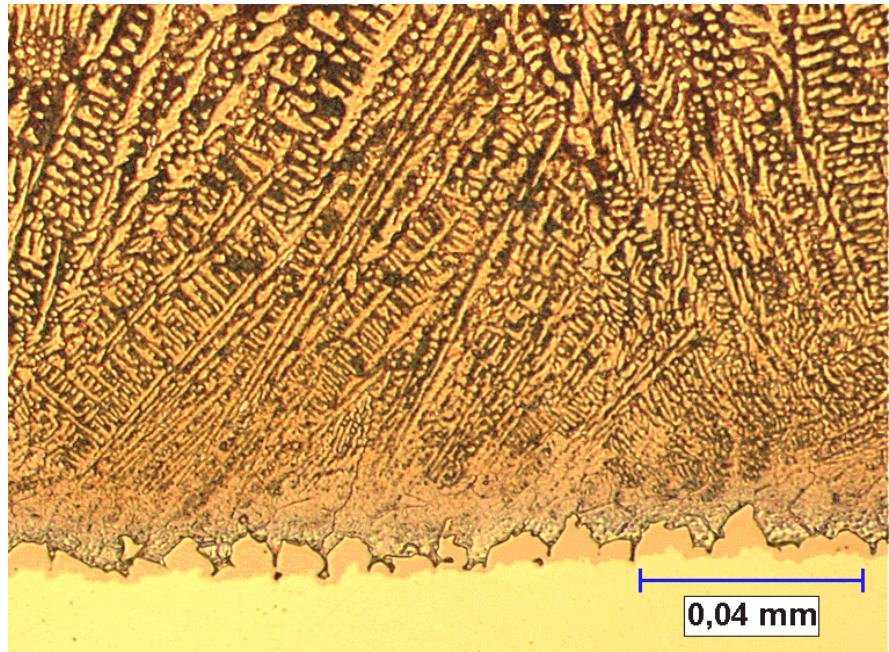


Sn/Ag couple
230°C; 5 min
E: mag. 200×
PL

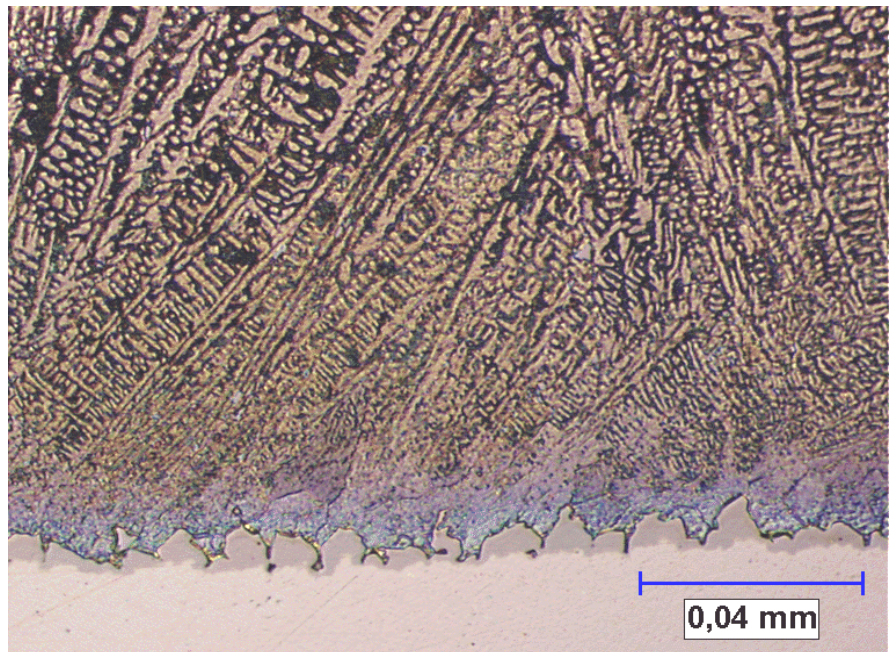


Sn/Ag couple
230°C; 5 min
E: mag. 200×
PC

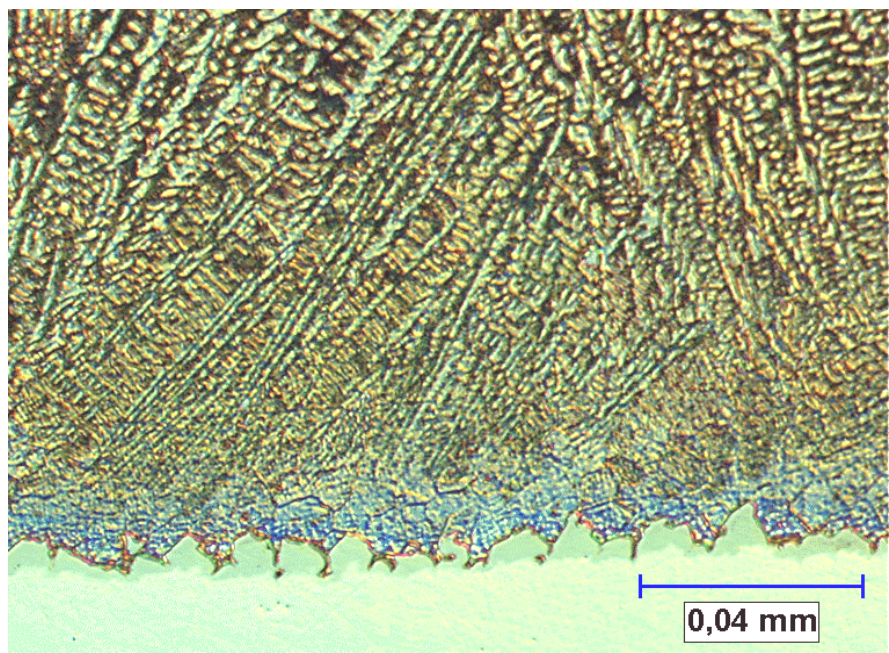
Sn/Ag couple
230°C; 5 min
E: mag. 500×
CL

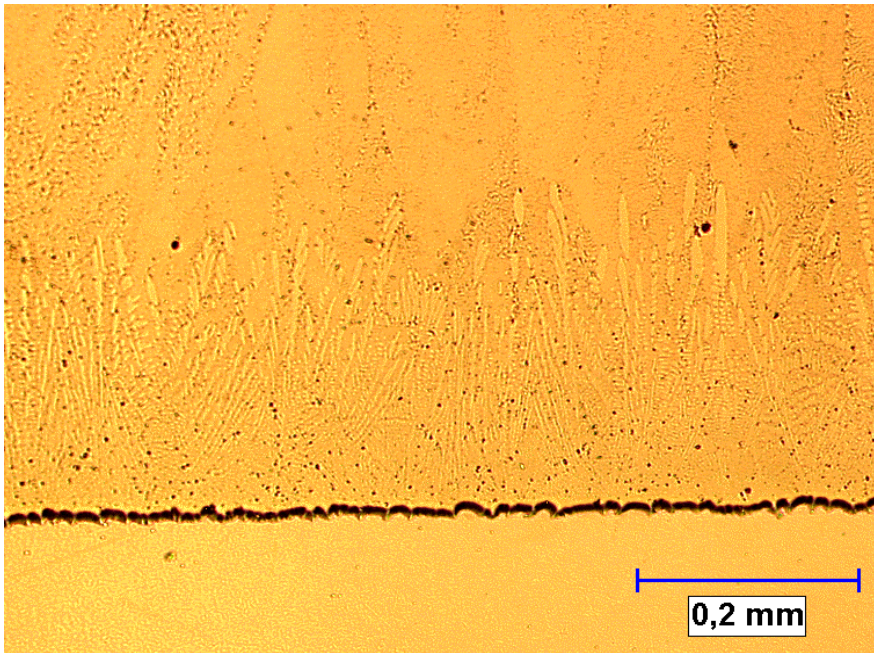


Sn/Ag couple
230°C; 5 min
E: mag. 500×
PL

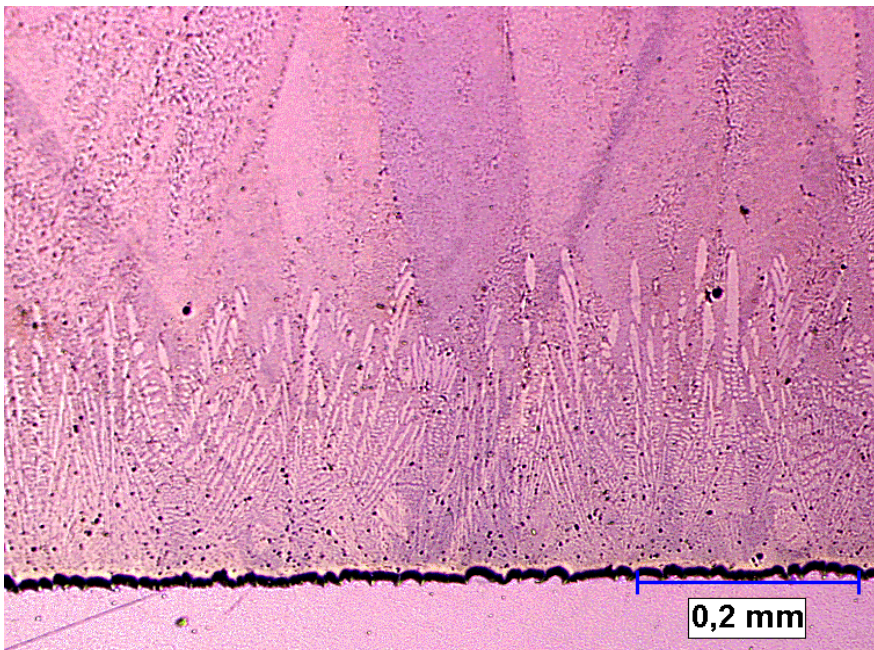


Sn/Ag couple
230°C; 5 min
E: mag. 500×
PC

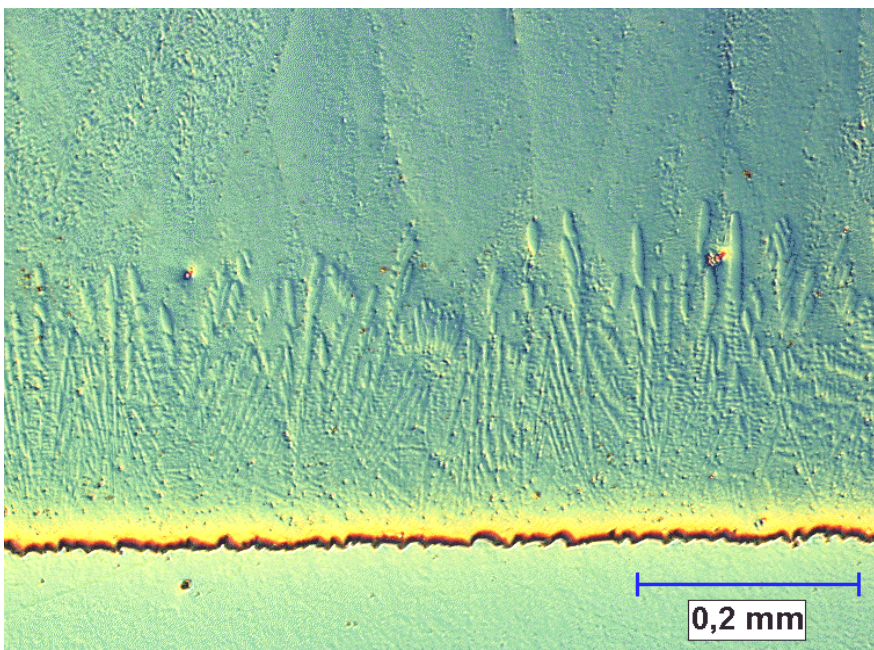




Sn/Ag couple
230°C; 30 min
E: mag. 100×
CL

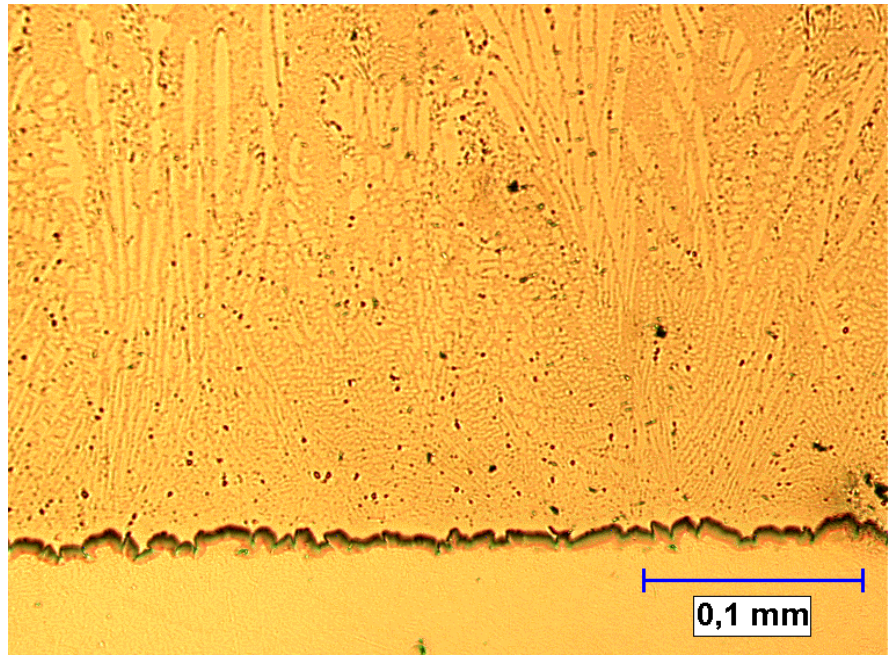


Sn/Ag couple
230°C; 30 min
E: mag. 100×
PL

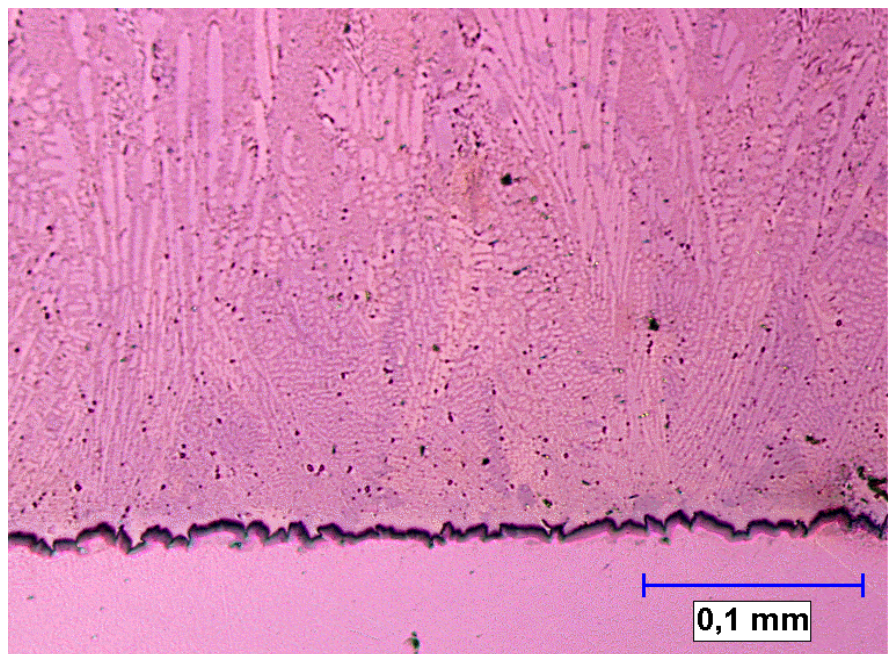


Sn/Ag couple
230°C; 30 min
E: mag. 100×
PC

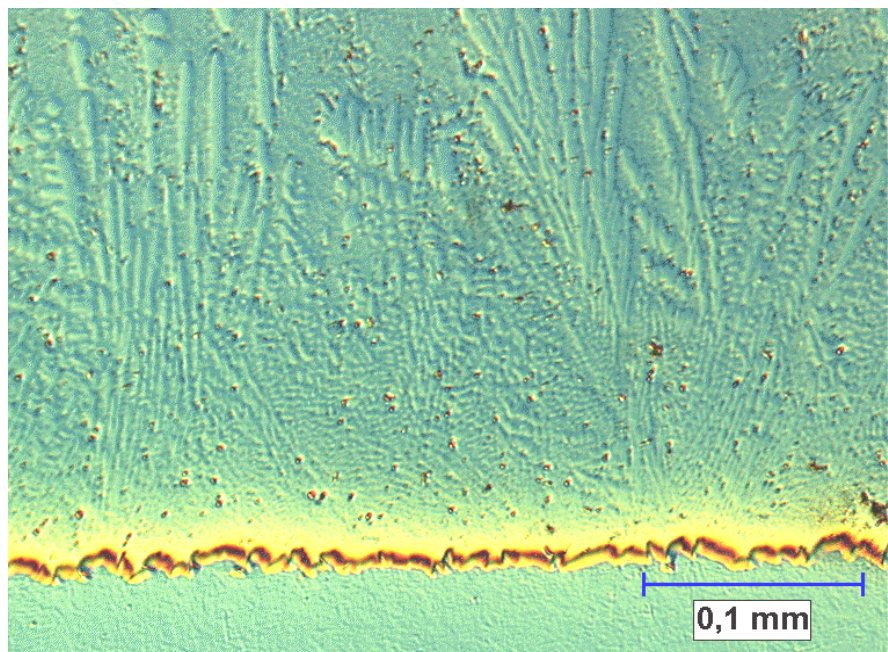
Sn/Ag couple
230°C; 30 min
E: mag. 200×
CL

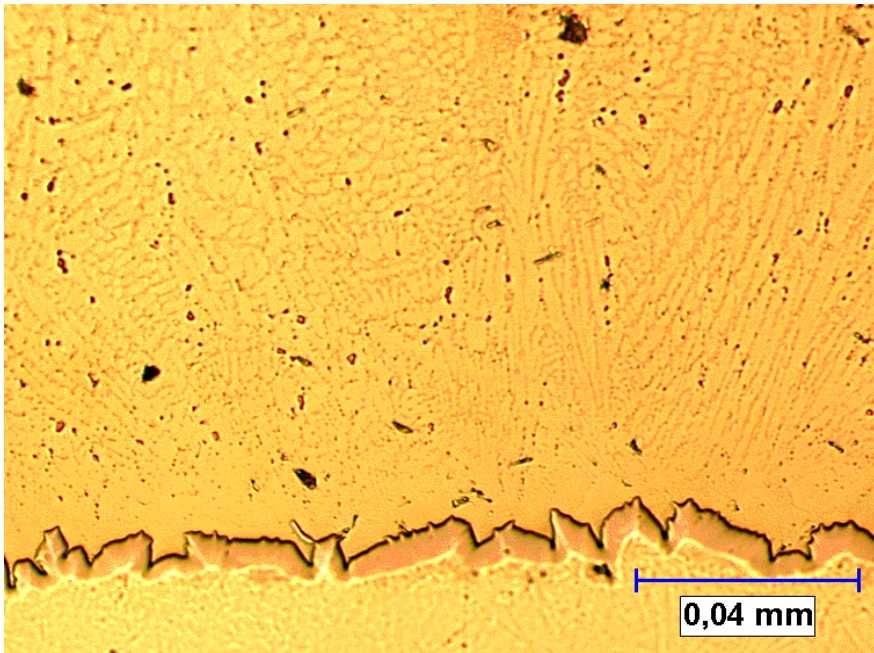


Sn/Ag couple
230°C; 30 min
E: mag. 200×
PL

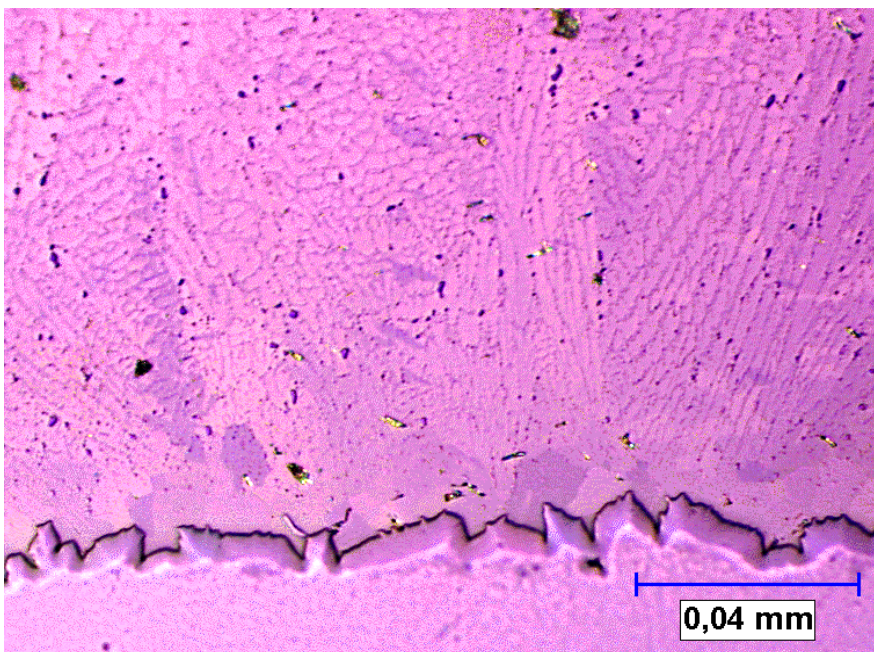


Sn/Ag couple
230°C; 30 min
E: mag. 200×
PC

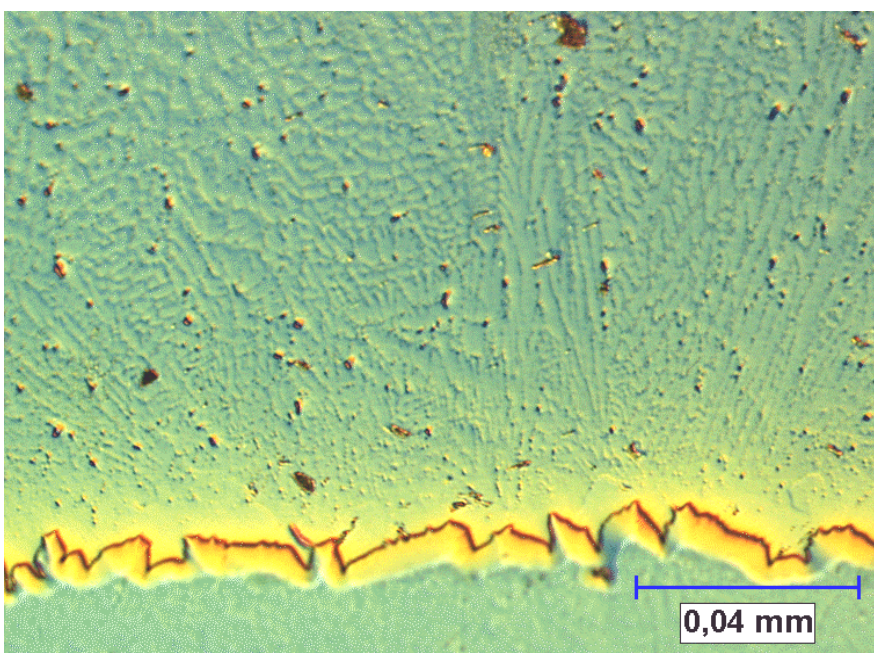




Sn/Ag couple
230°C; 30 min
E: mag. 500×
CL

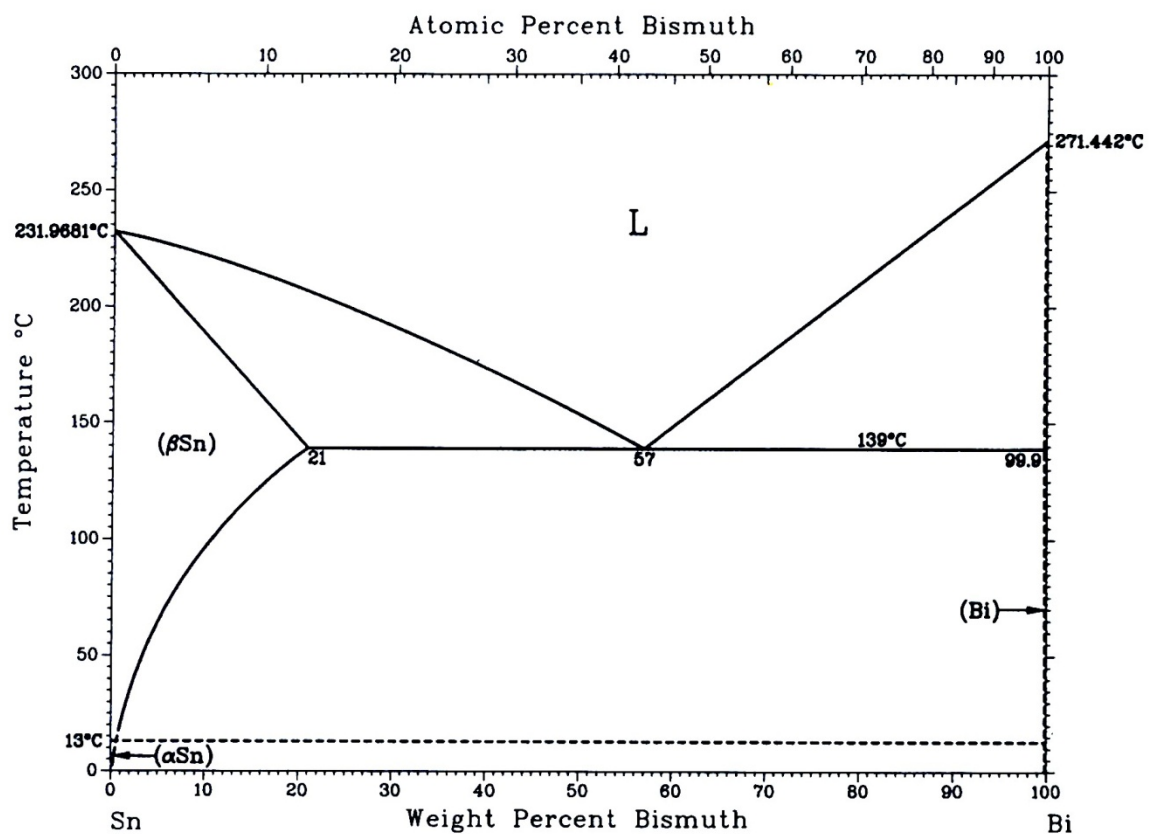
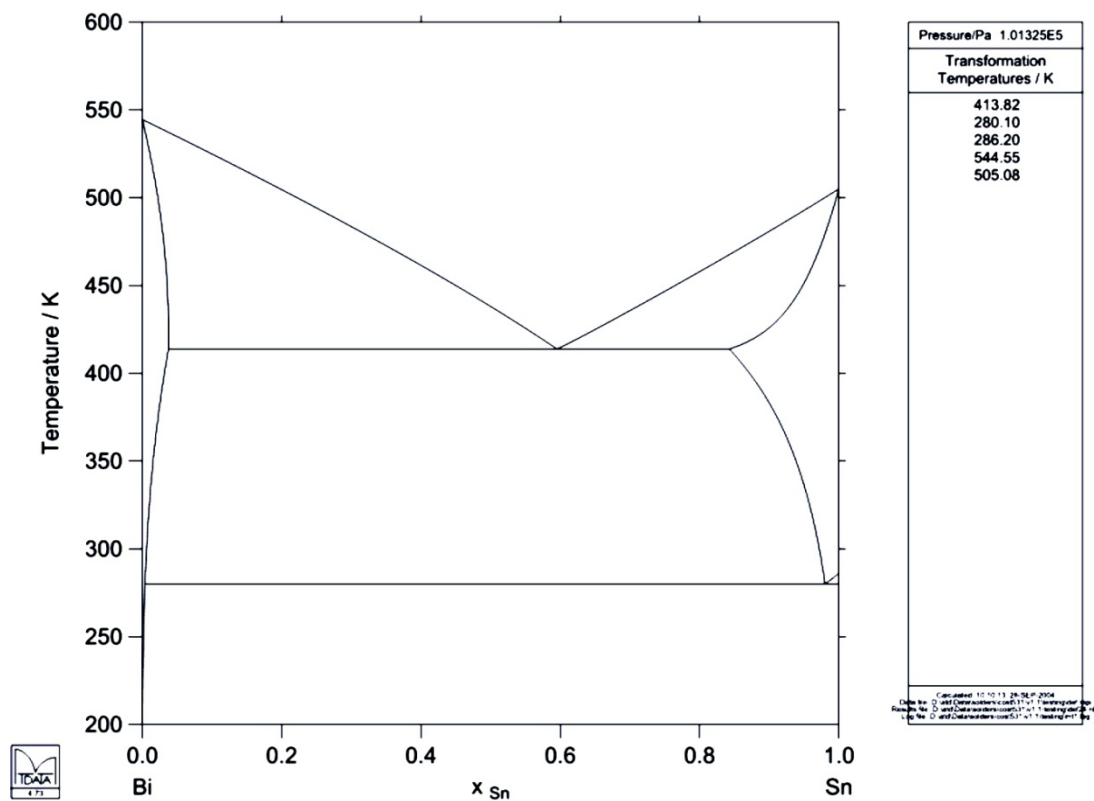


Sn/Ag couple
230°C; 30 min
E: mag. 500×
PL



Sn/Ag couple
230°C; 30 min
E: mag. 500×
PC

Sn – Bi



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•106)

H. Okamoto, 1990

Phase	Composition, wt% Bi	Pearson symbol	Space group
(β Sn)	0 to 21	<i>tI4</i>	<i>I4₁/amd</i>
(α Sn)	0 to ?	<i>cF8</i>	<i>Fd$\bar{3}m$</i>
(Bi)	99.9 to 100	<i>hR2</i>	<i>R$\bar{3}m$</i>

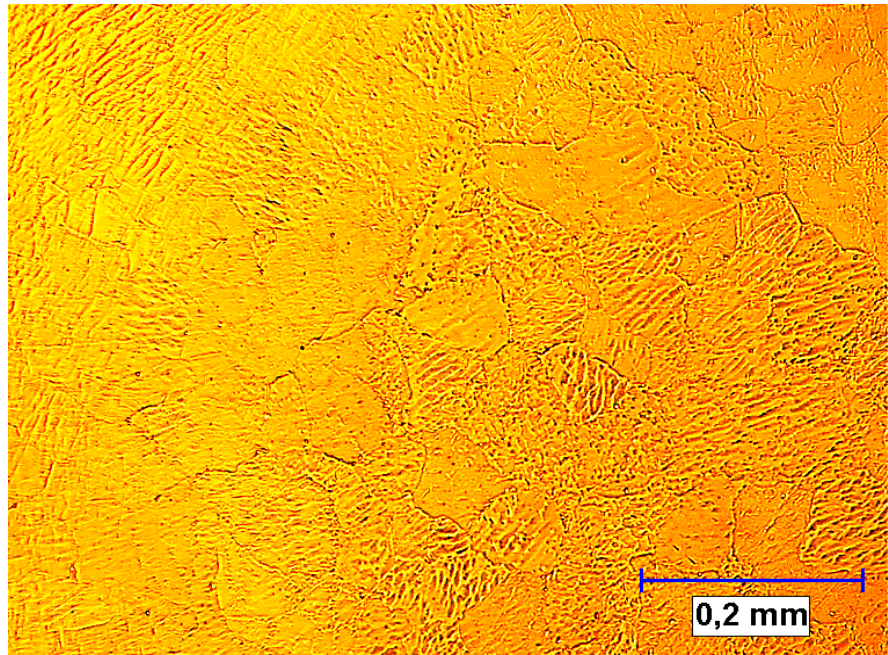
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•106)

Properties of solder/substrate couples:

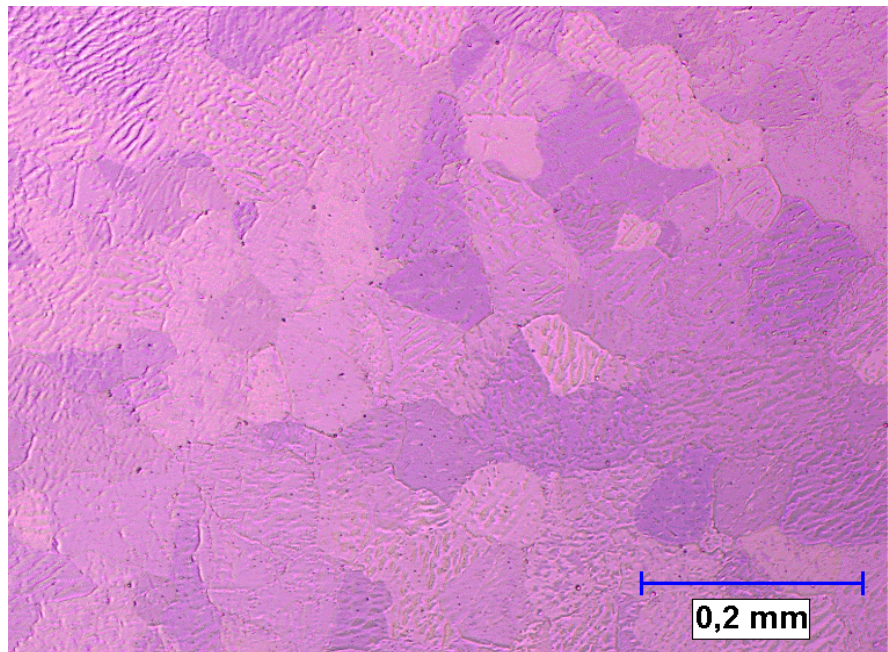
Couple	Conditions	θ , deg	τ , MPa
Sn / Bi	230°C, 5 min, flux	$\sim 0^\circ$	*
Sn / Bi	230°C, 30 min, flux	$\sim 0^\circ$	*

* impossible to measure due to a low contact angle

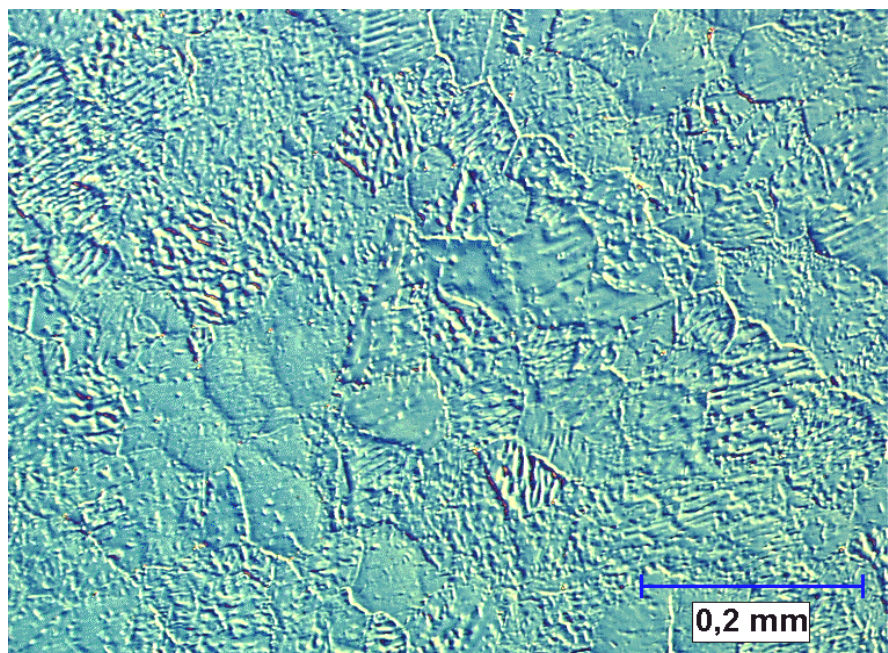
SnBi2.5 alloy (AC)
E: mag. 100×
CL

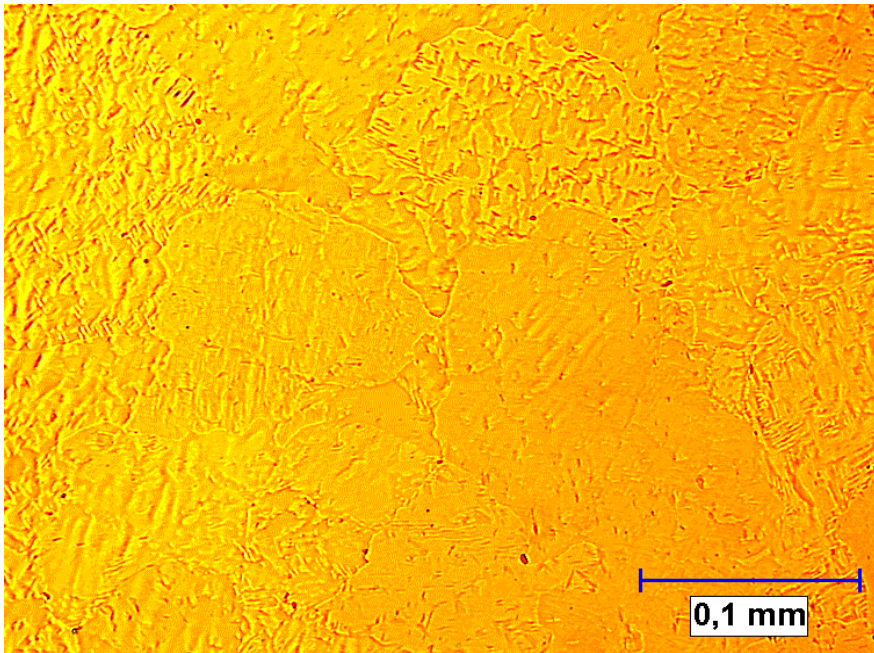


SnBi2.5 alloy (AC)
E: mag. 100×
PL

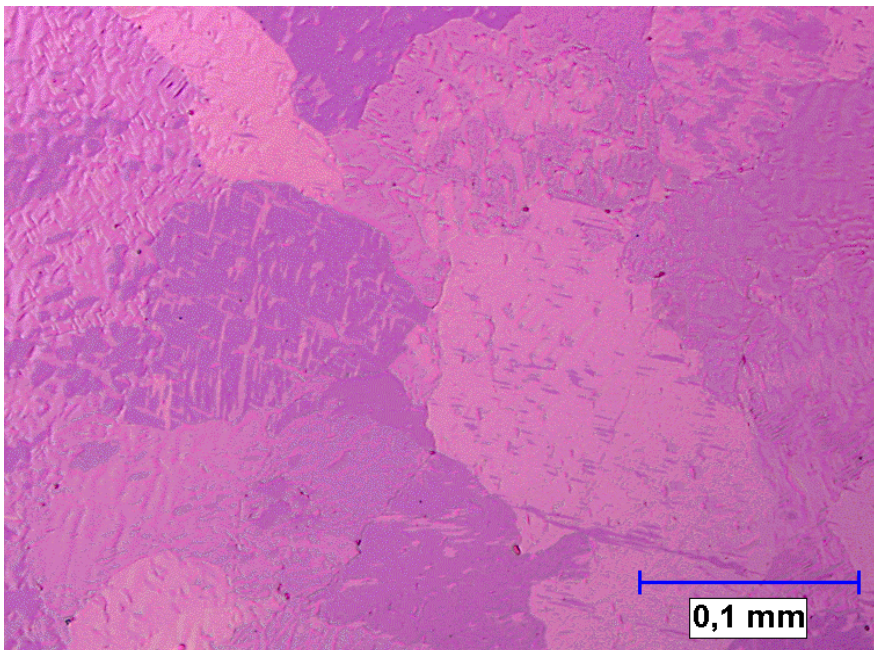


SnBi2.5 alloy (AC)
E: mag. 100×
PC

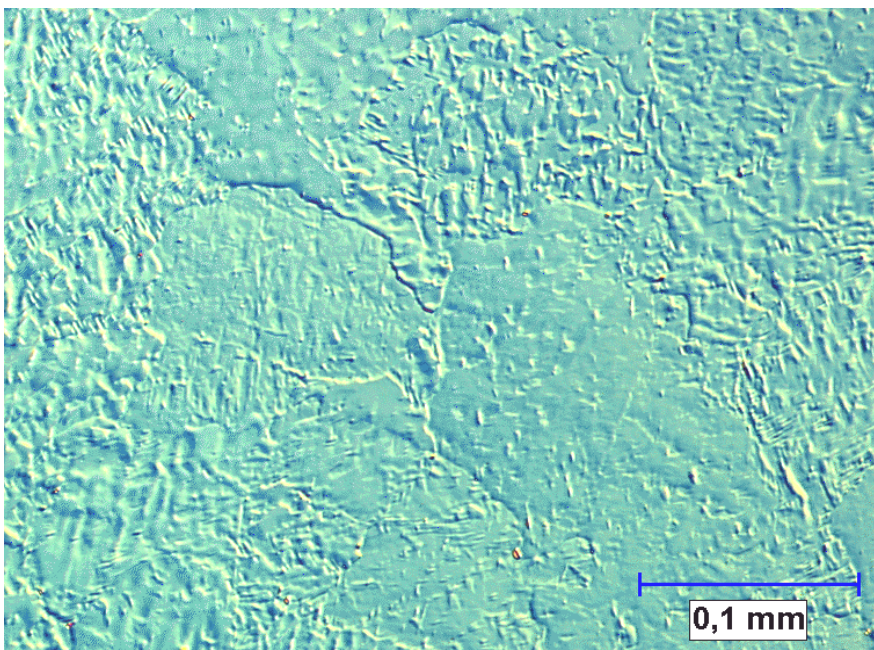




SnBi_{2.5} alloy (AC)
E: mag. 200×
CL

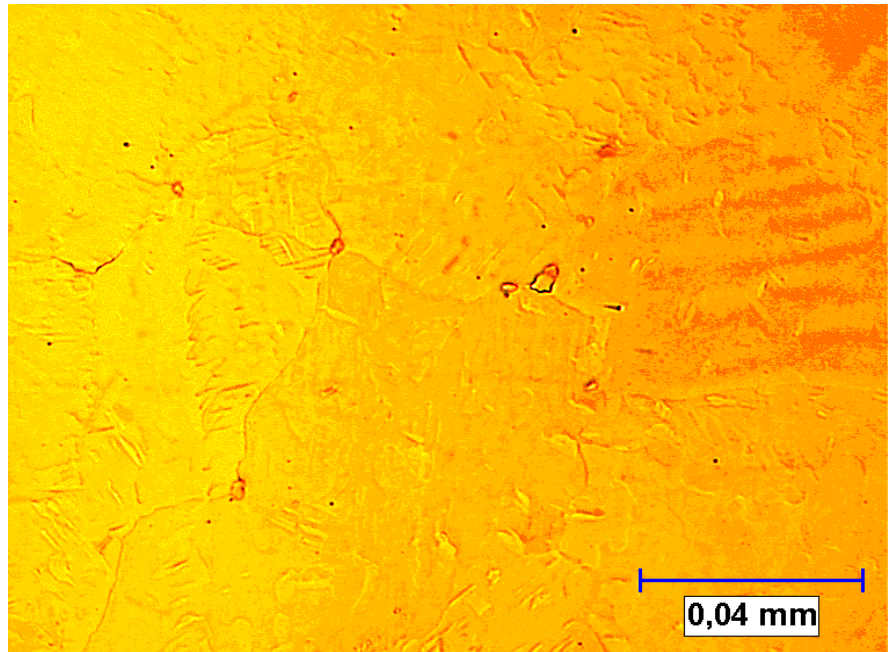


SnBi_{2.5} alloy (AC)
E: mag. 200×
PL

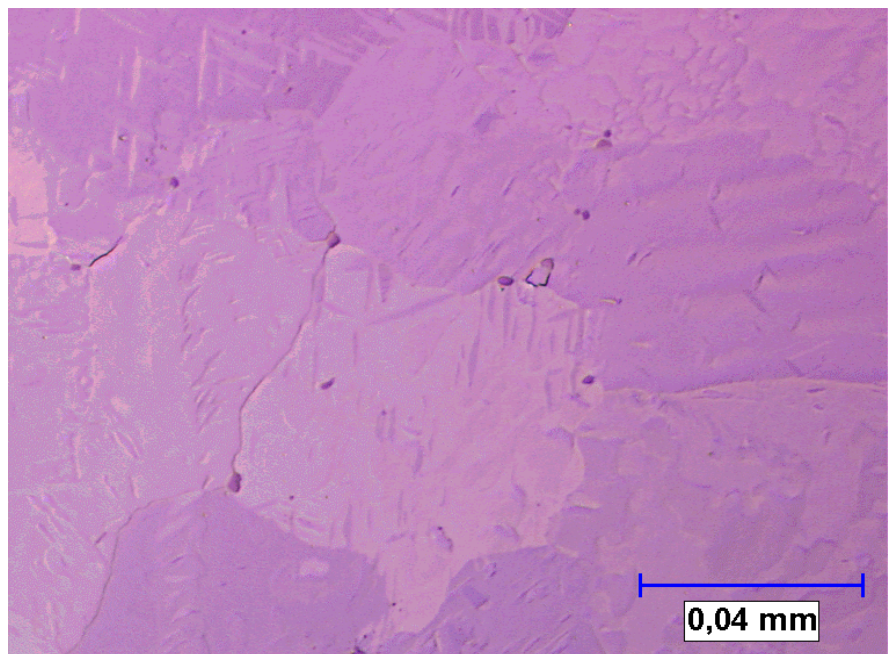


SnBi_{2.5} alloy (AC)
E: mag. 100×
PC

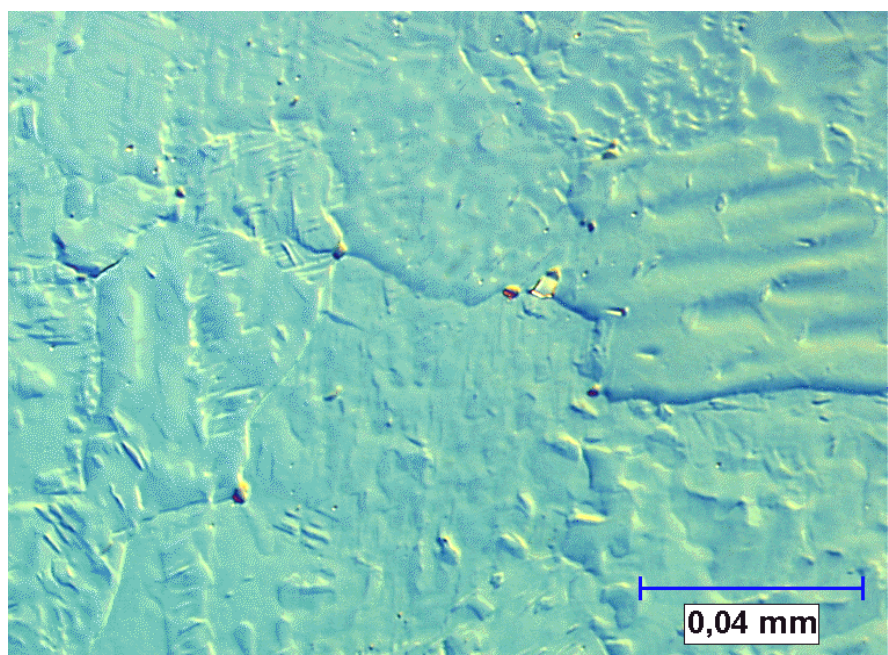
SnBi2.5 alloy (AC)
E: mag. 500×
CL

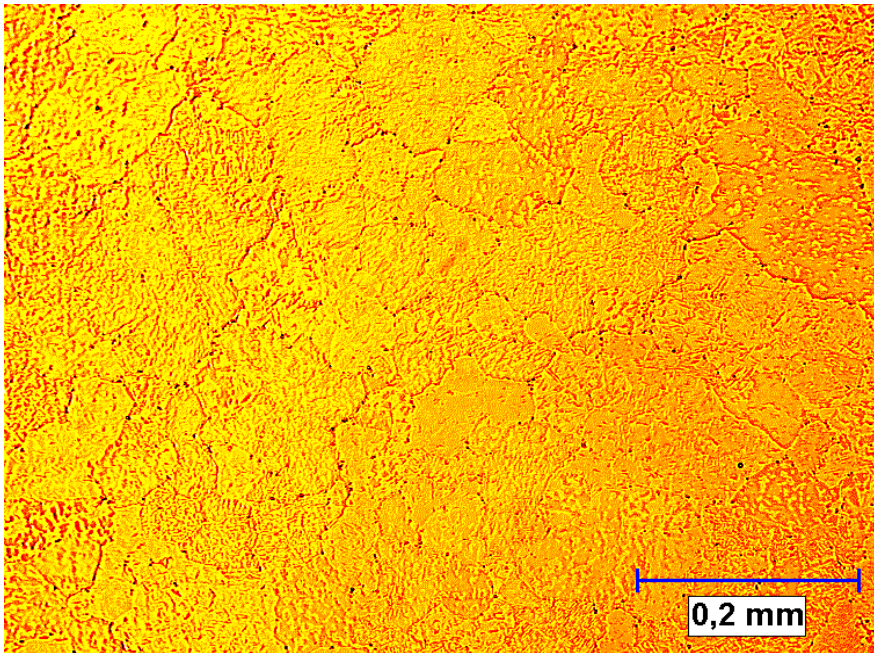


SnBi2.5 alloy (AC)
E: mag. 500×
PL

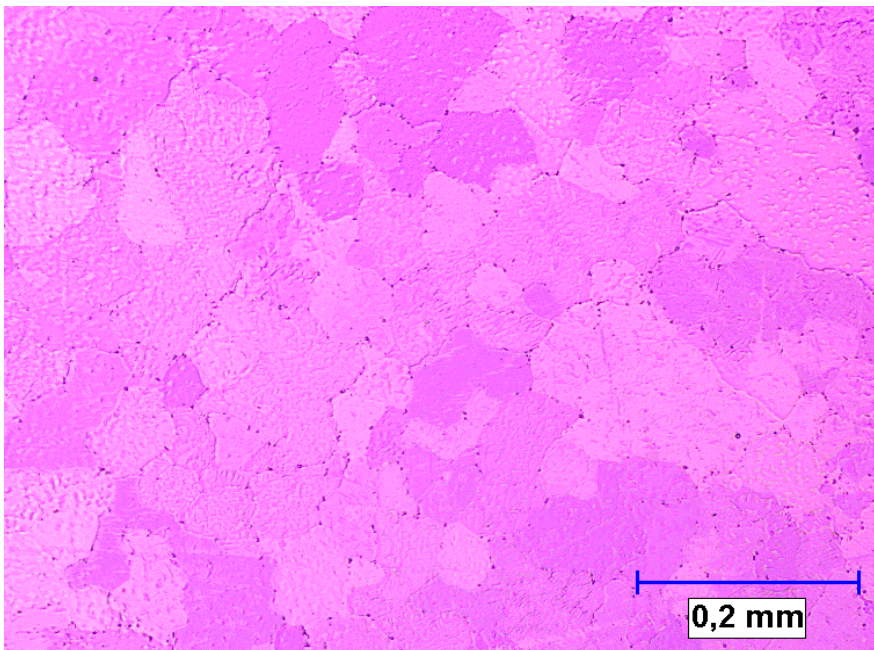


SnBi2.5 alloy (AC)
E: mag. 500×
PC

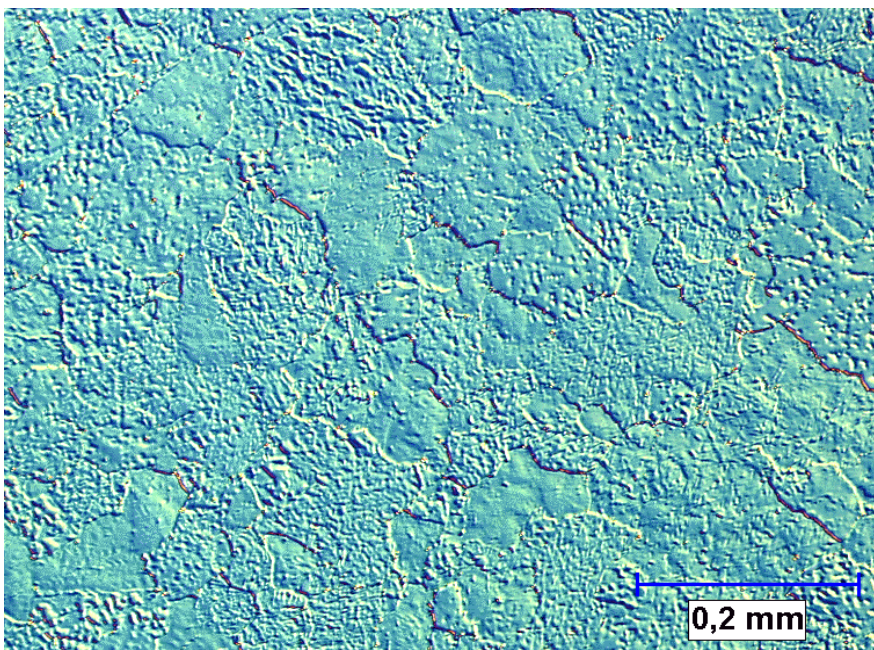




SnBi5 alloy (AC)
E: mag. 100×
CL

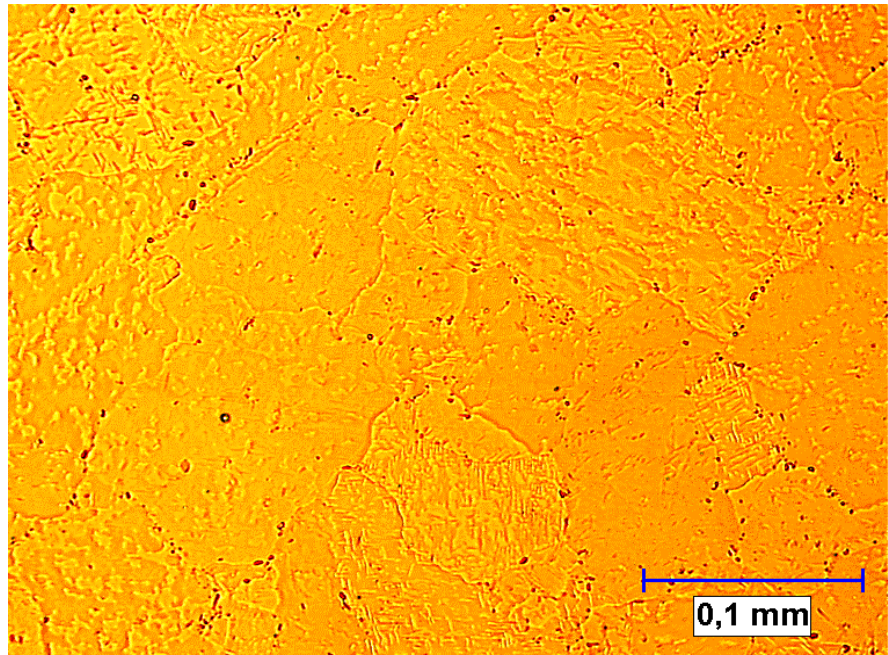


SnBi5 alloy (AC)
E: mag. 100×
PL

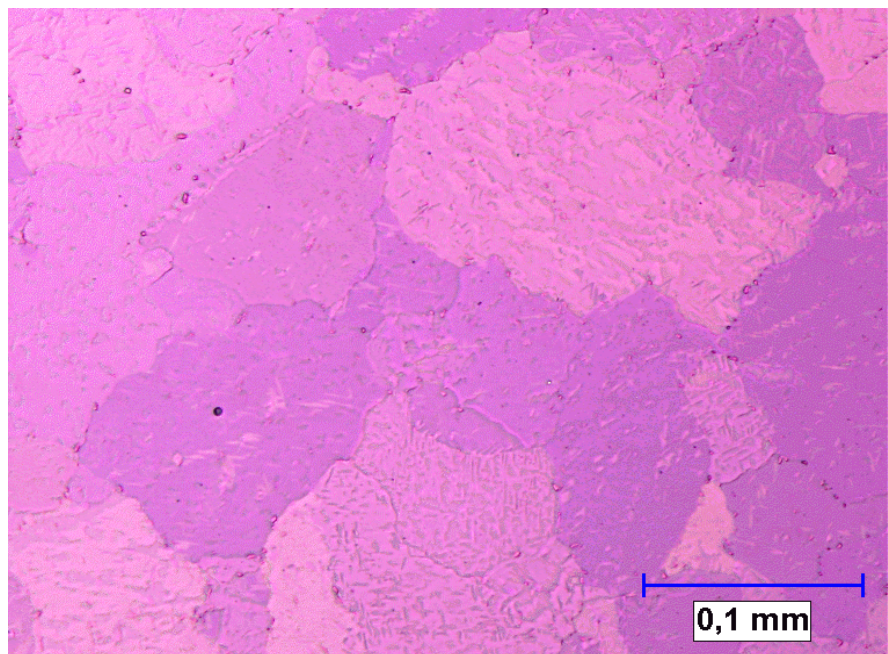


SnBi5 alloy (AC)
E: mag. 100×
PC

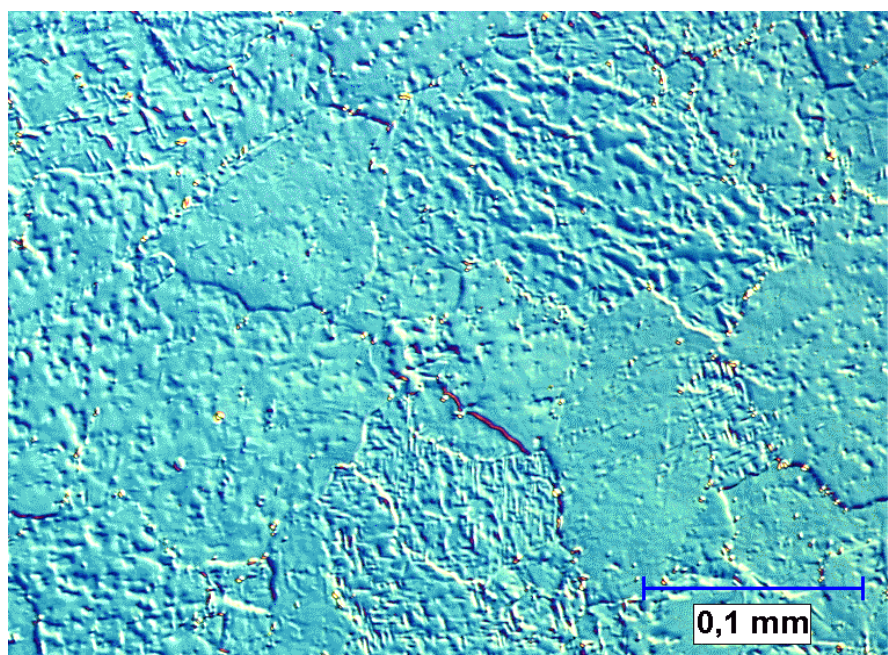
SnBi5 alloy (AC)
E: mag. 200×
CL

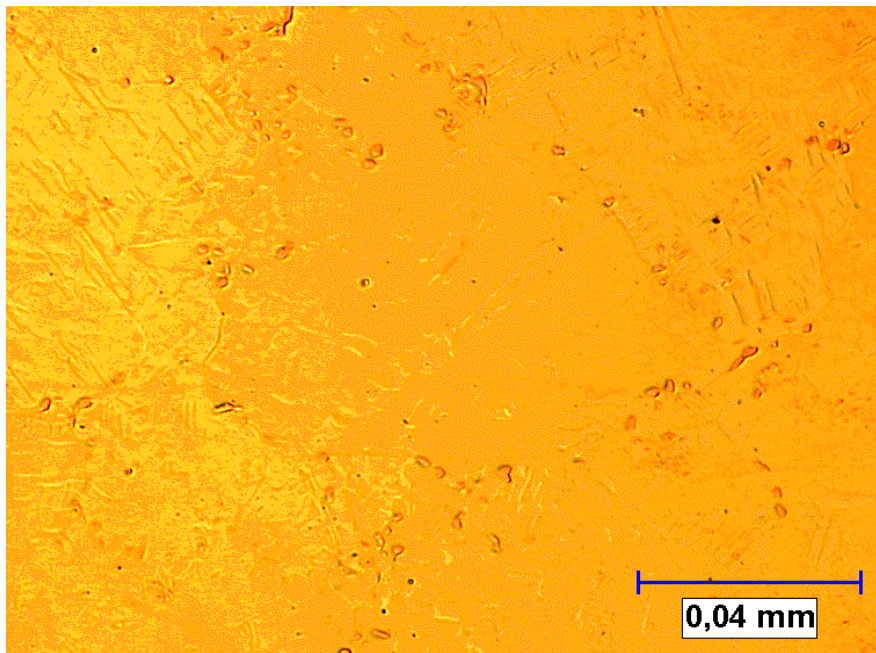


SnBi5 alloy (AC)
E: mag. 200×
PL

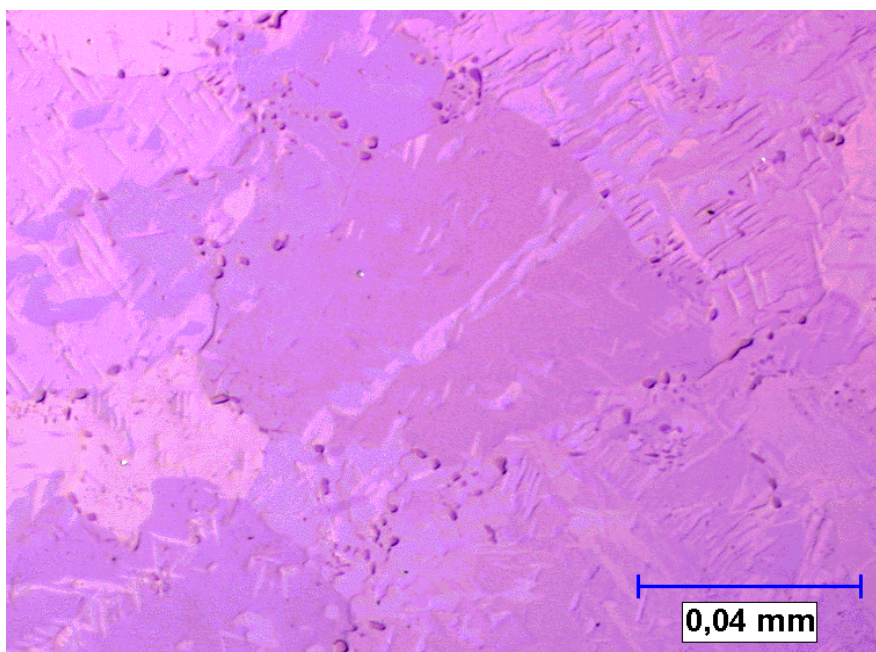


SnBi5 alloy (AC)
E: mag. 200×
PC

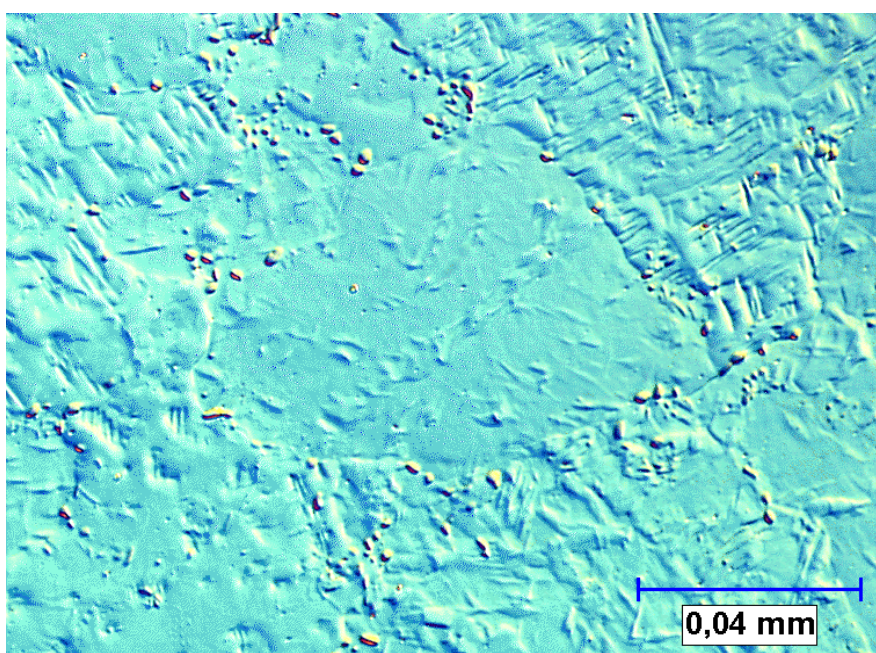




SnBi5 alloy (AC)
E: mag. 500×
CL

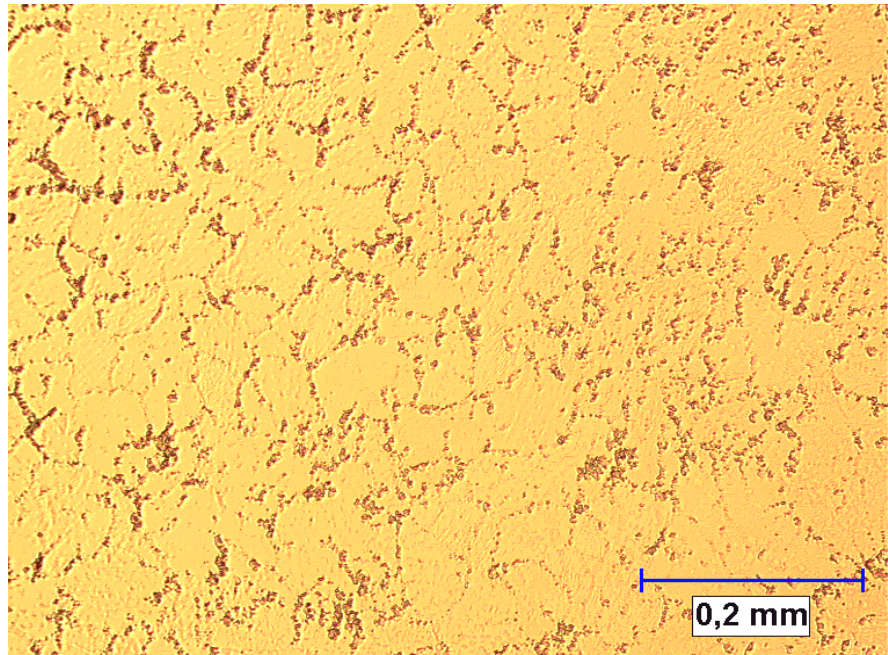


SnBi5 alloy (AC)
E: mag. 500×
PL

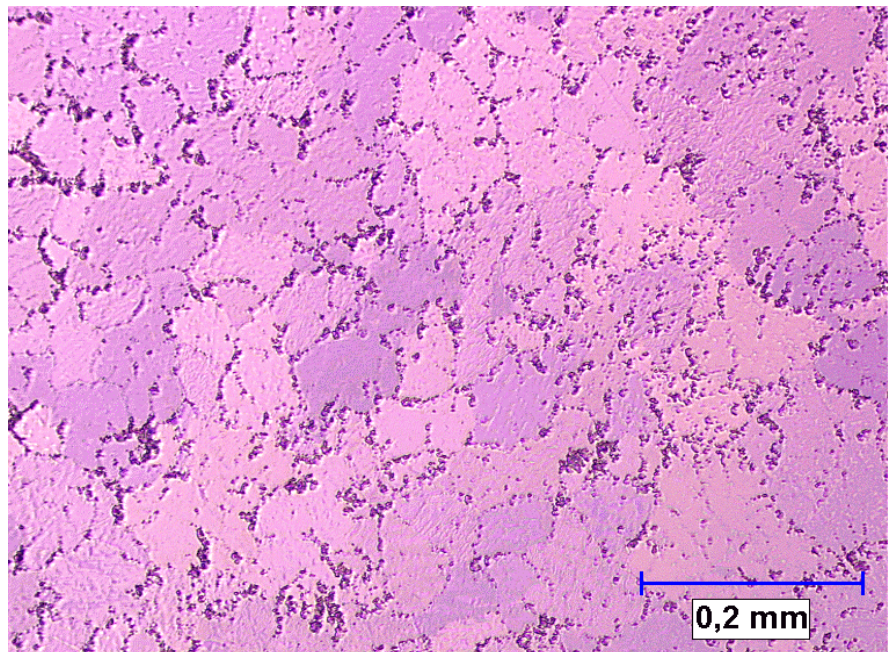


SnBi5 alloy (AC)
E: mag. 500×
PC

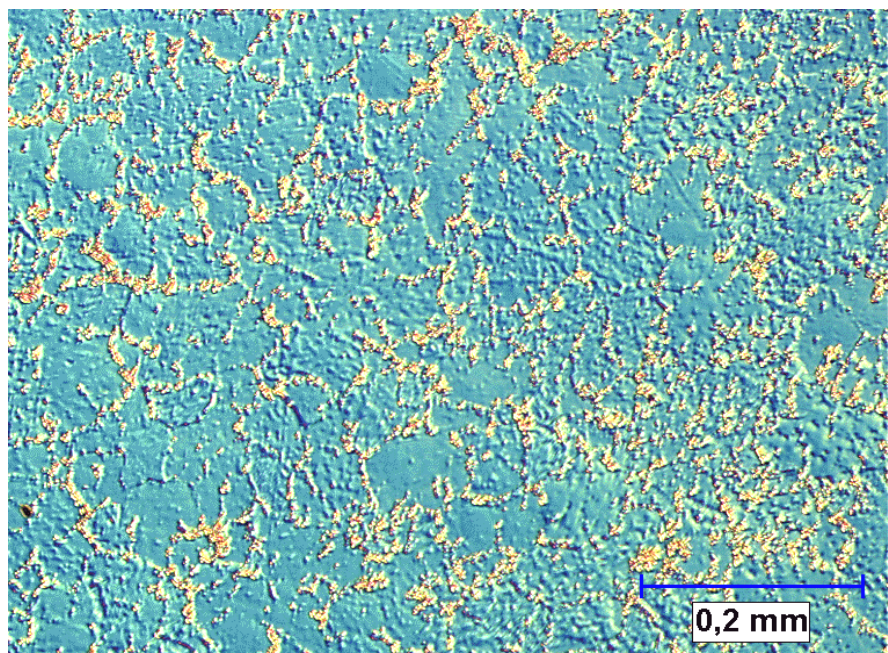
SnBi10 alloy (AC)
E: mag. 100×
CL

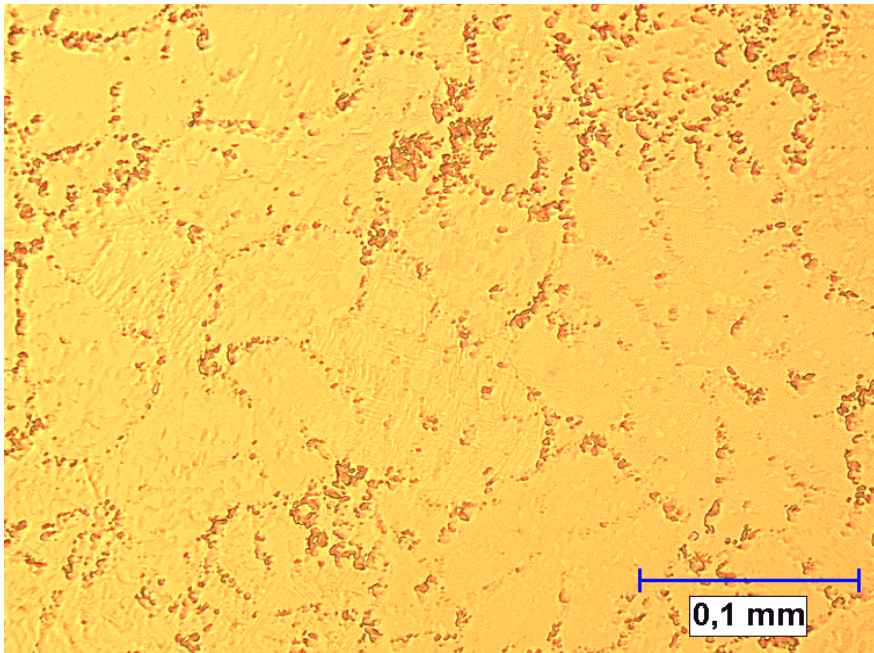
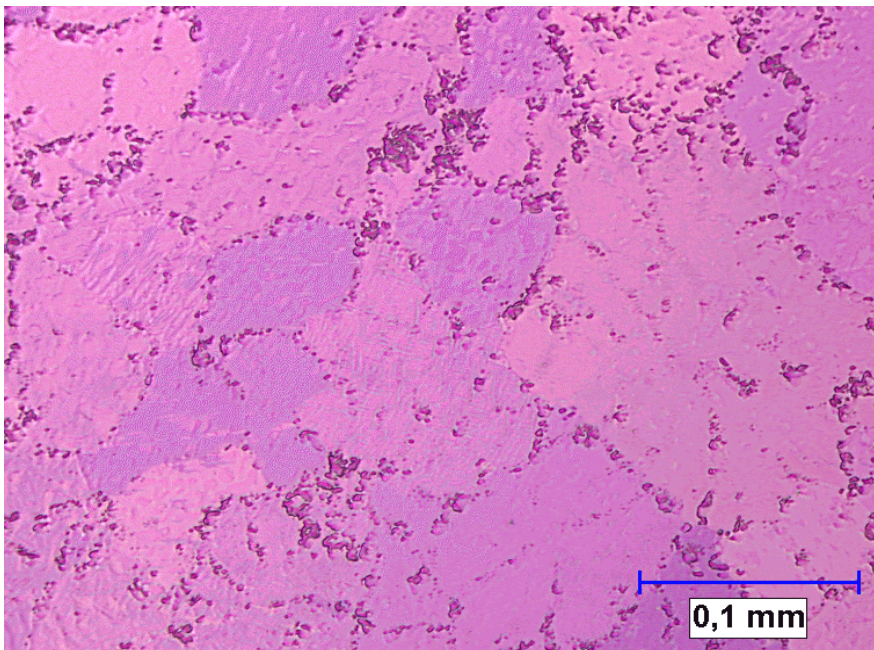
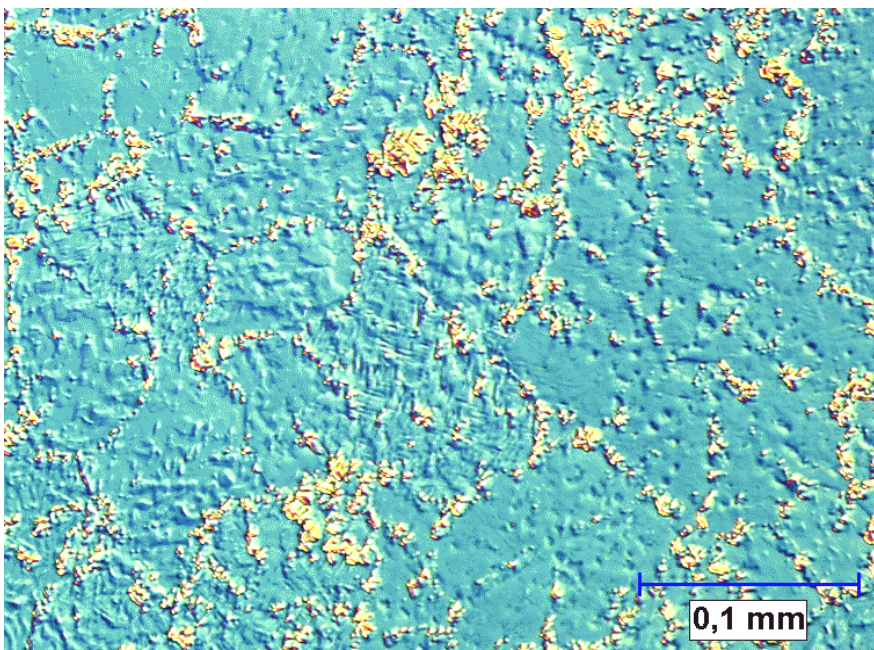


SnBi10 alloy (AC)
E: mag. 100×
PL

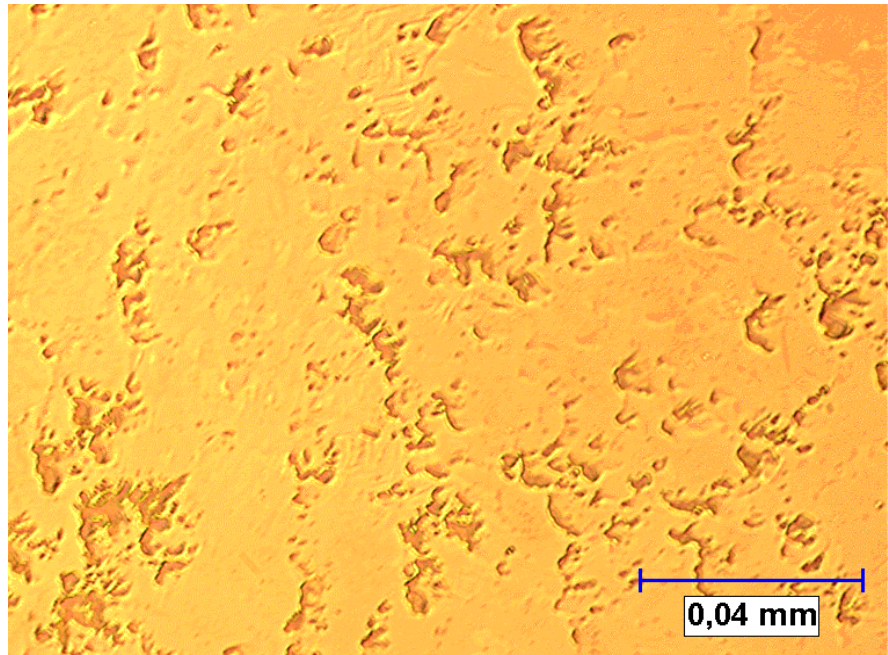


SnBi10 alloy (AC)
E: mag. 100×
PC

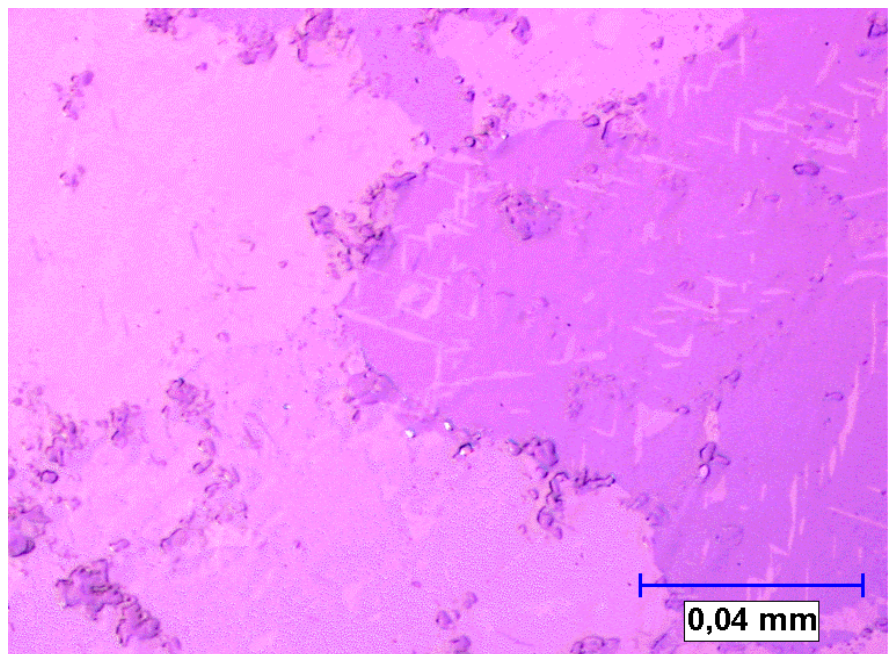


**SnBi10 alloy (AC)****E: mag. 200×****CL****SnBi10 alloy (AC)****E: mag. 200×****PL****SnBi10 alloy (AC)****E: mag. 200×****PC**

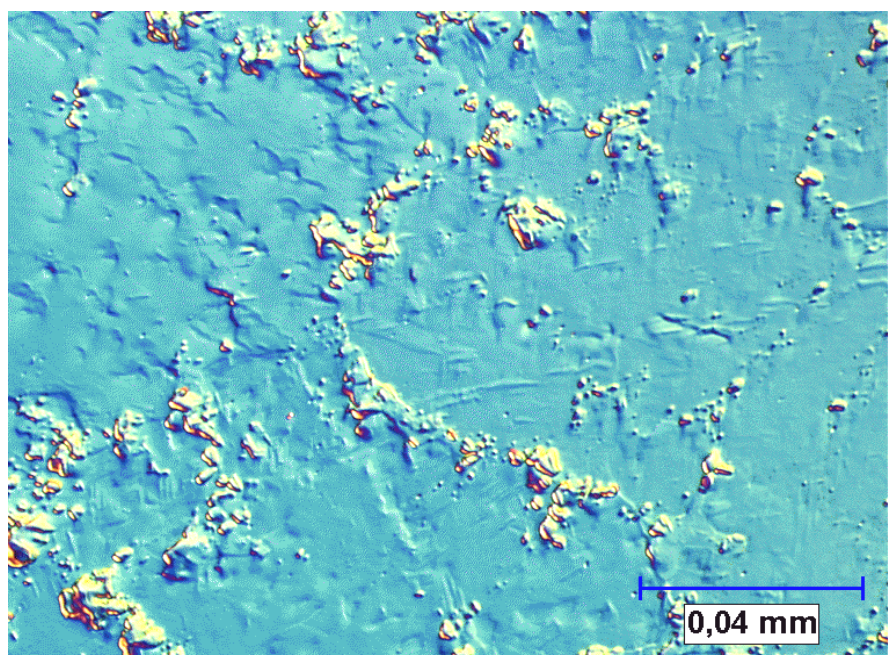
SnBi10 alloy (AC)
E: mag. 500×
CL

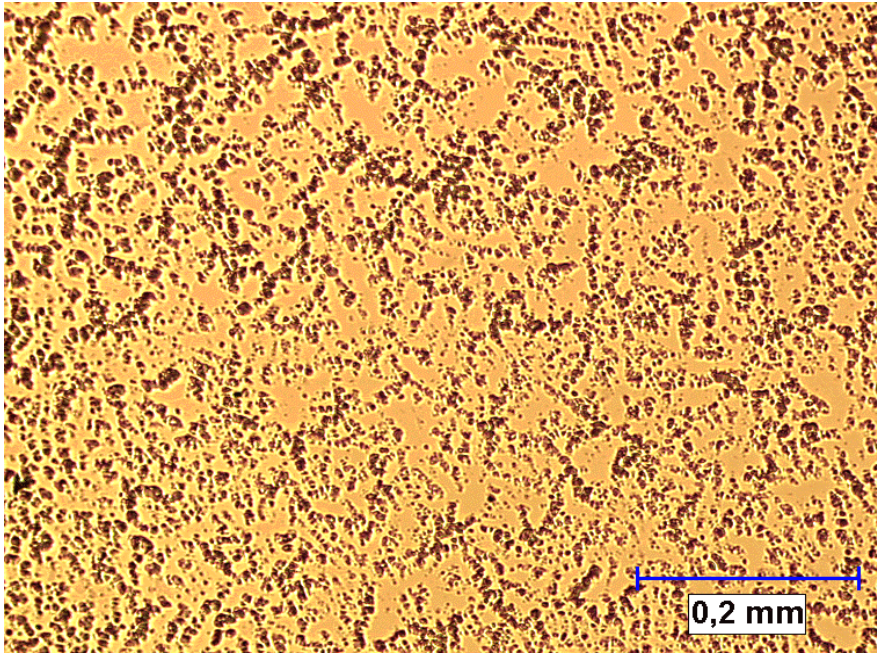


SnBi10 alloy (AC)
E: mag. 500×
PL

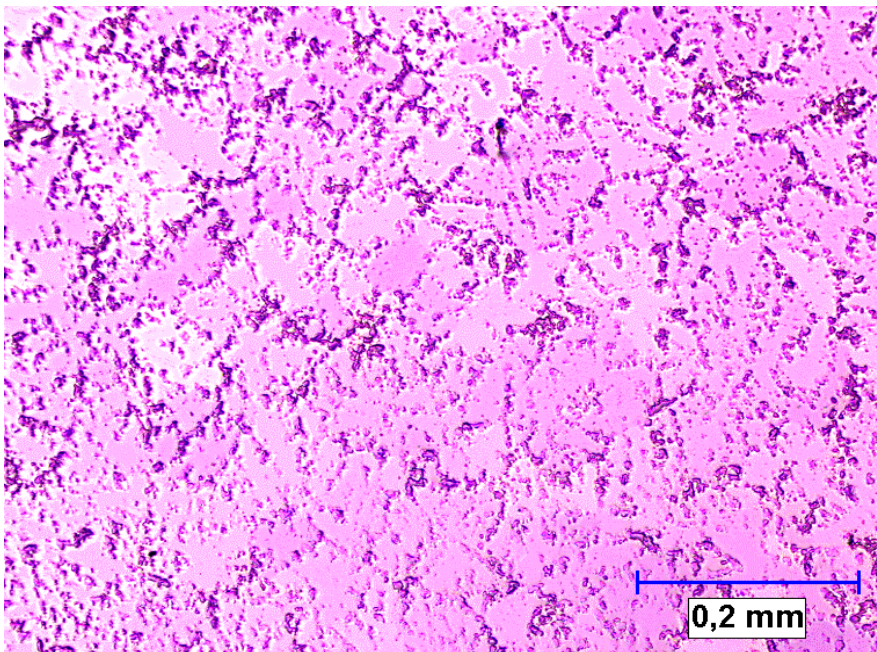


SnBi10 alloy (AC)
E: mag. 500×
PC

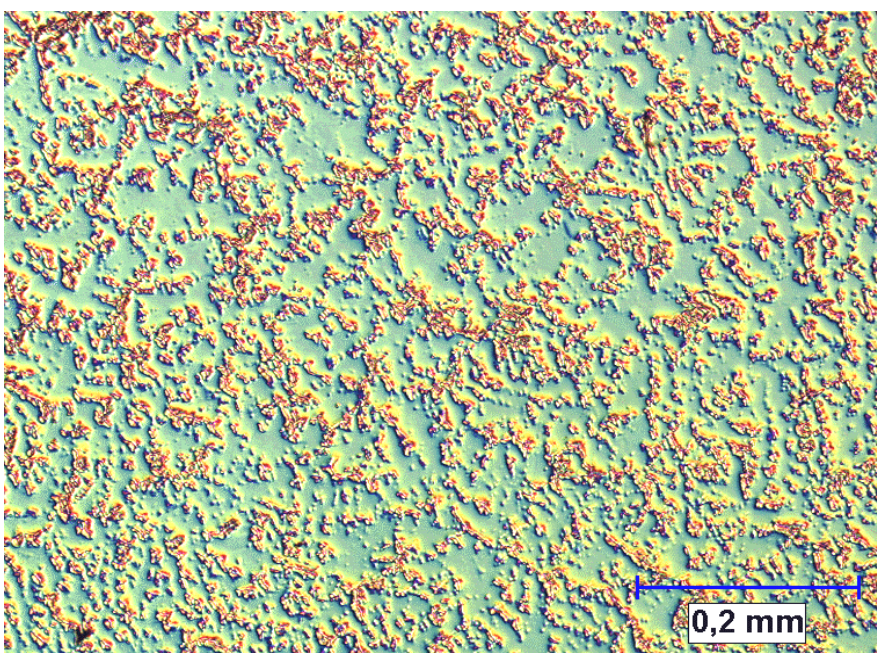




SnBi15 alloy (AC)
E: mag. 100×
CL

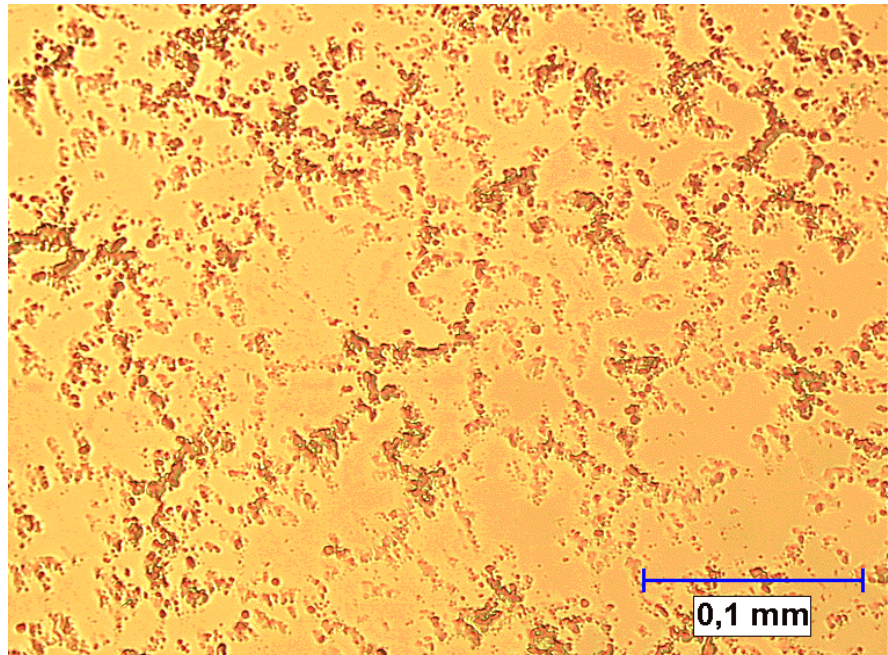


SnBi15 alloy (AC)
E: mag. 100×
PL

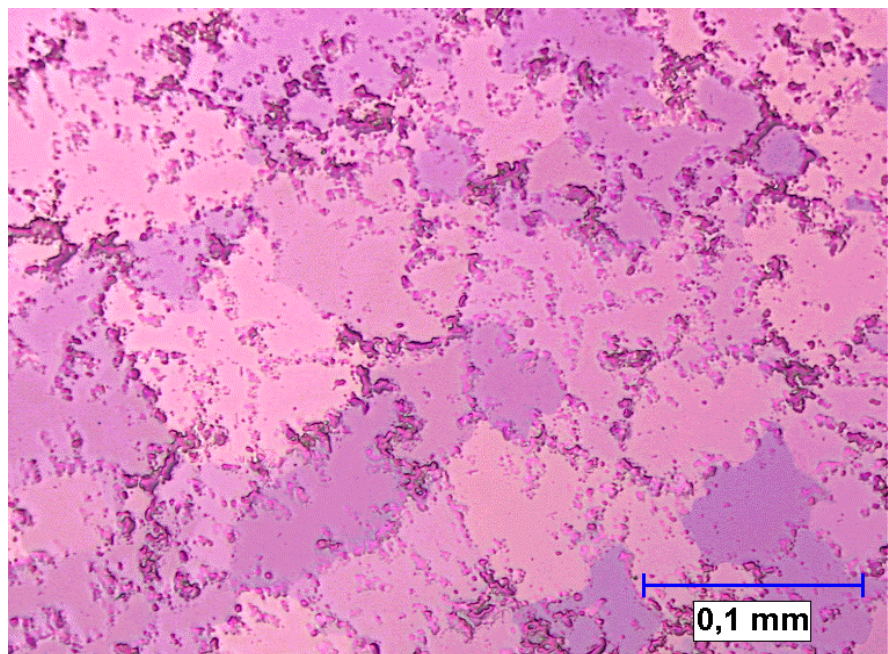


SnBi15 alloy (AC)
E: mag. 100×
PC

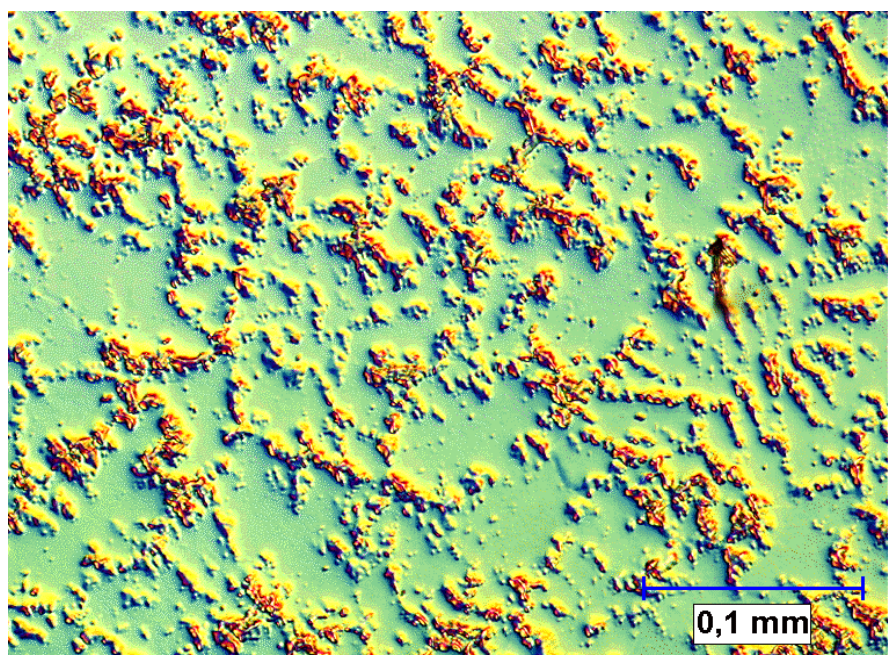
SnBi15 alloy (AC)
E: mag. 200×
CL

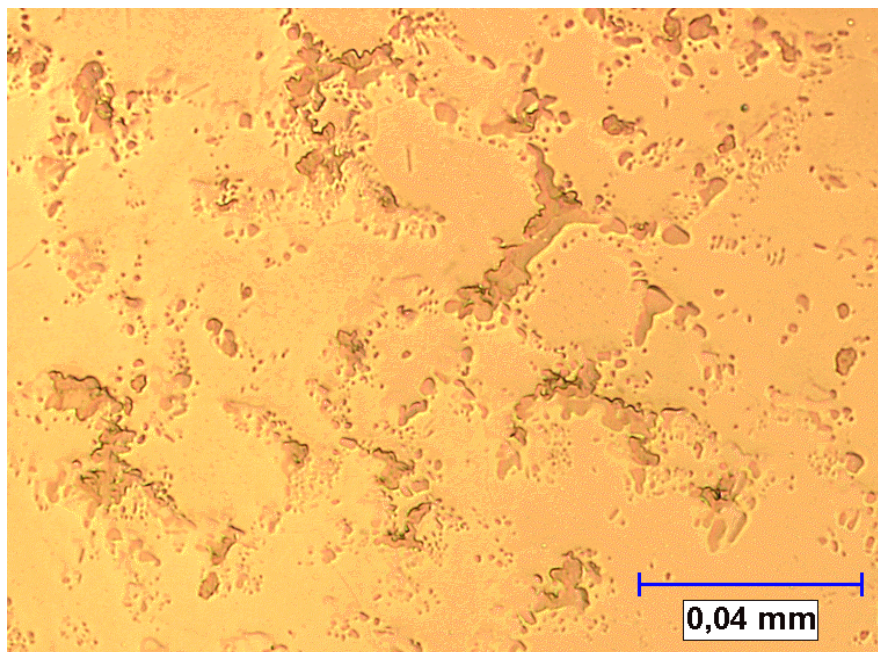
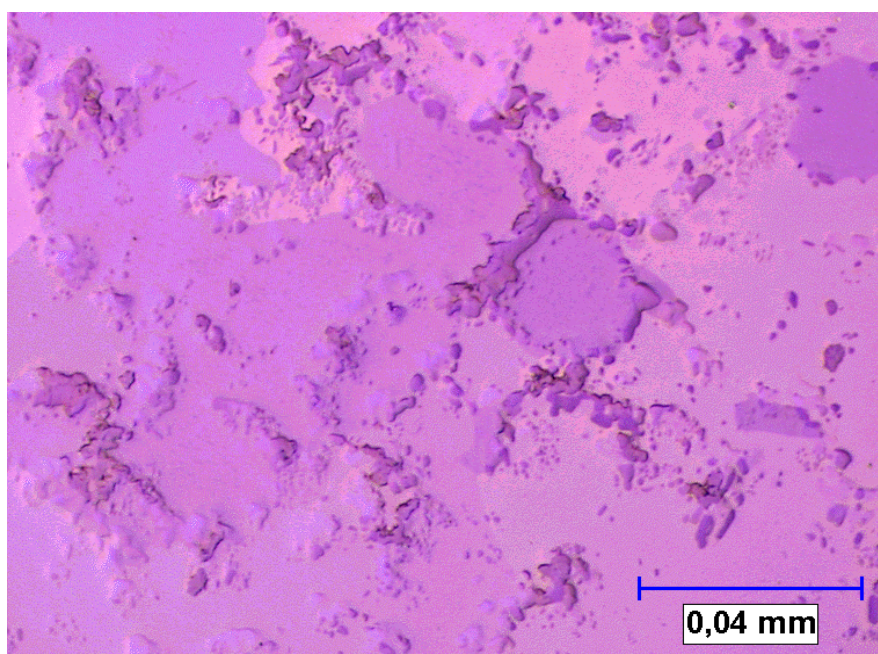
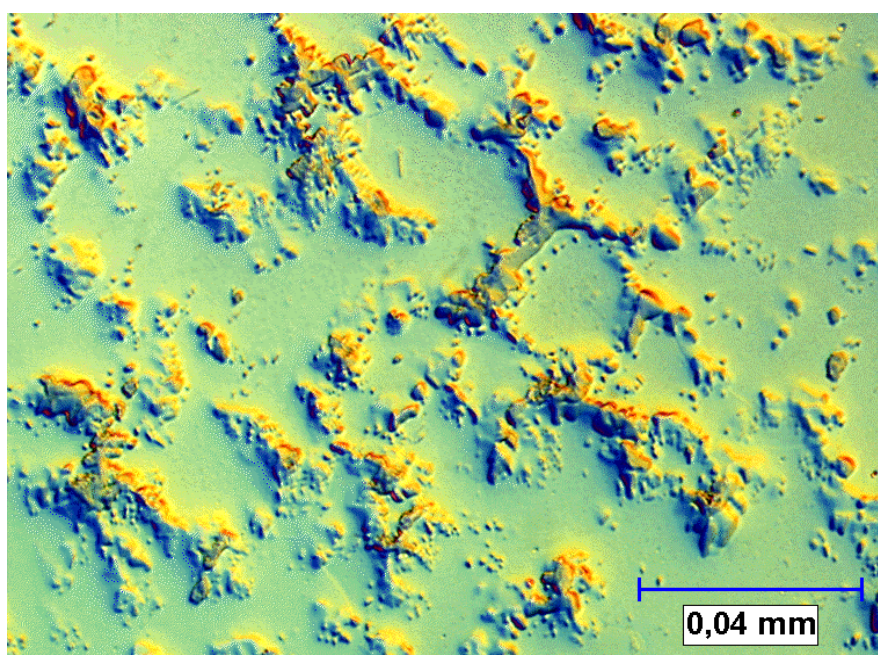


SnBi15 alloy (AC)
E: mag. 200×
PL

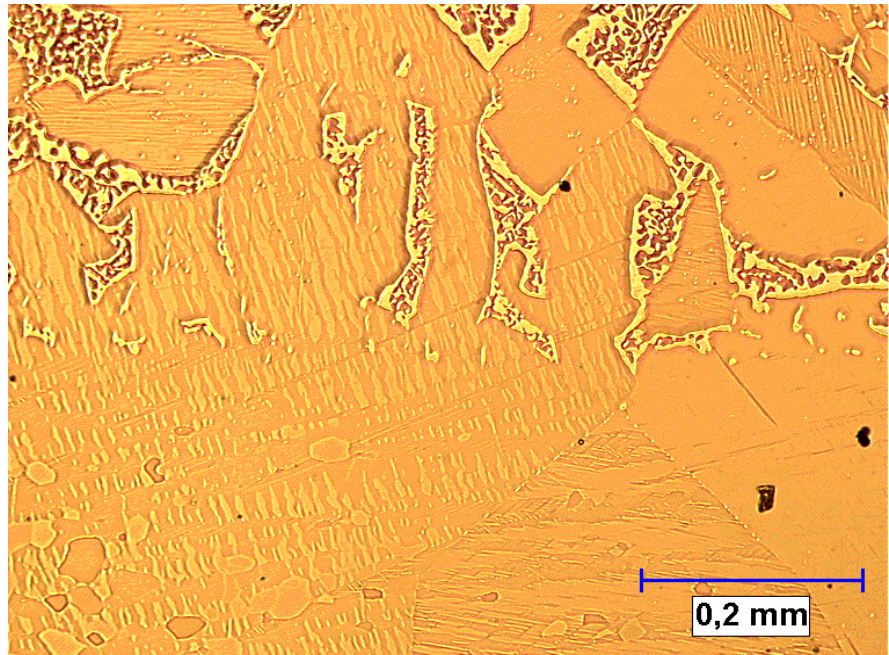


SnBi15 alloy (AC)
E: mag. 200×
PC

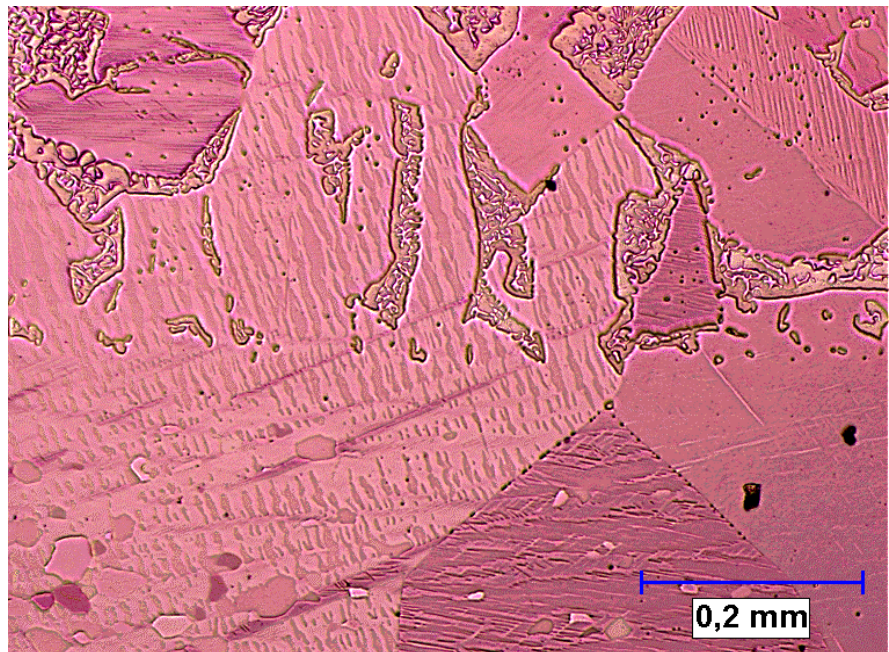


**SnBi15 alloy (AC)****E: mag. 500×****CL****SnBi15 alloy (AC)****E: mag. 500×****PL****SnBi15 alloy (AC)****E: mag. 500×****PC**

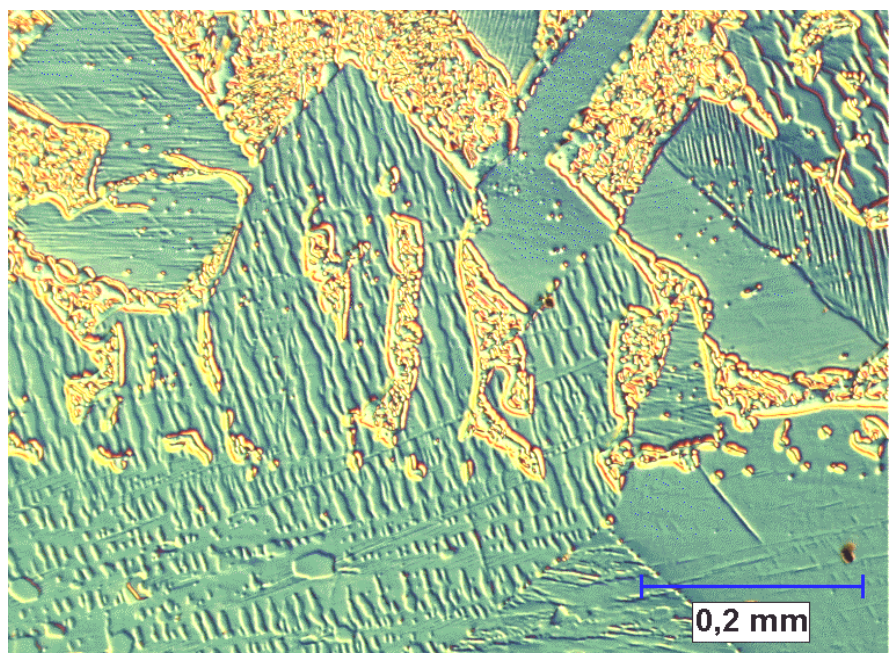
Sn/Bi couple
230°C; 5 min
E: mag. 100×
CL

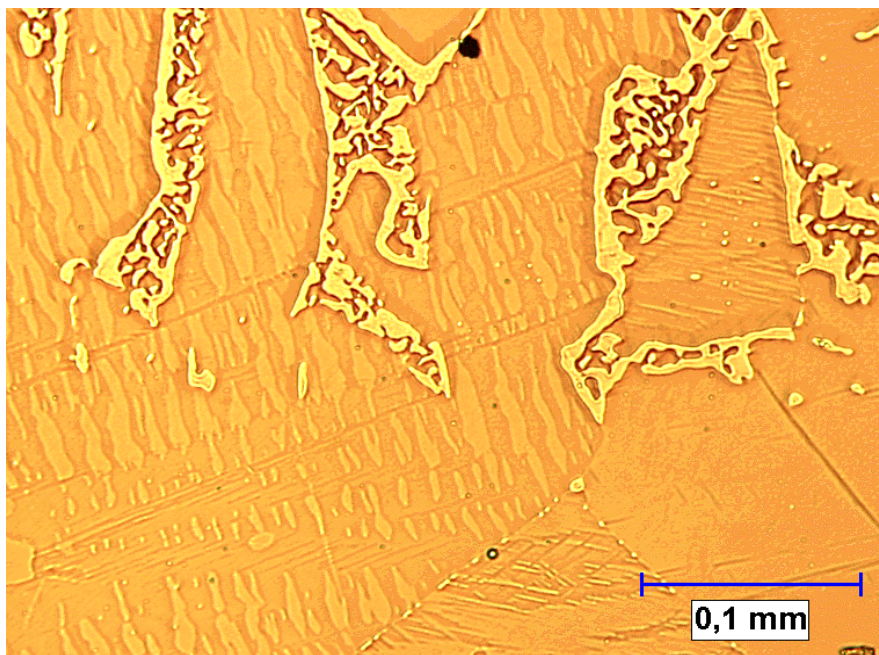


Sn/Bi couple
230°C; 5 min
E: mag. 100×
PL

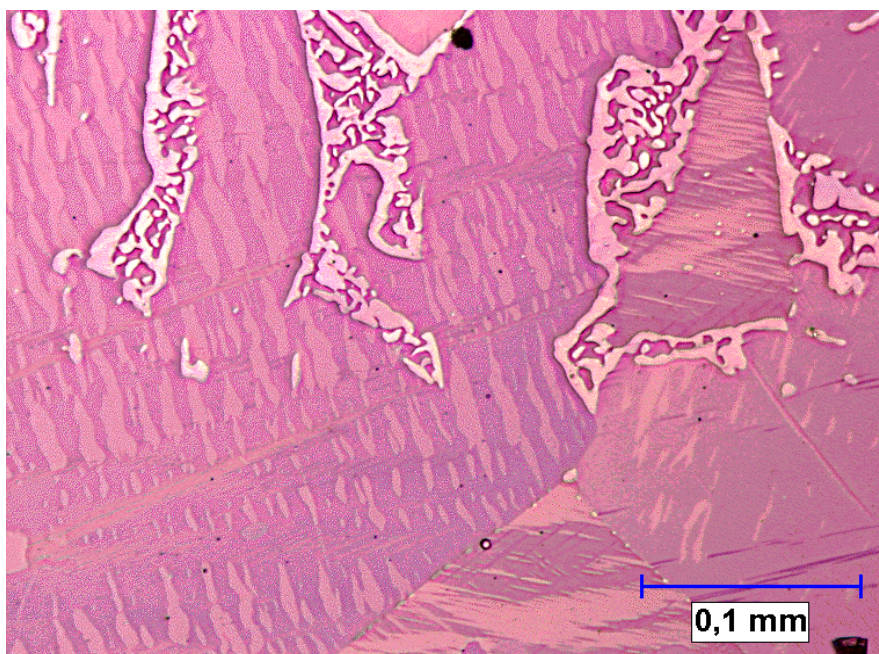


Sn/Bi couple
230°C; 5 min
E: mag. 100×
PC

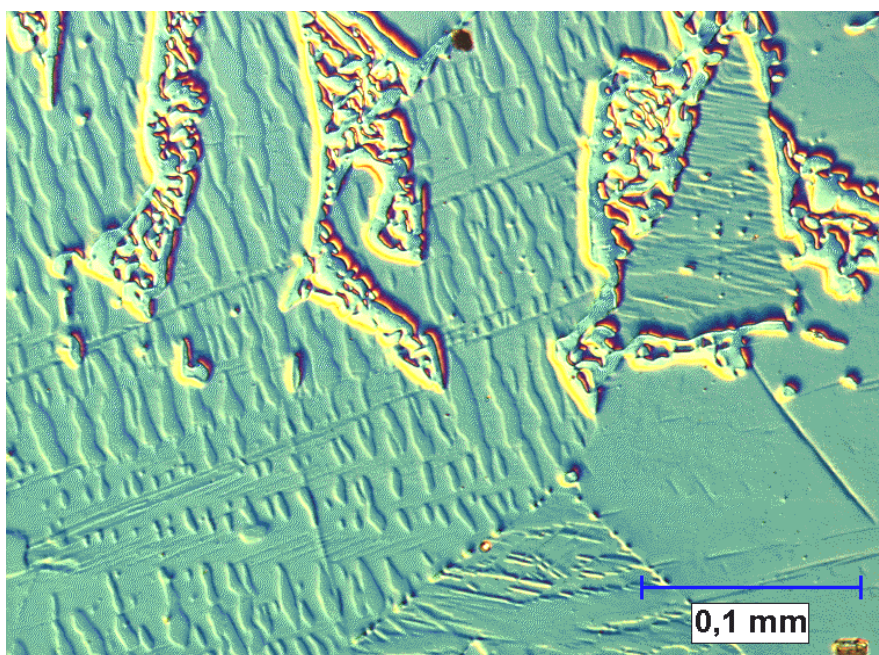




Sn/Bi couple
230°C; 5 min
E: mag. 200×
CL

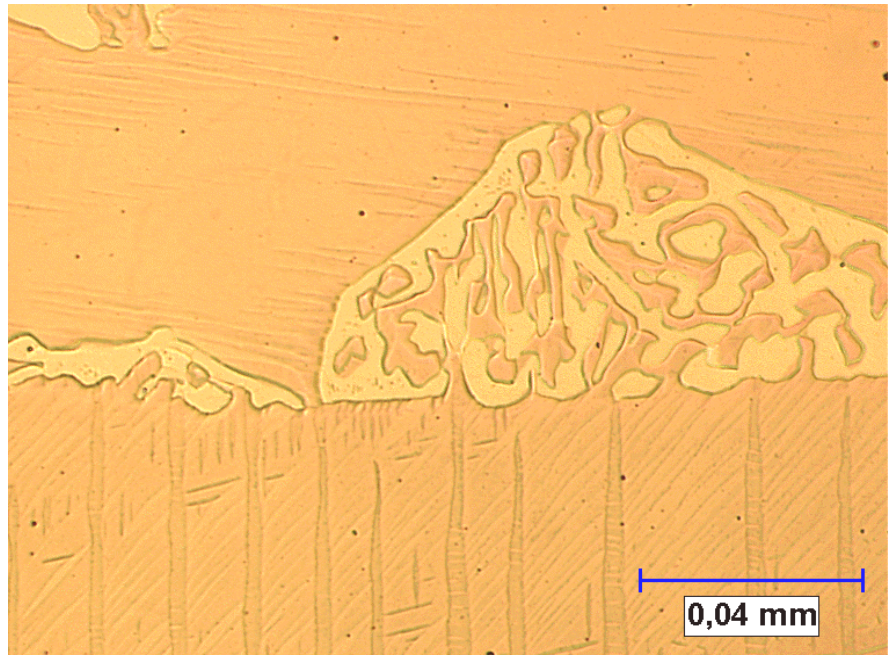


Sn/Bi couple
230°C; 5 min
E: mag. 200×
PL

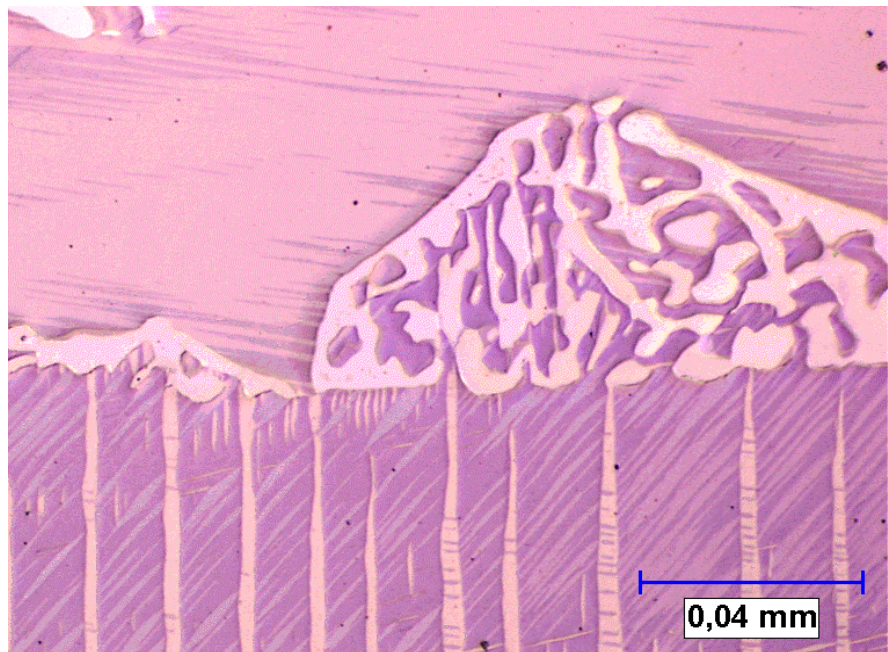


Sn/Bi couple
230°C; 5 min
E: mag. 200×
PC

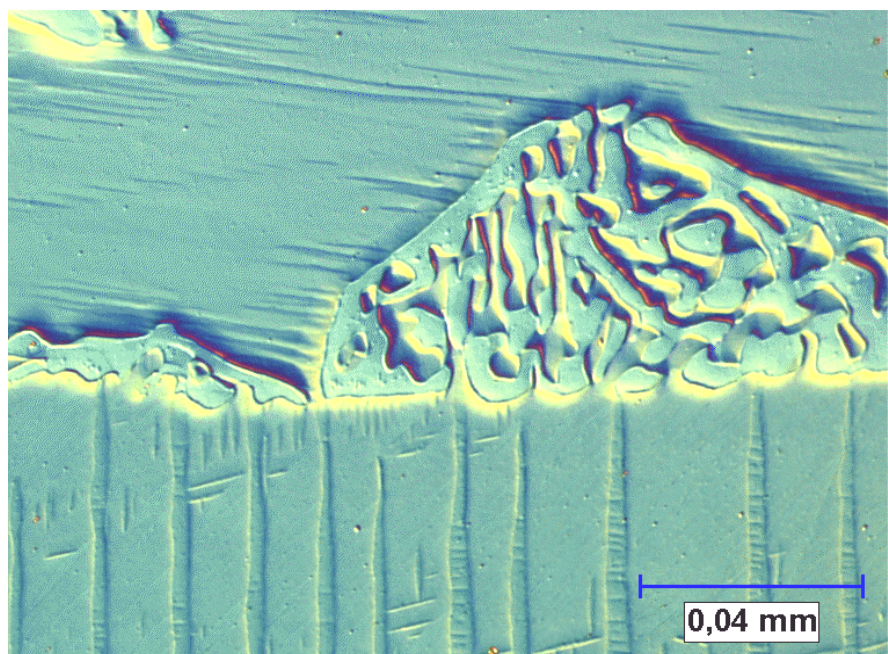
Sn/Bi couple
230°C; 5 min
E: mag. 500×
CL

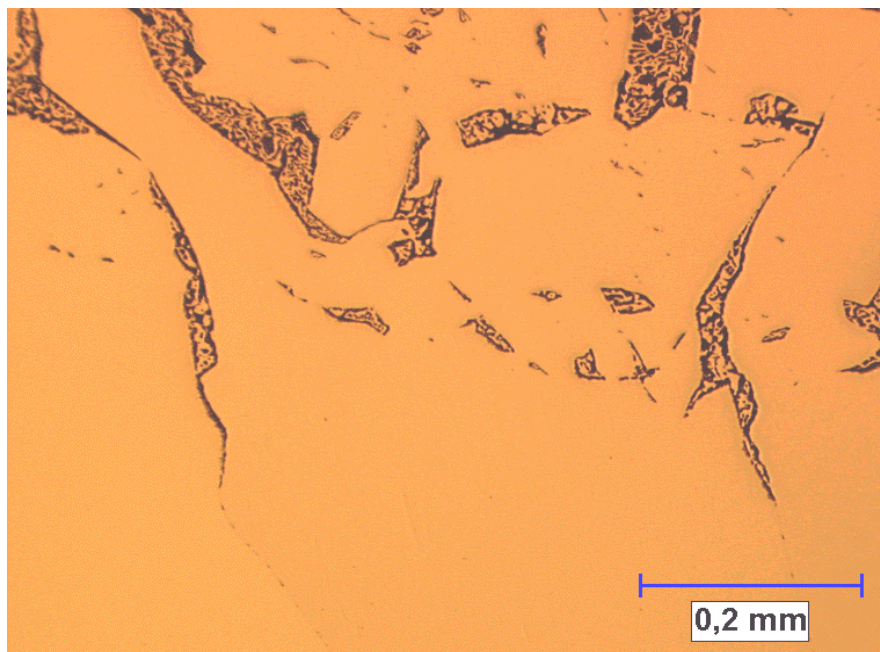


Sn/Bi couple
230°C; 5 min
E: mag. 500×
PL

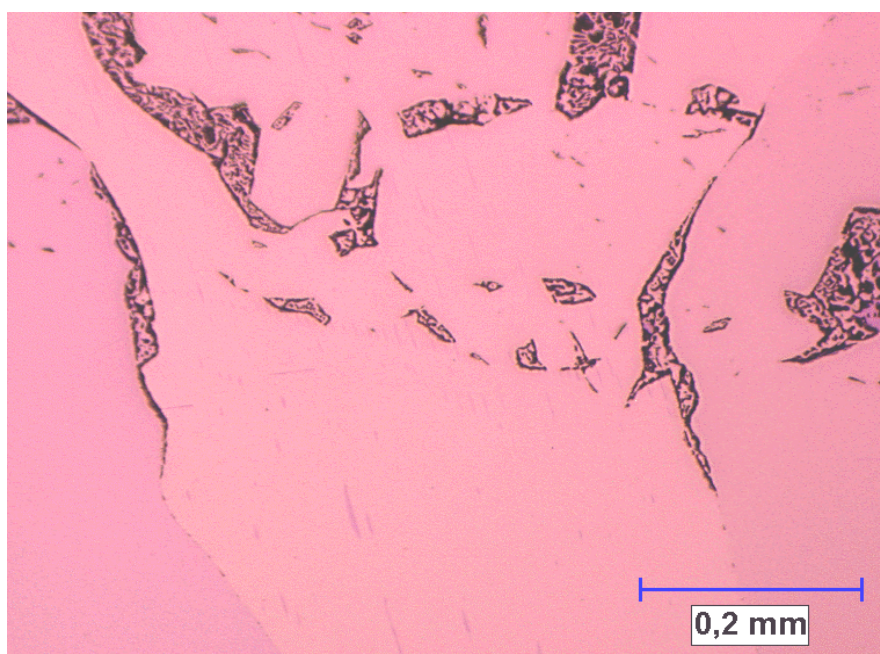


Sn/Bi couple
230°C; 5 min
E: mag. 500×
PC

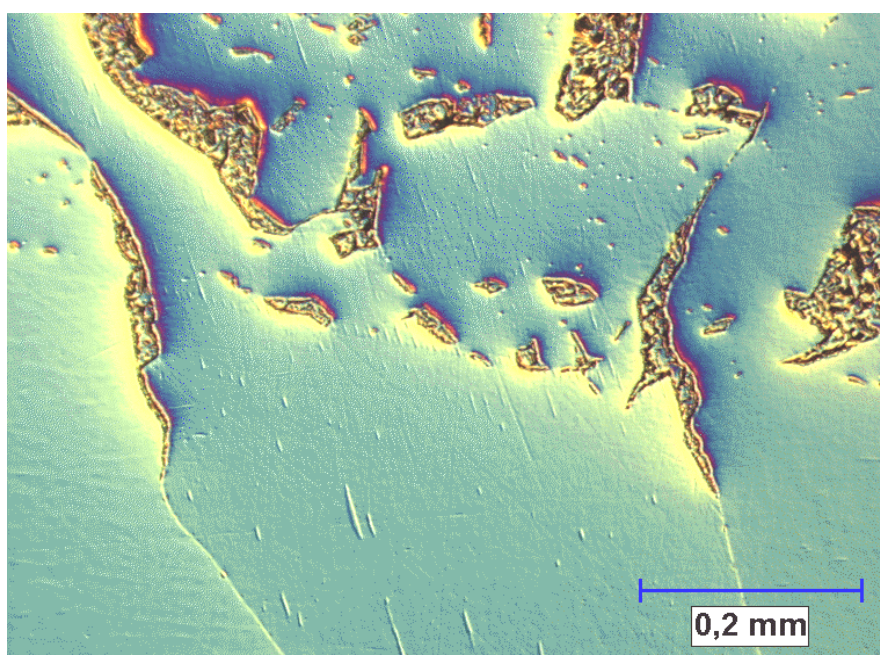




Sn/Bi couple
230°C; 30 min
E: mag. 100×
CL

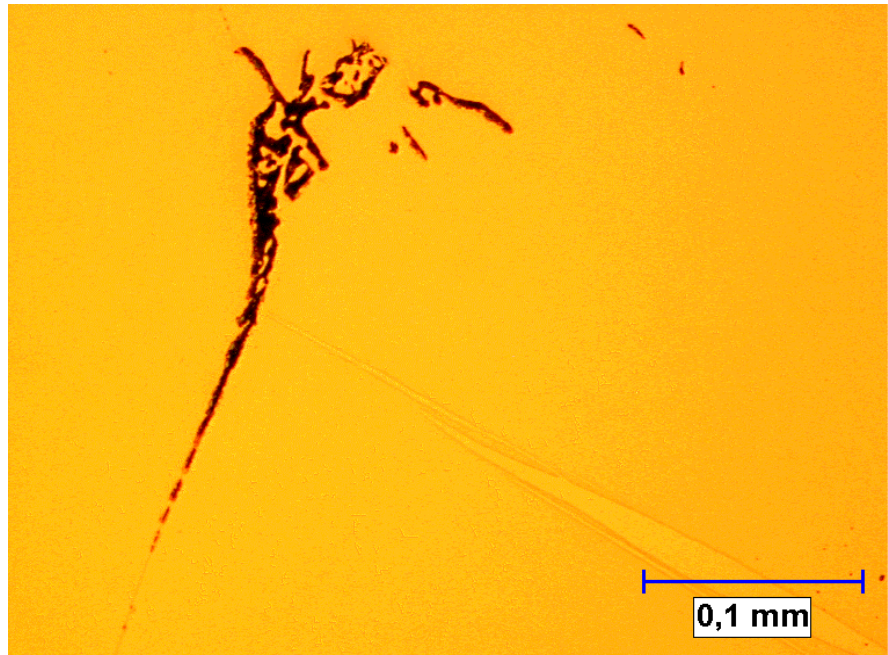


Sn/Bi couple
230°C; 30 min
E: mag. 100×
PL

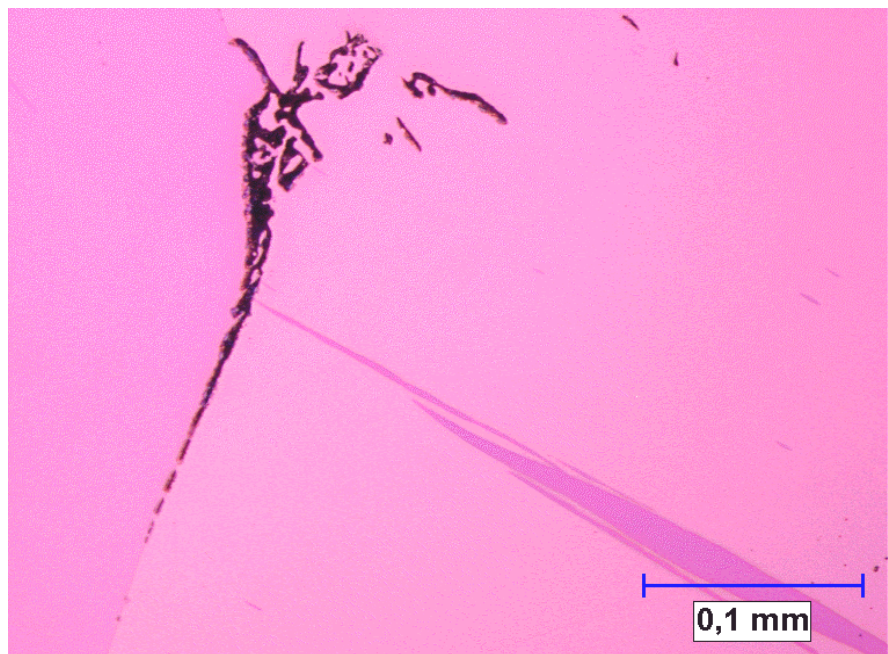


Sn/Bi couple
230°C; 30 min
E: mag. 100×
PC

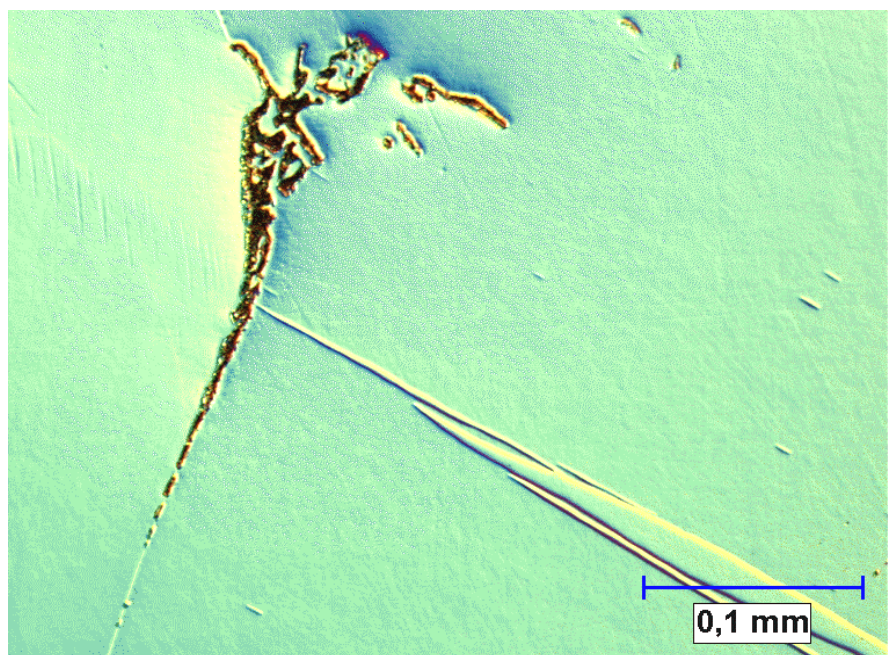
Sn/Bi couple
230°C; 30 min
E: mag. 200×
CL

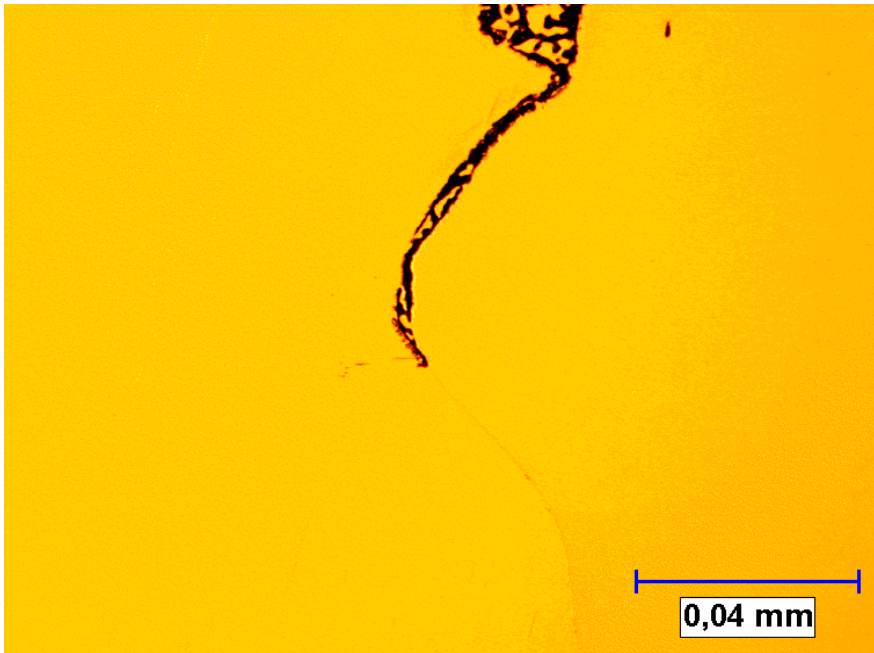


Sn/Bi couple
230°C; 30 min
E: mag. 200×
PL

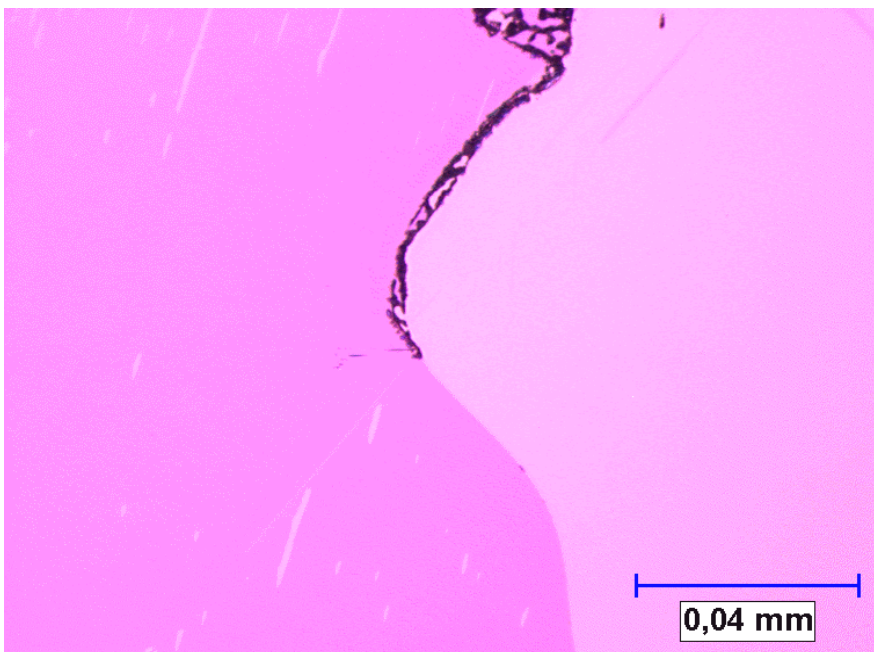


Sn/Bi couple
230°C; 30 min
E: mag. 200×
PC

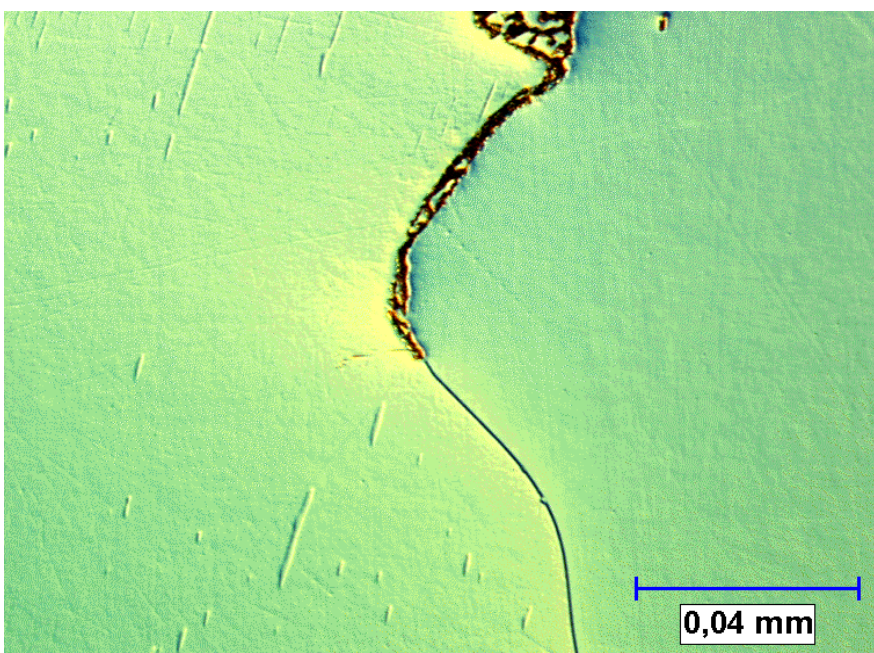




Sn/Bi couple
230°C; 30 min
E: mag. 500×
CL

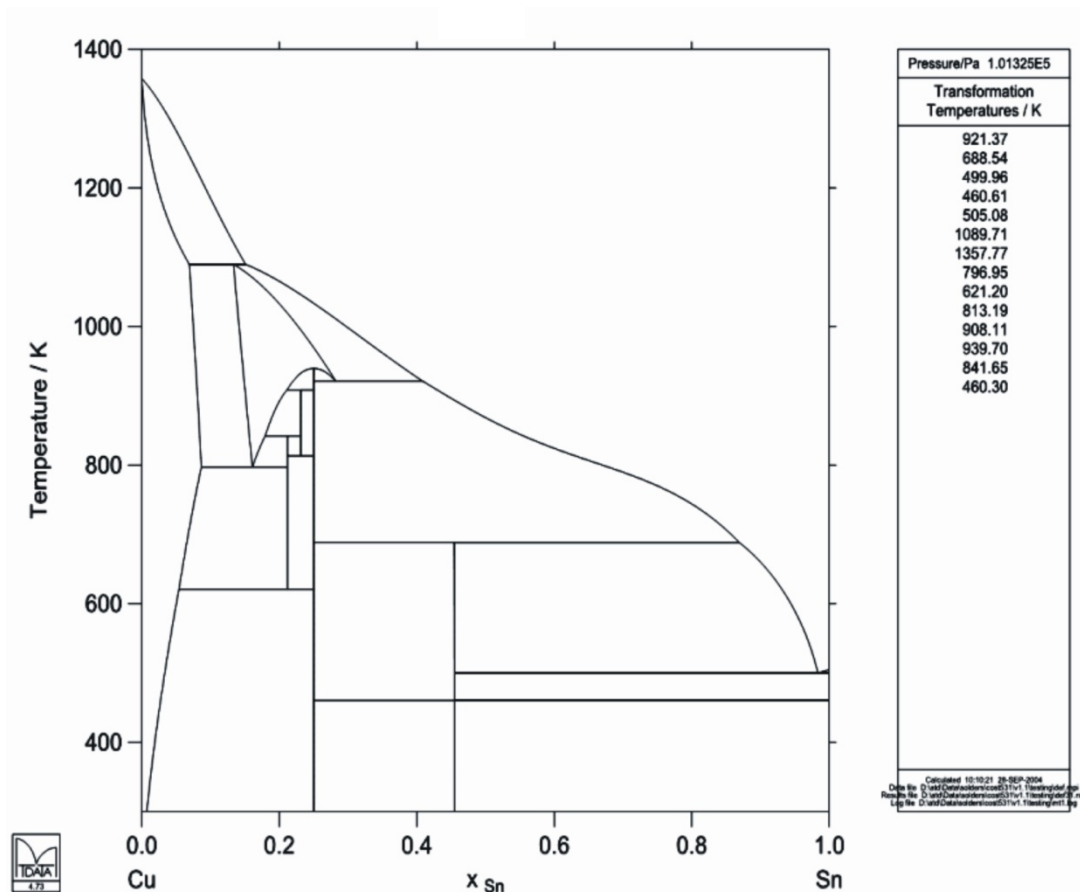


Sn/Bi couple
230°C; 30 min
E: mag. 500×
PL

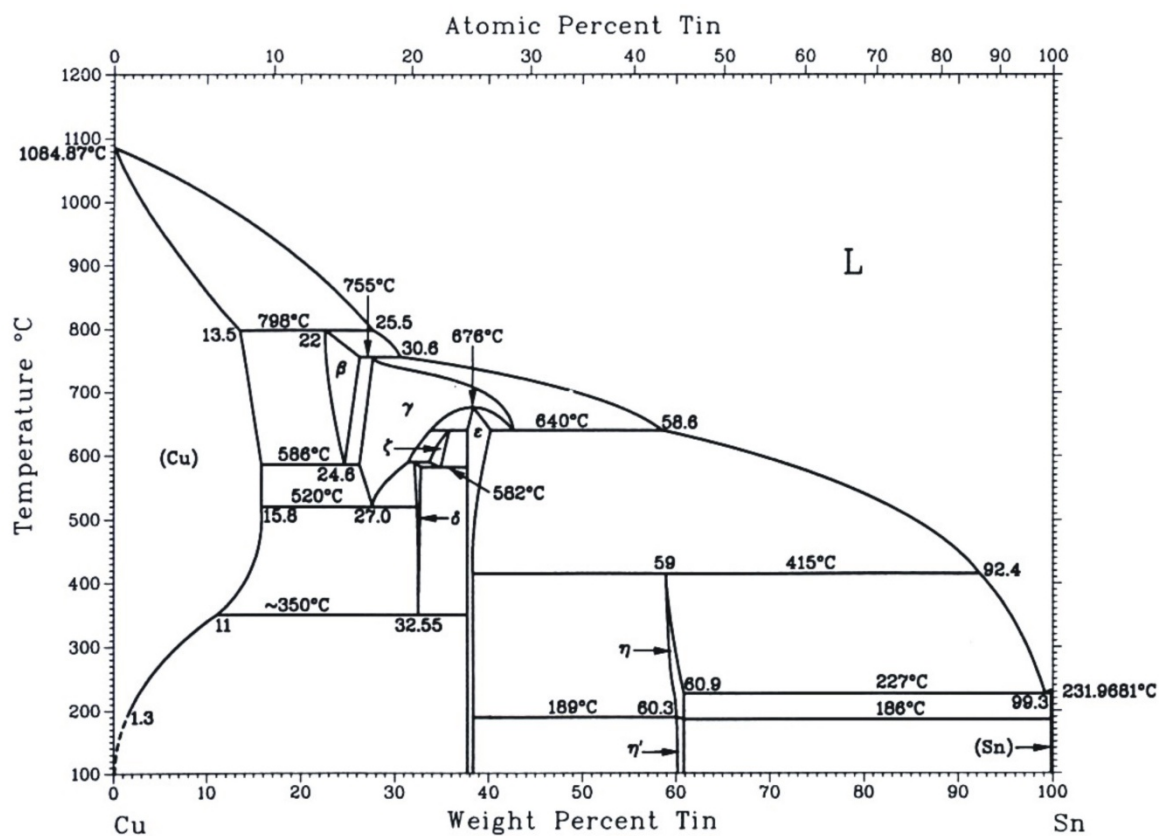


Sn/Bi couple
230°C; 30 min
E: mag. 500×
PC

Sn – Cu



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•178)

N. Saunders and A.P. Miodownik, 1990

Phase	Composition, wt% Sn	Pearson symbol	Space group
α	0 to 15.8	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
β	22.0 to 27.0	<i>cI2</i>	<i>Im$\bar{3}m$</i>
γ	25.5 to 41.5	<i>cF16</i>	<i>Fm$\bar{3}m$</i>
δ	32 to 33	<i>cF416</i>	<i>F$\bar{4}3m$</i>
ζ	32.2 to 35.2	<i>hP26</i>	<i>P6$_3$</i>
ϵ	27.7 to 39.5	<i>oC80</i>	<i>Cmcm</i>
η	59.0 to 60.9	<i>hP4</i>	<i>P6$_3$/mmc</i>
η'	44.8 to 60.9	(a)	...
(β Sn)	~100	<i>tI4</i>	<i>I4$_1$/amd</i>
(α Sn)	100	<i>cF8</i>	<i>Fd$\bar{3}m$</i>

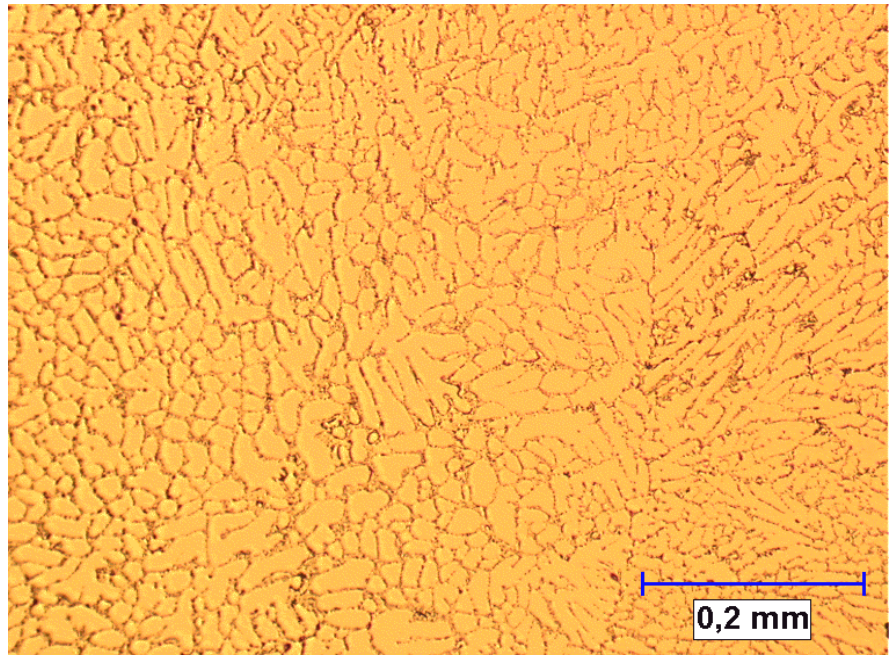
Note: Lattice parameter data can be found in [Pearson3]. (a) Hexagonal; superlattice based on NiAs-type structure

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•178)

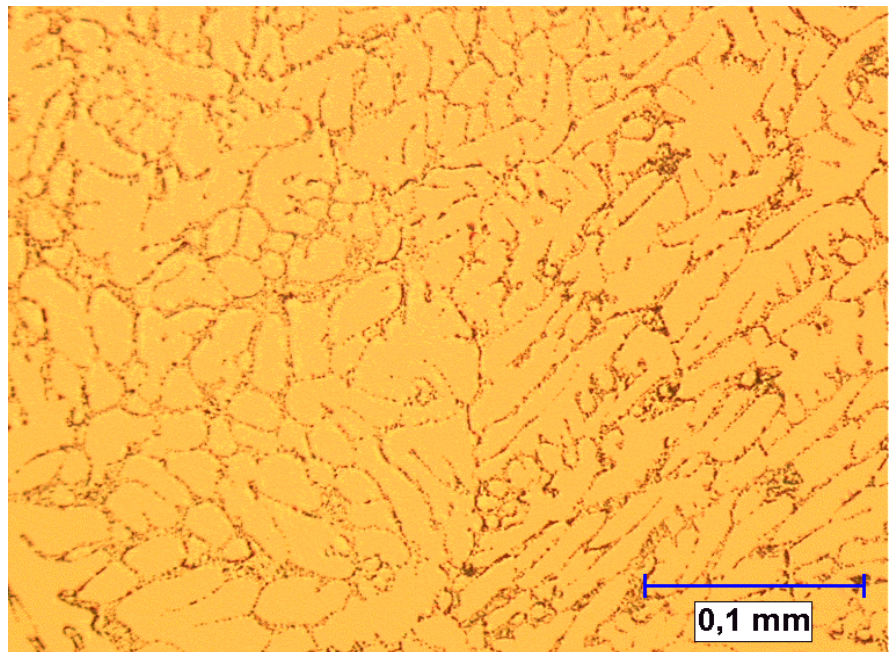
Properties of solder/substrate couple:

Couple	Conditions	θ , deg	τ , MPa
Sn / Cu	230°C, 5 min, flux	44	16
Sn / Cu	230°C, 30 min, flux	36	–
Sn / Cu	230°C, 5 min, vac	99	14
SnCu0.5 / Cu	230°C, 5 min, flux	53	15
SnCu0.5 / Cu	230°C, 5 min, vac	36	16
SnCu1 / Cu	230°C, 5 min, flux	40	21
SnCu1 / Cu	230°C, 5 min, vac	107	31

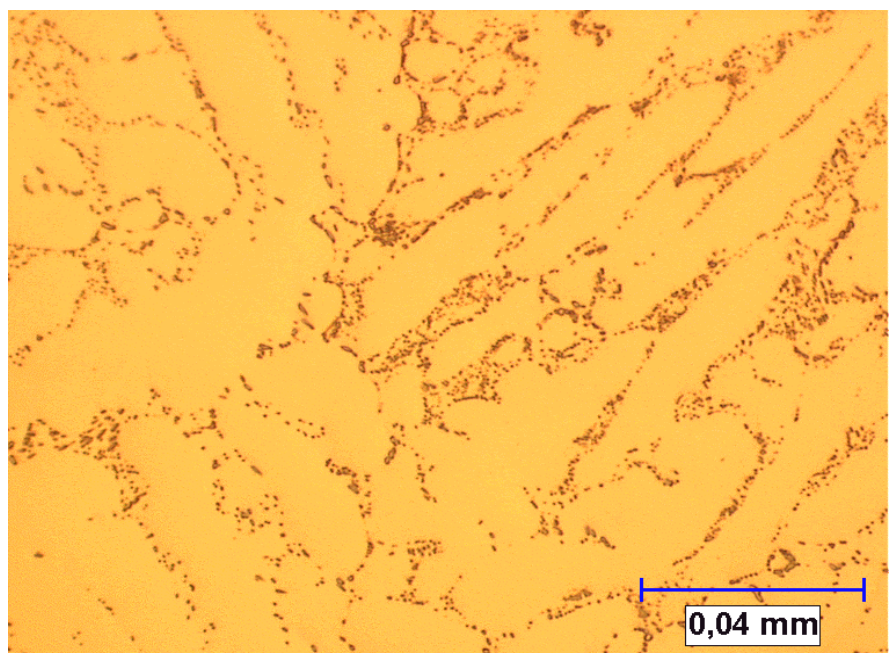
SnCu0.5 alloy (AC)
E: mag. 100×
CL

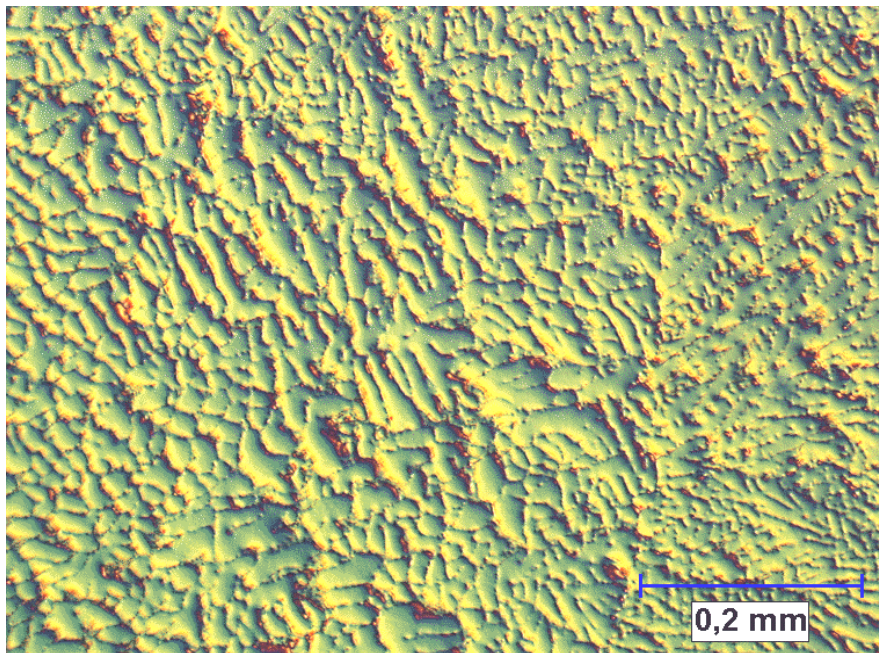


SnCu0.5 alloy (AC)
E: mag. 200×
CL

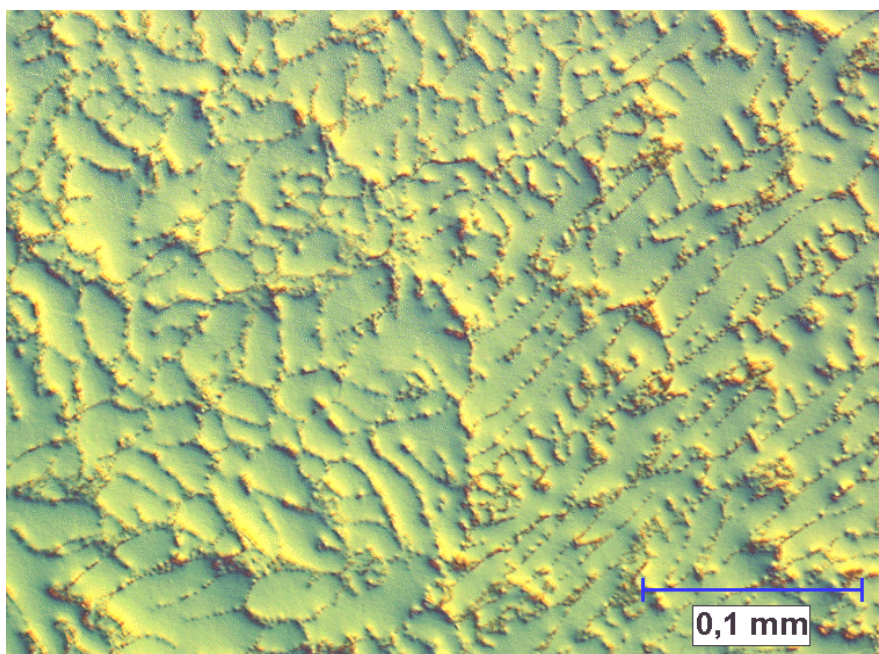


SnCu0.5 alloy (AC)
E: mag. 500×
CL

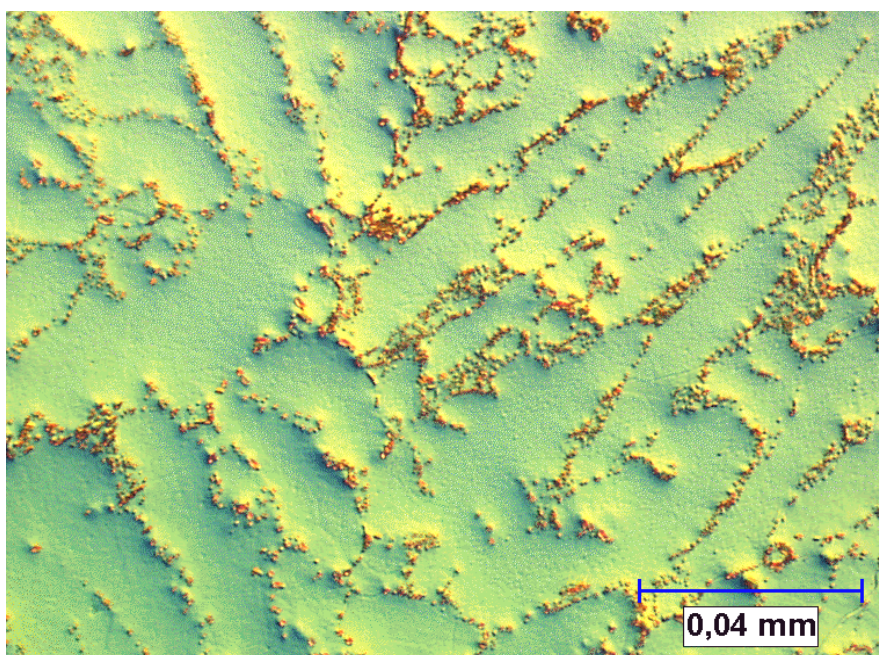




SnCu_{0.5} alloy
E: mag. 100×
PC

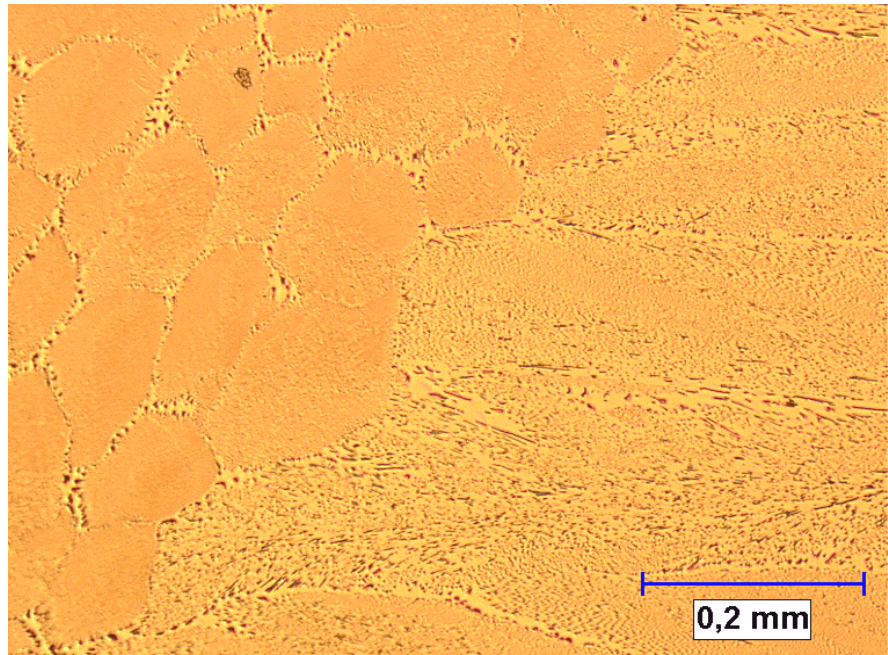


SnCu_{0.5} alloy
E: mag. 200×
PC

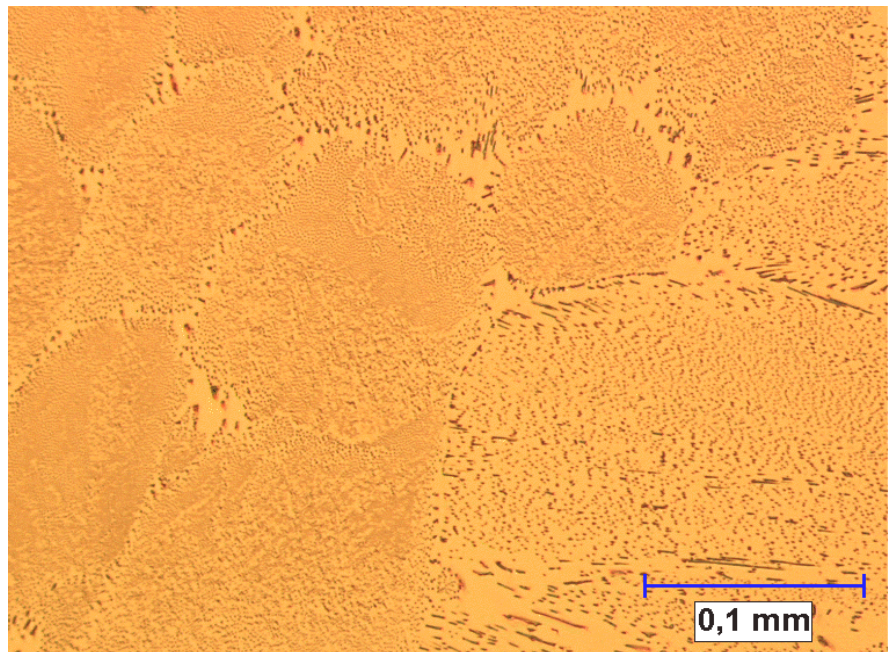


SnCu_{0.5} alloy
E: mag. 500×
PC

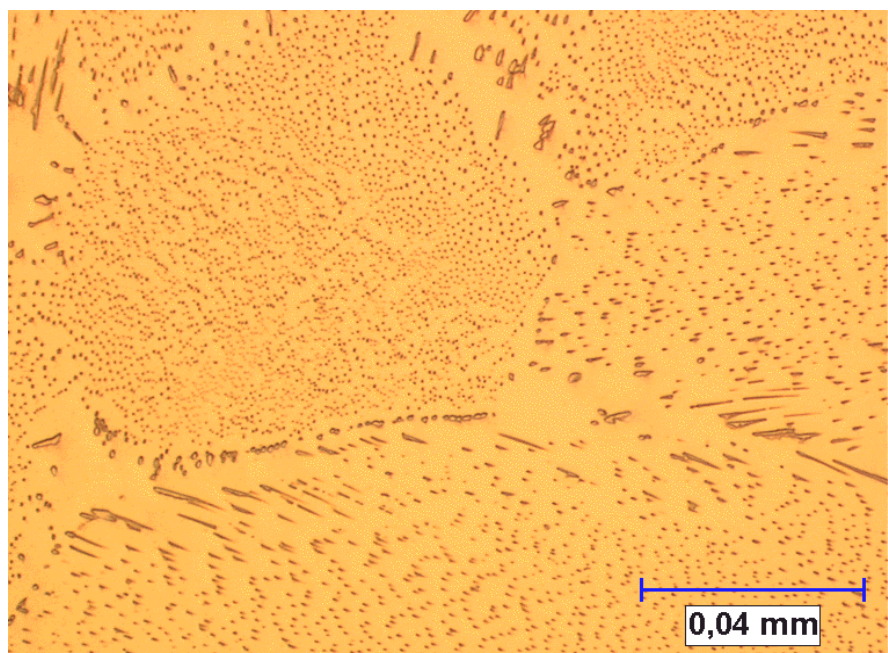
SnCu1 alloy (AC)
E: mag. 100×
CL

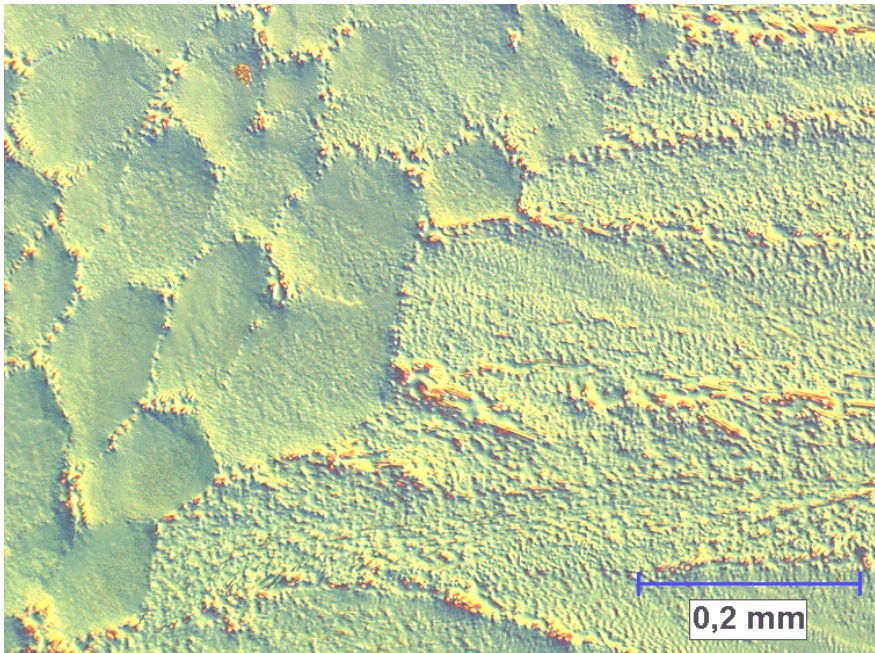


SnCu1 alloy (AC)
E: mag. 200×
CL

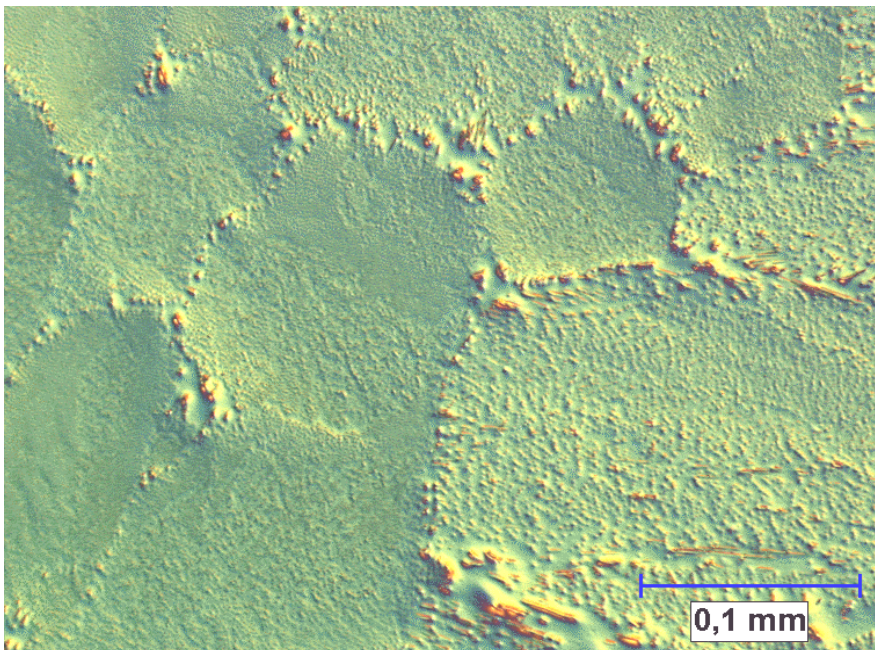


SnCu1 alloy (AC)
E: mag. 500×
CL

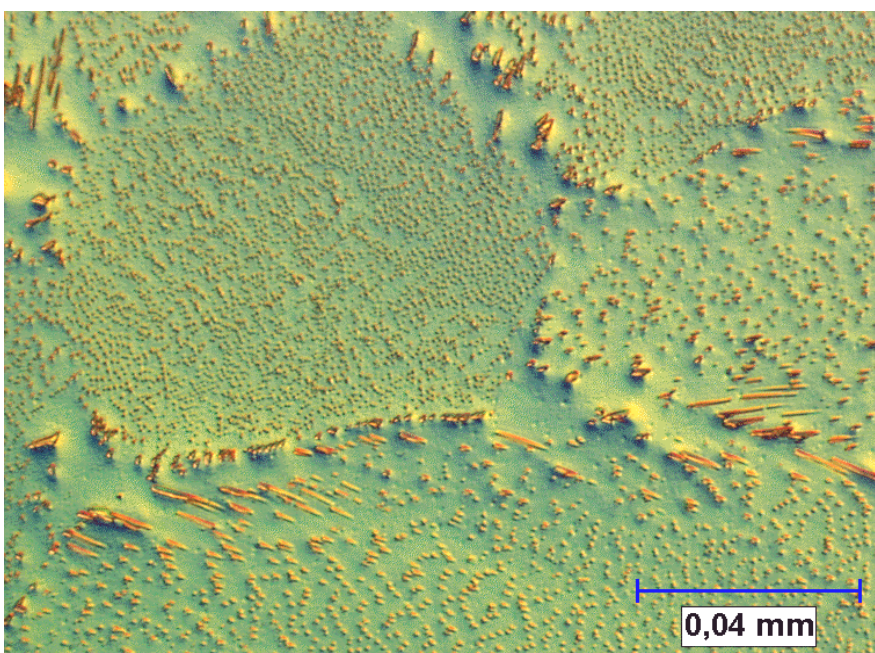




SnCu1 alloy (AC)
E: mag. 100×
PC

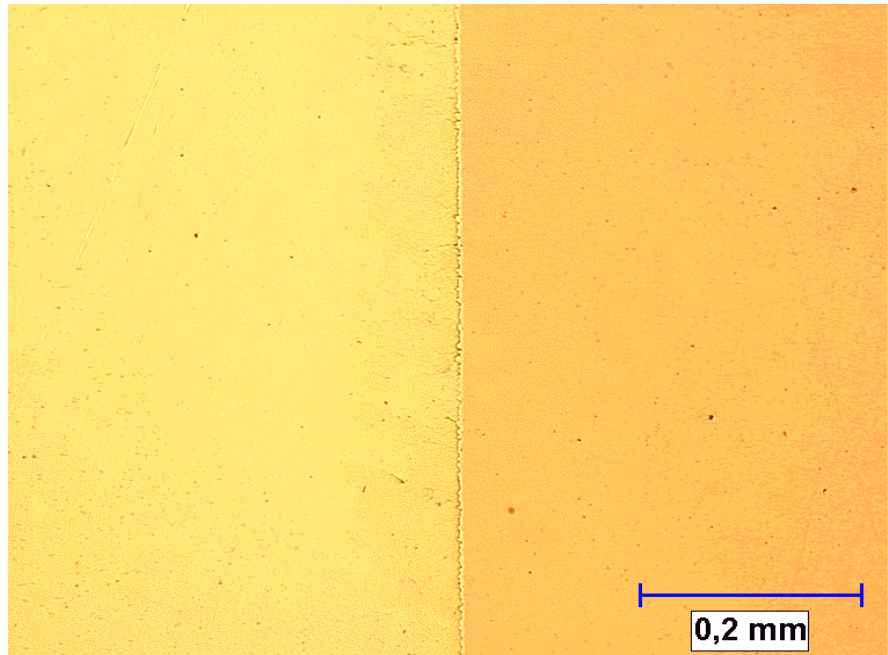


SnCu1 alloy (AC)
E: mag. 200×
PC

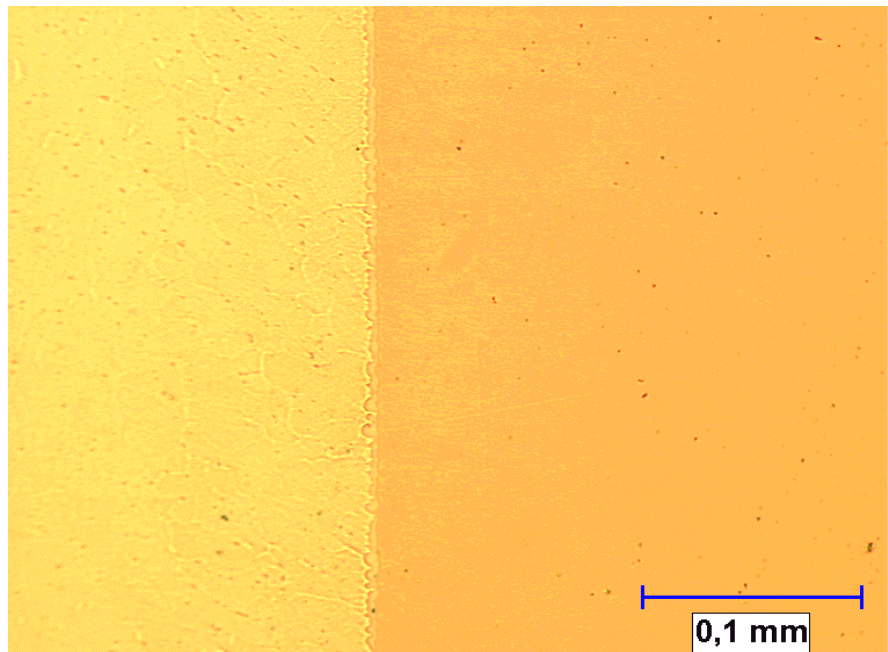


SnCu1 alloy (AC)
E: mag. 500×
PC

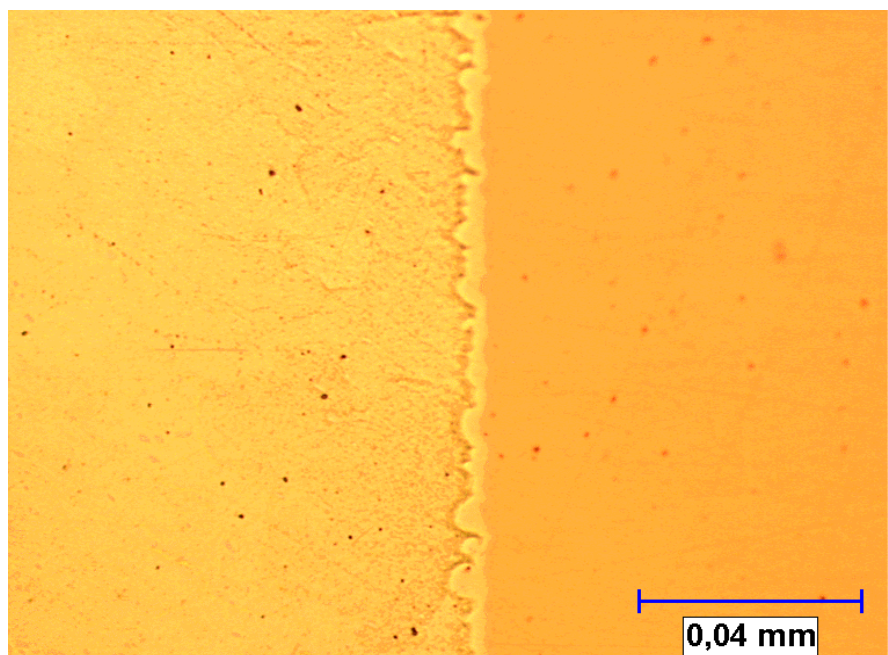
Sn/Cu couple
230°C; 5 min
NE: mag. 100×
CL

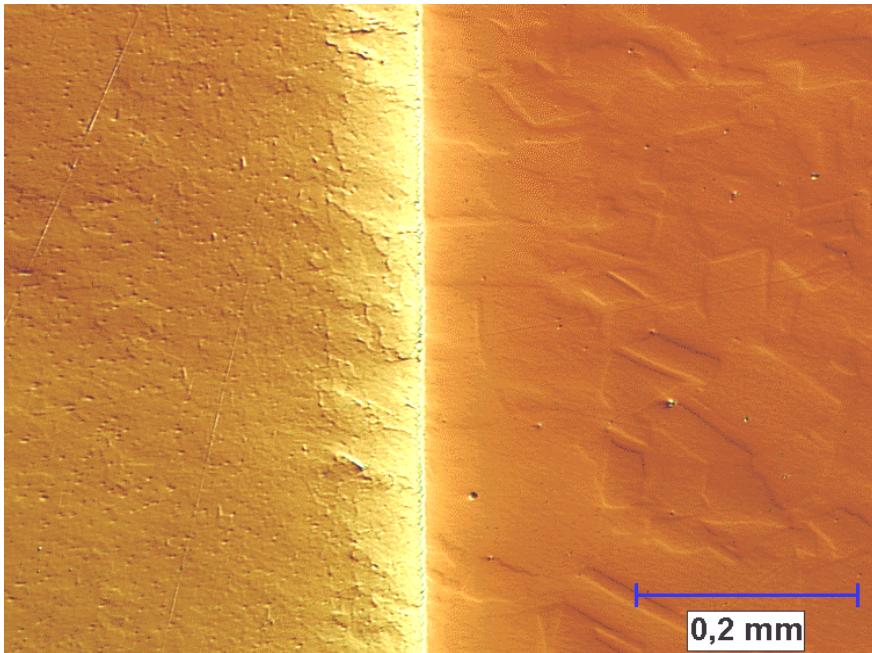


Sn/Cu couple
230°C; 5 min
NE: mag. 200×
CL

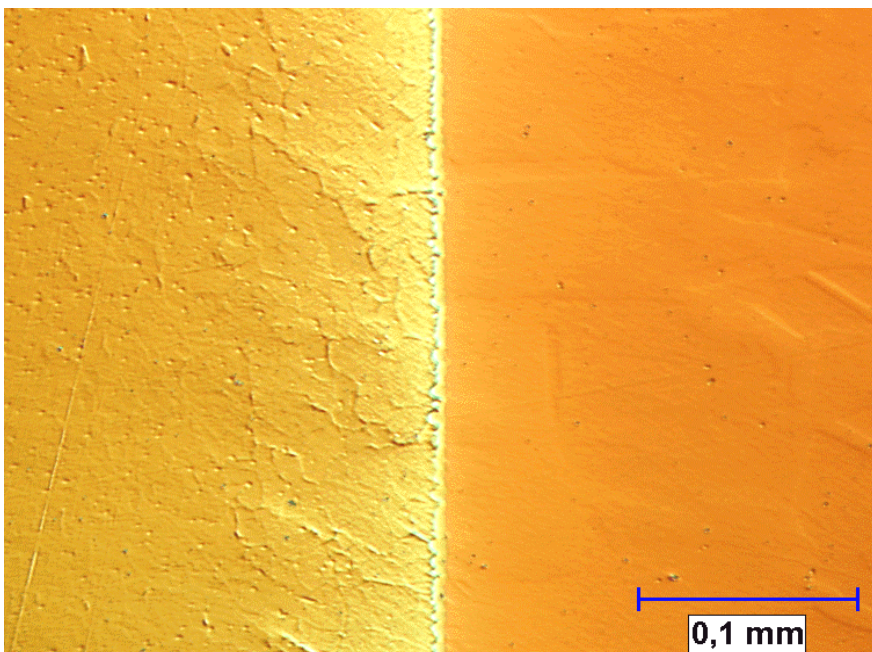


Sn/Cu couple
230°C; 5 min
NE: mag. 500×
CL

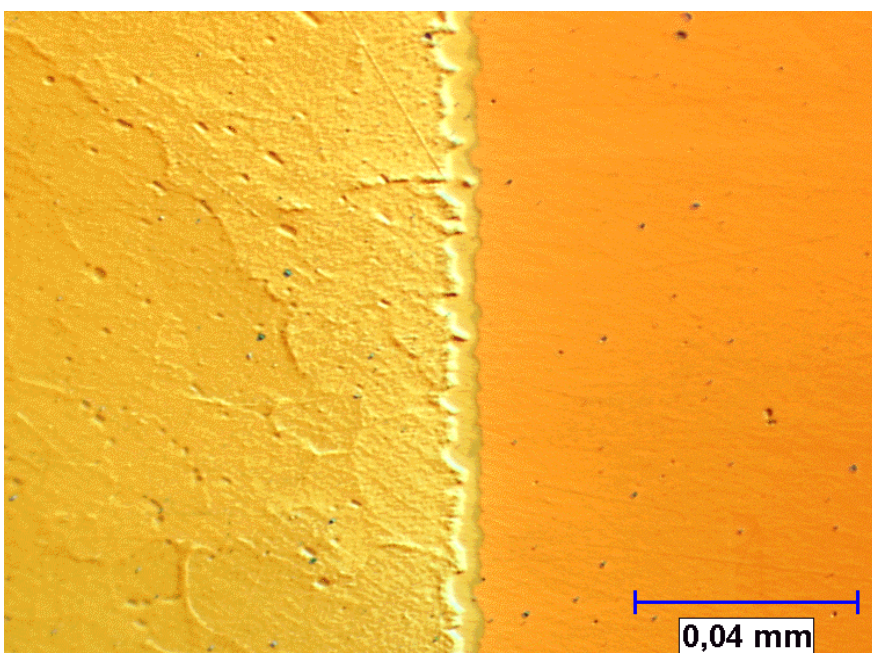




Sn/Cu couple
230°C; 5 min
NE: mag. 100×
PC

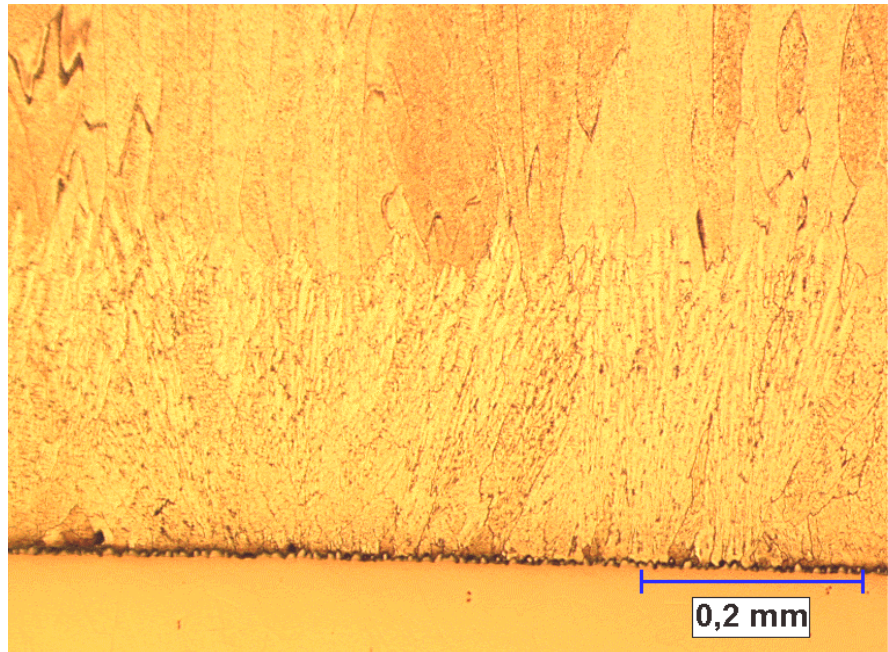


Sn/Cu couple
230°C; 5 min
NE: mag. 200×
PC

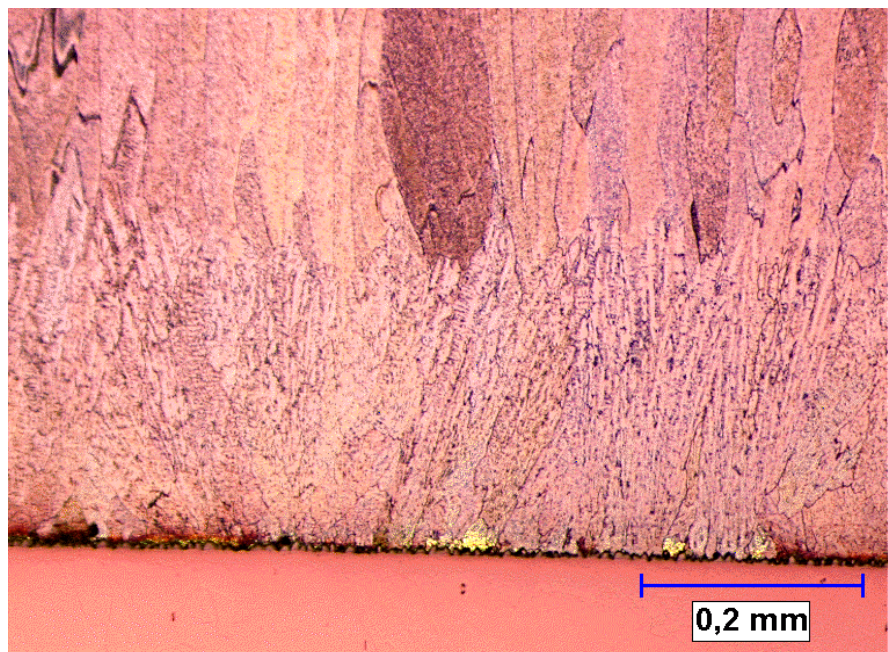


Sn/Cu couple
230°C; 5 min
NE: mag. 500×
PC

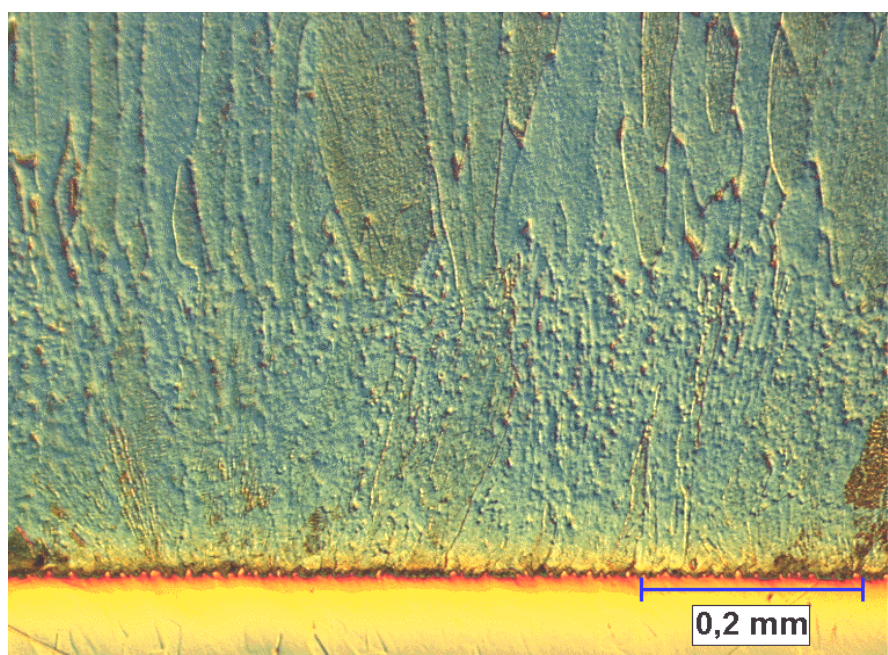
Sn/Cu couple
230°C; 30 min
E: mag. 100×
CL

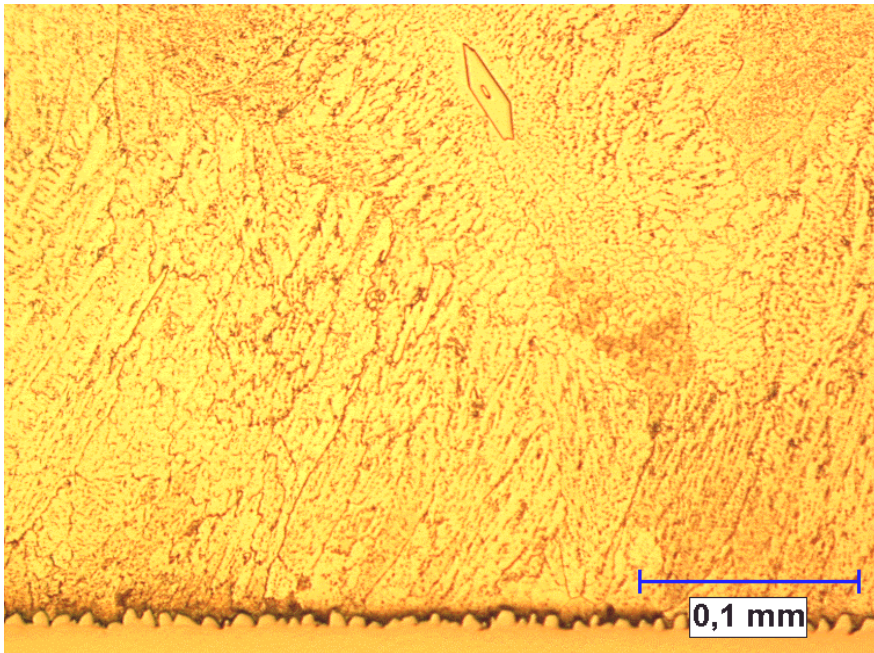


Sn/Cu couple
230°C; 30 min
E: mag. 100×
PL

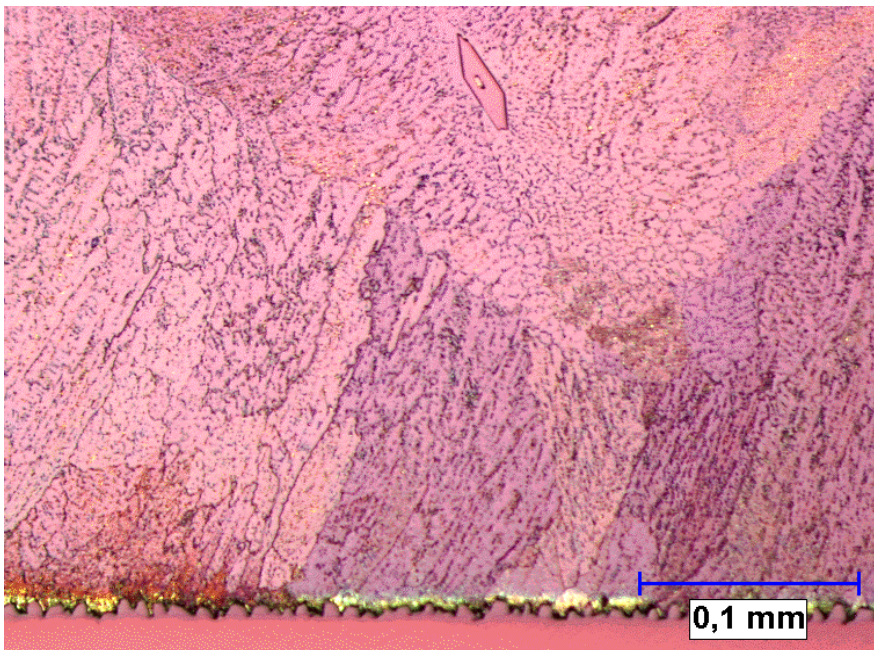


Sn/Cu couple
230°C; 30 min
E: mag. 100×
PC

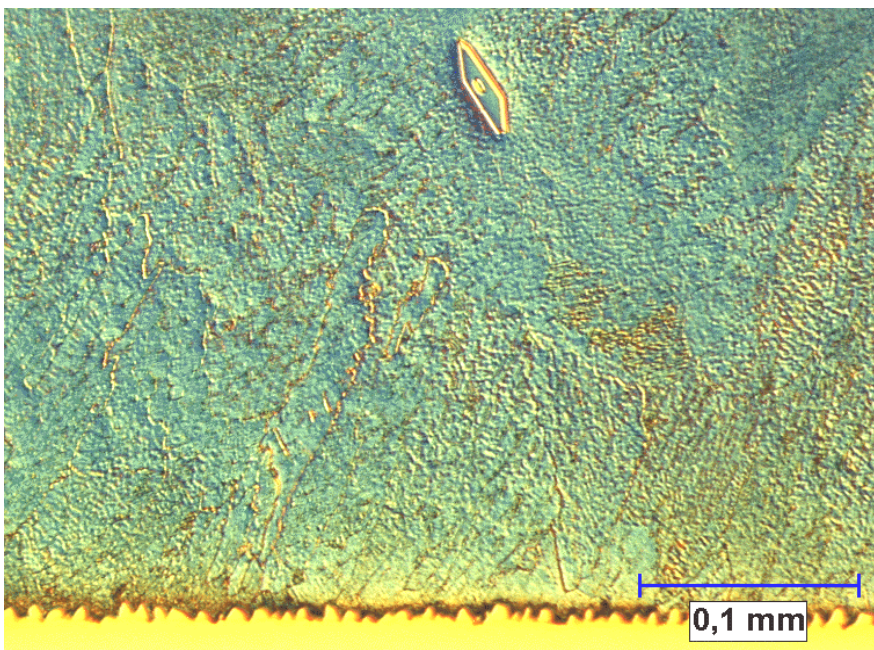




Sn/Cu couple
230°C; 30 min
E: mag. 200×
CL

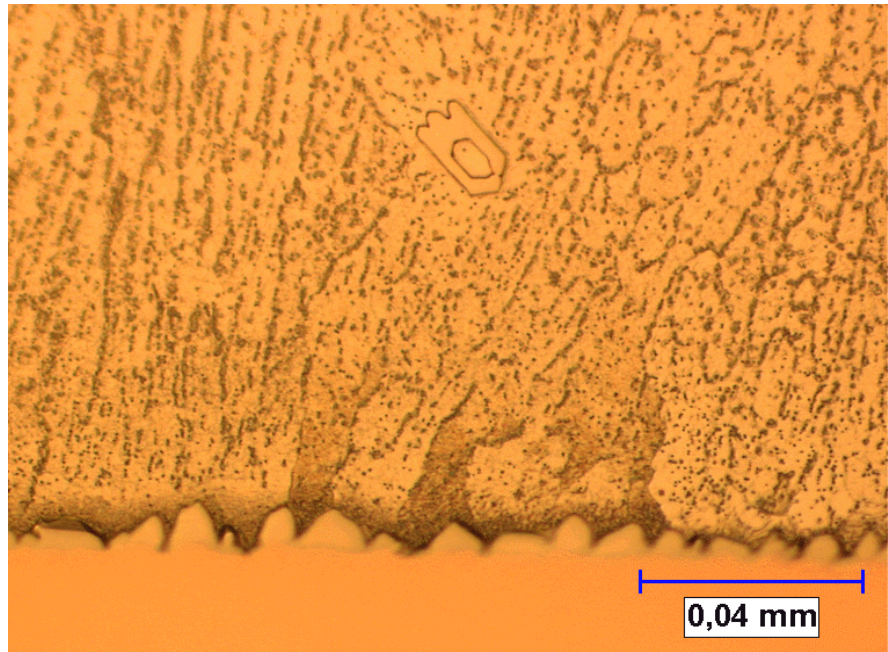


Sn/Cu couple
230°C; 30 min
E: mag. 200×
PL

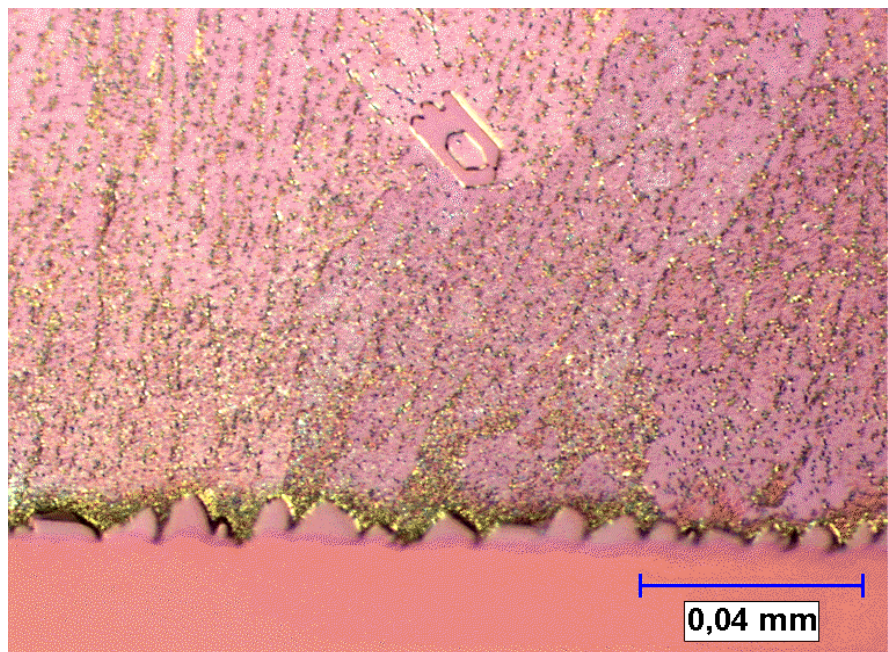


Sn/Cu couple
230°C; 30 min
E: mag. 200×
PC

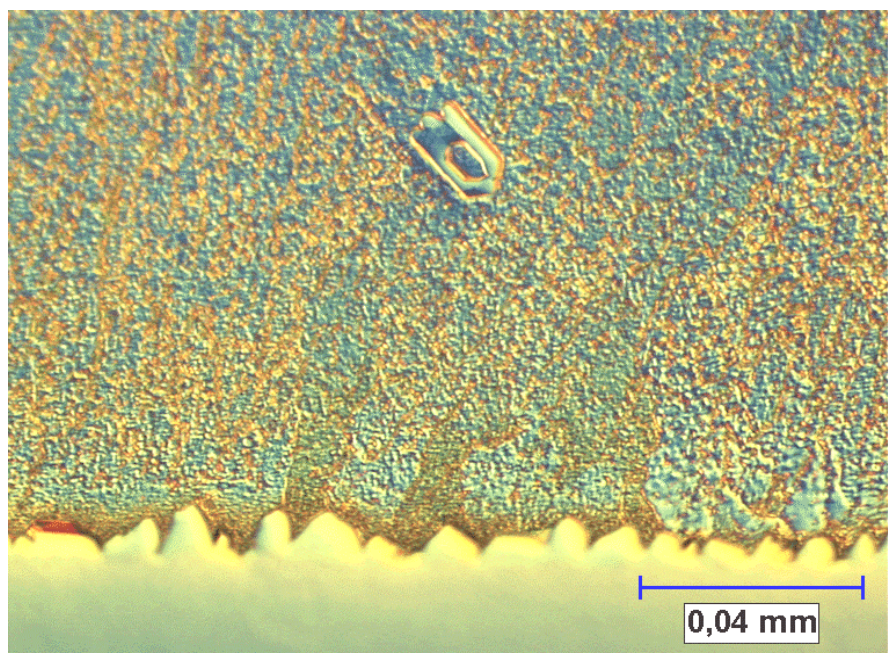
Sn/Cu couple
230°C; 30 min
E: mag. 500×
CL



Sn/Cu couple
230°C; 30 min
E: mag. 500×
PL

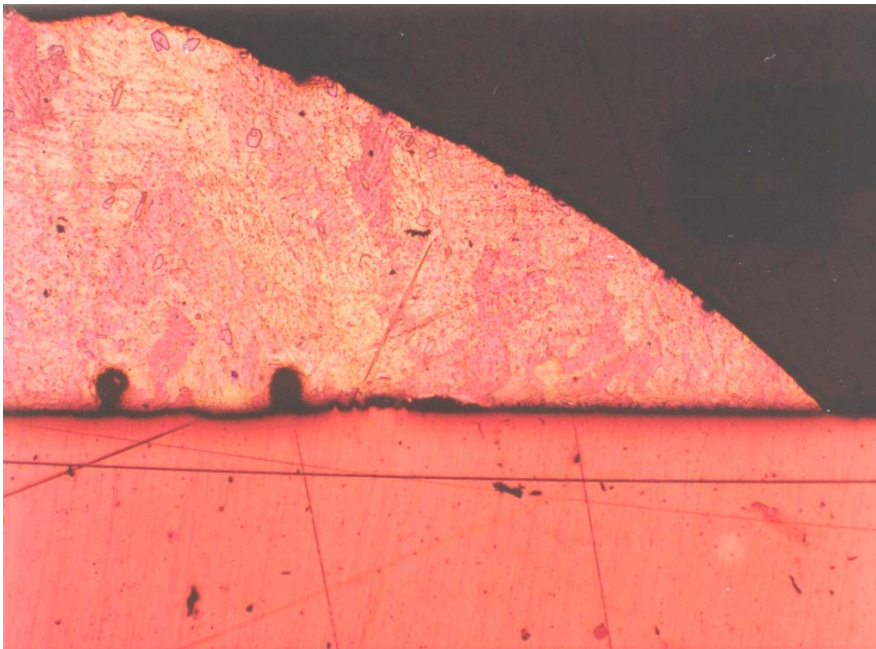


Sn/Cu couple
230°C; 30 min
E: mag. 500×
PC

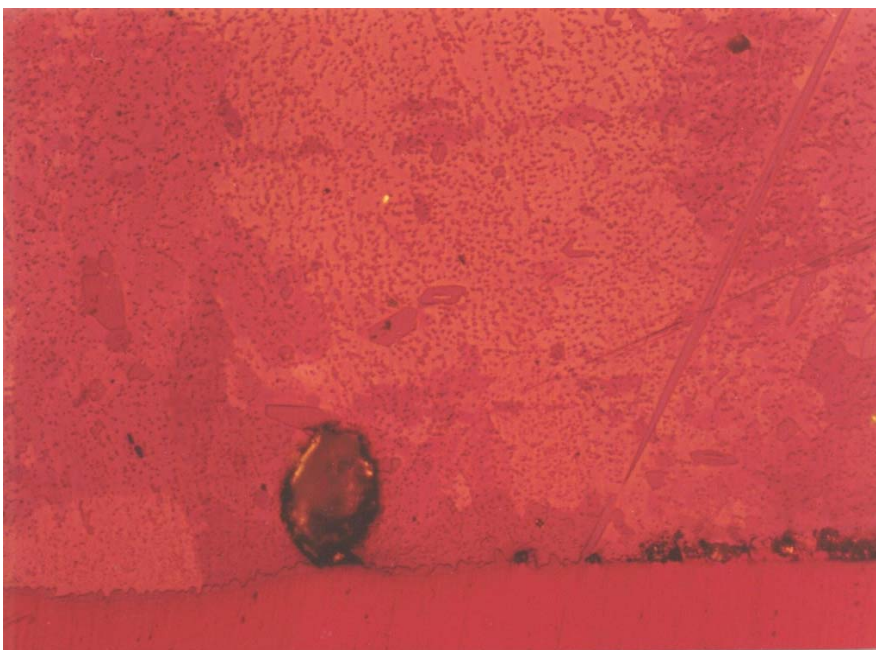




SnCu_{0.5}/Cu couple
230°C; 5 min
NE: mag. 25×

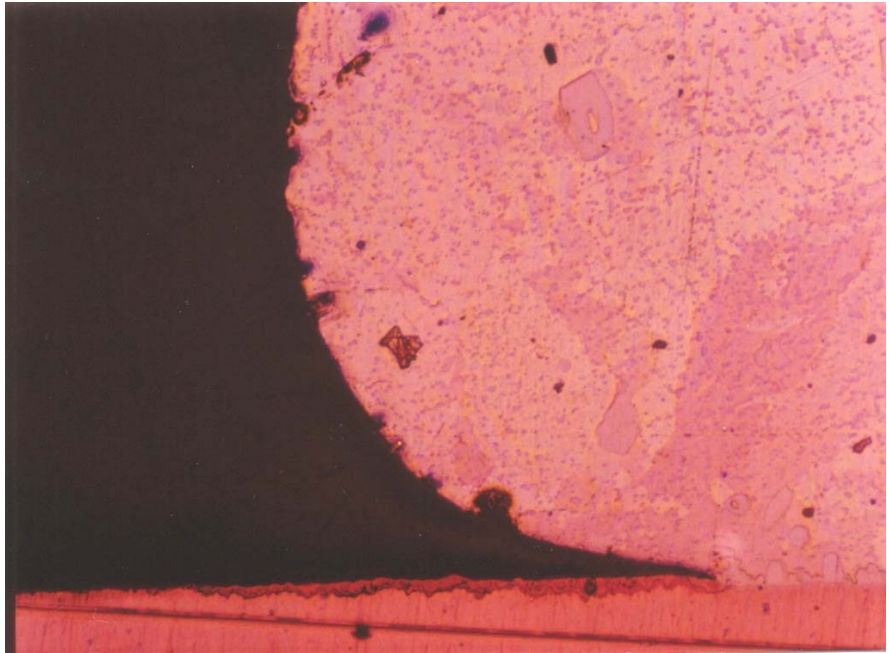


SnCu_{0.5}/Cu couple
230°C; 5 min
NE: mag. 25×



SnCu_{0.5}/Cu couple
230°C; 5 min
NE: mag. 100×

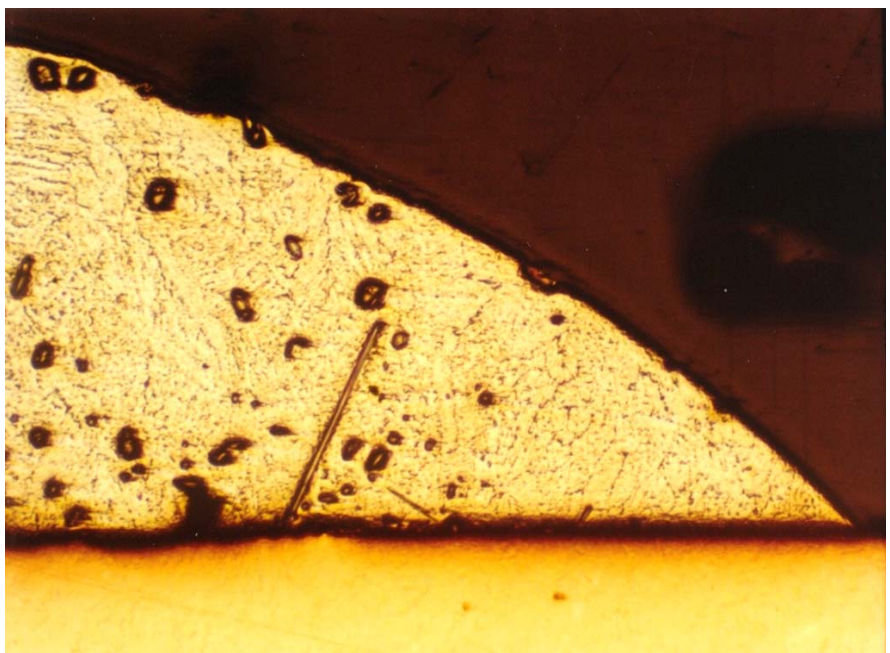
SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 150×

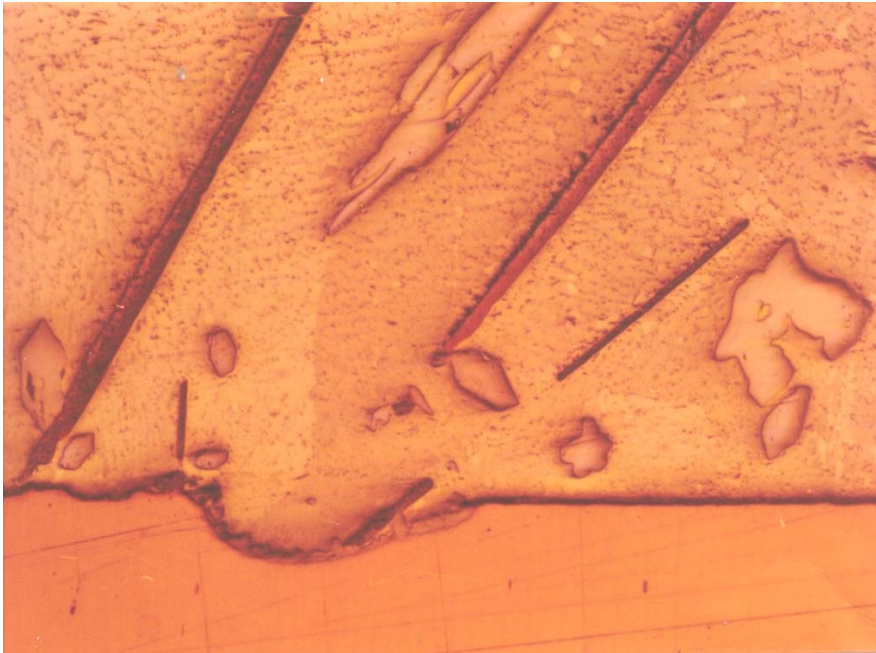


SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 200×

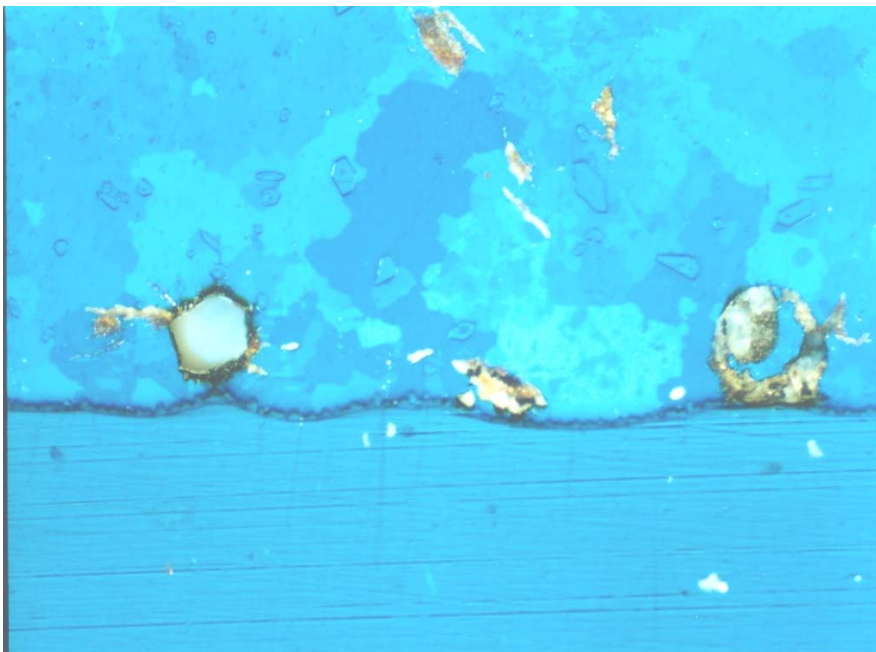


SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 25×

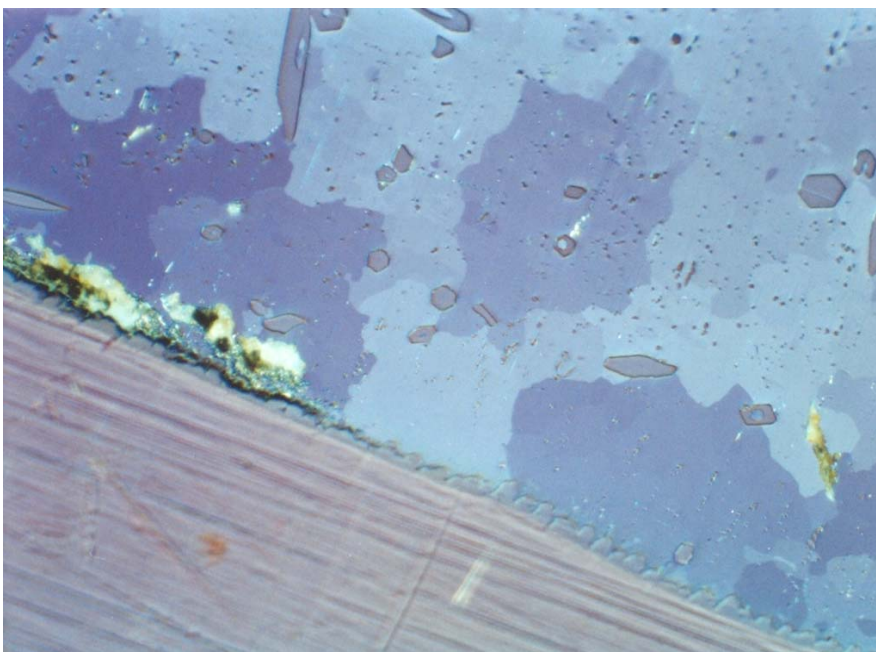




SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 150×

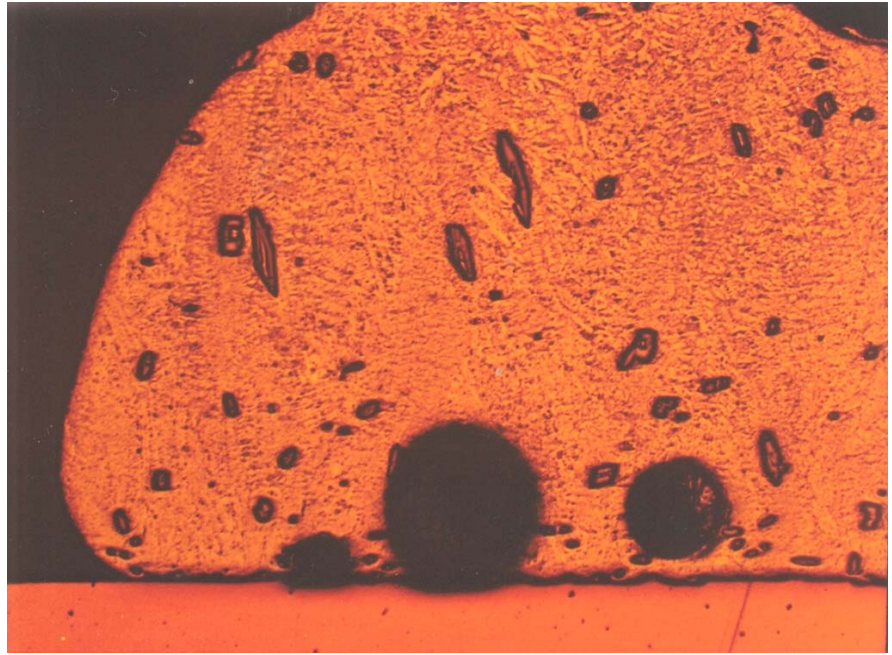


SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 100×

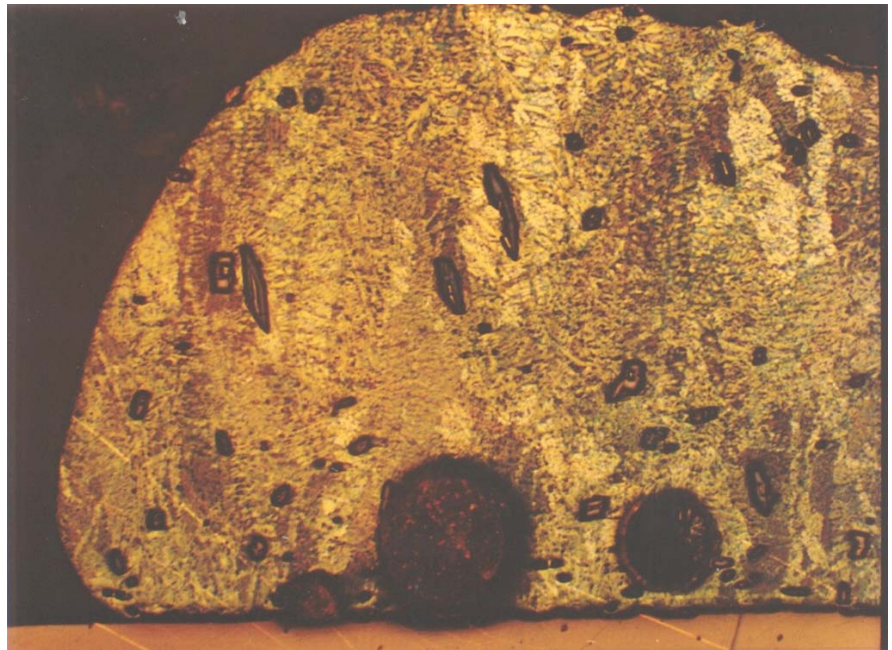


SnCu0.5/Cu couple
230°C; 5 min
NE: mag. 200×

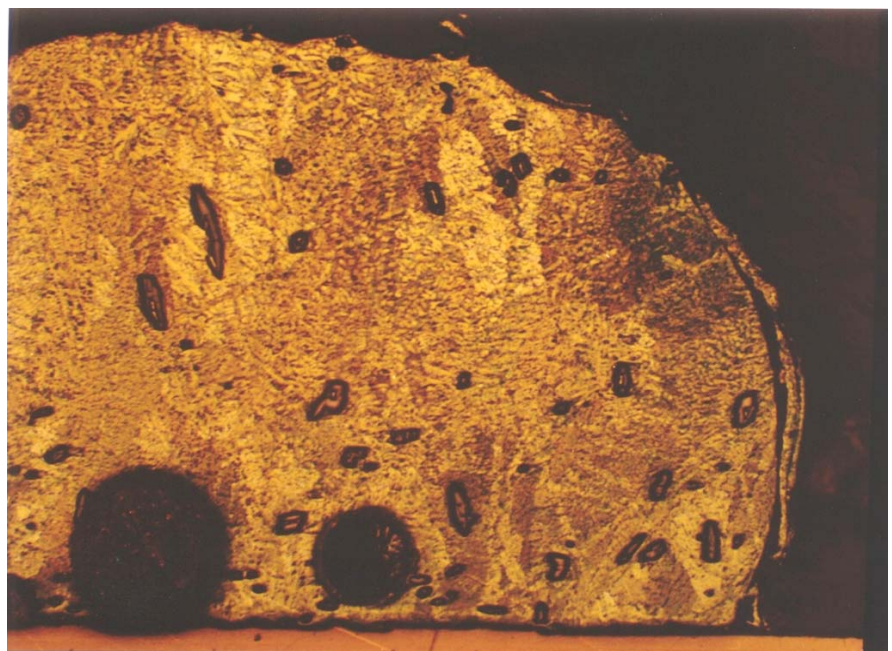
SnCu1/Cu couple
230°C; 5 min
NE: mag. 25×

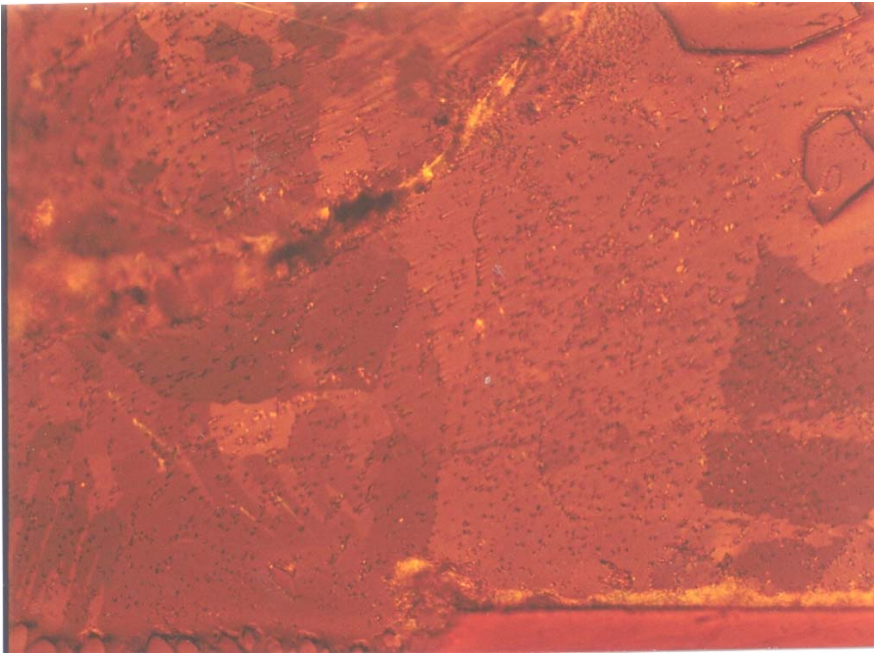


SnCu1/Cu couple
230°C; 5 min
NE: mag. 25×

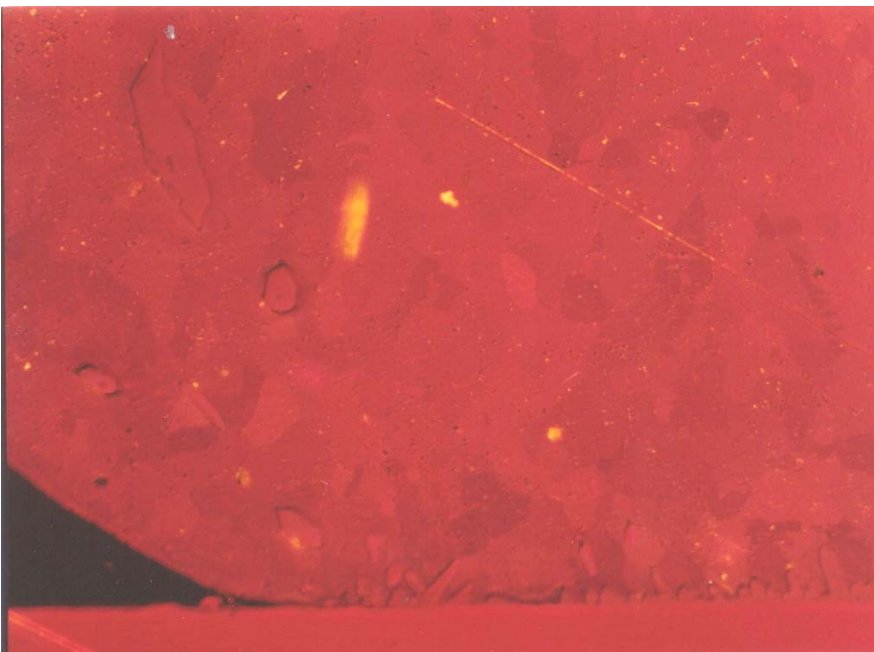


SnCu1/Cu couple
230°C; 5 min
NE: mag. 25×

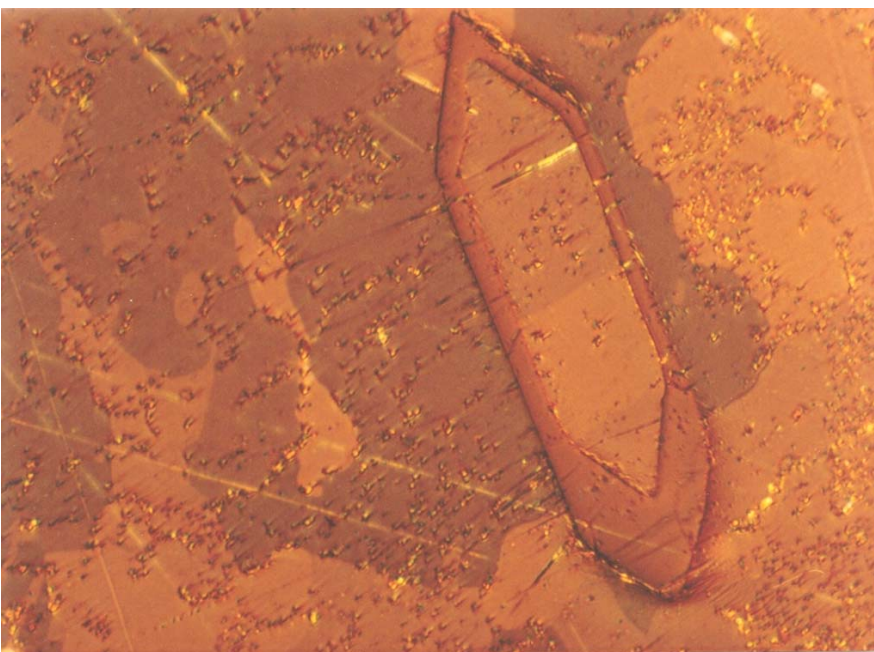




SnCu1/Cu couple
230°C; 5 min
NE: mag. 320×

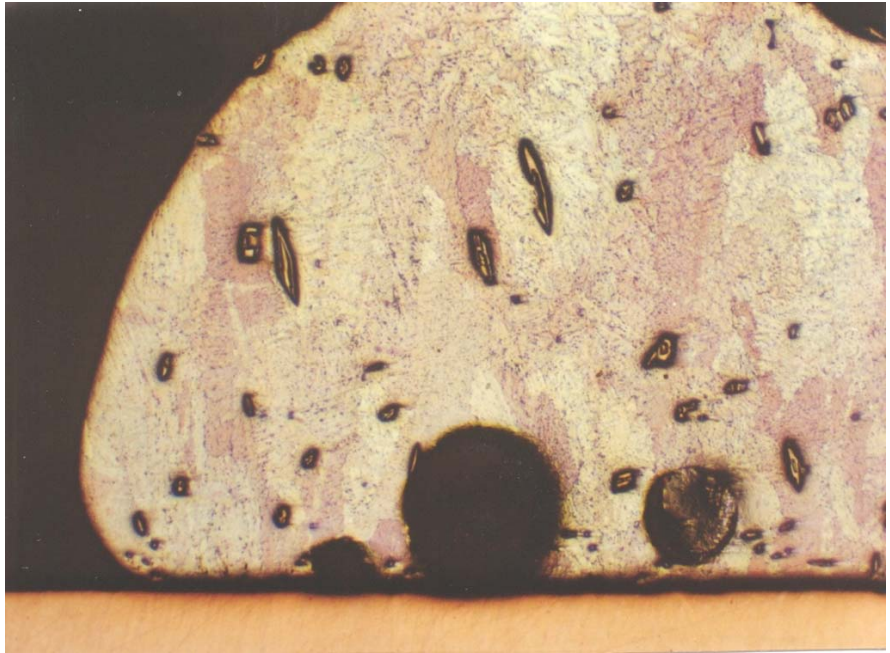


SnCu1/Cu couple
230°C; 5 min
NE: mag. 200×

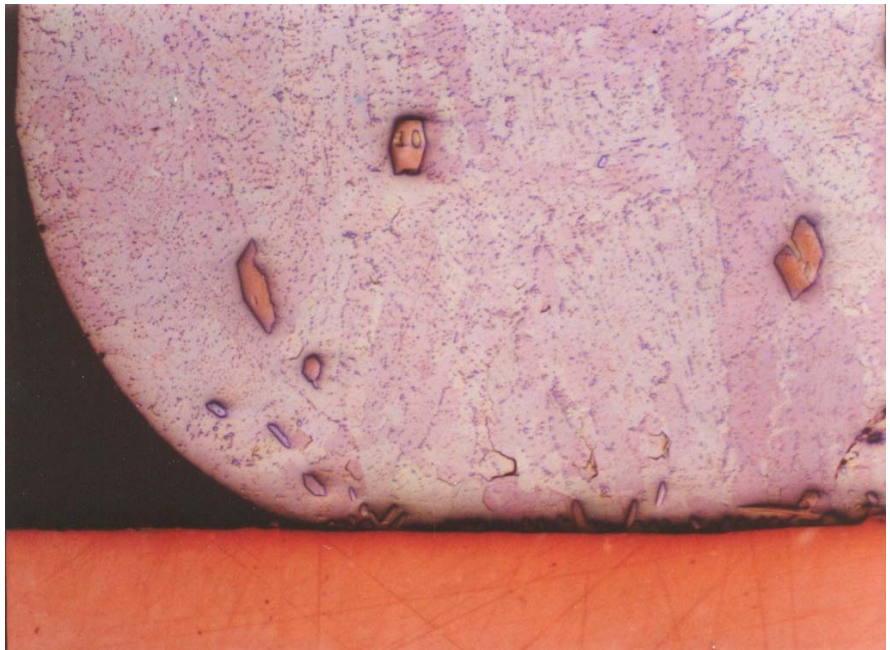


SnCu1/Cu couple
230°C; 5 min
NE: mag. 500×

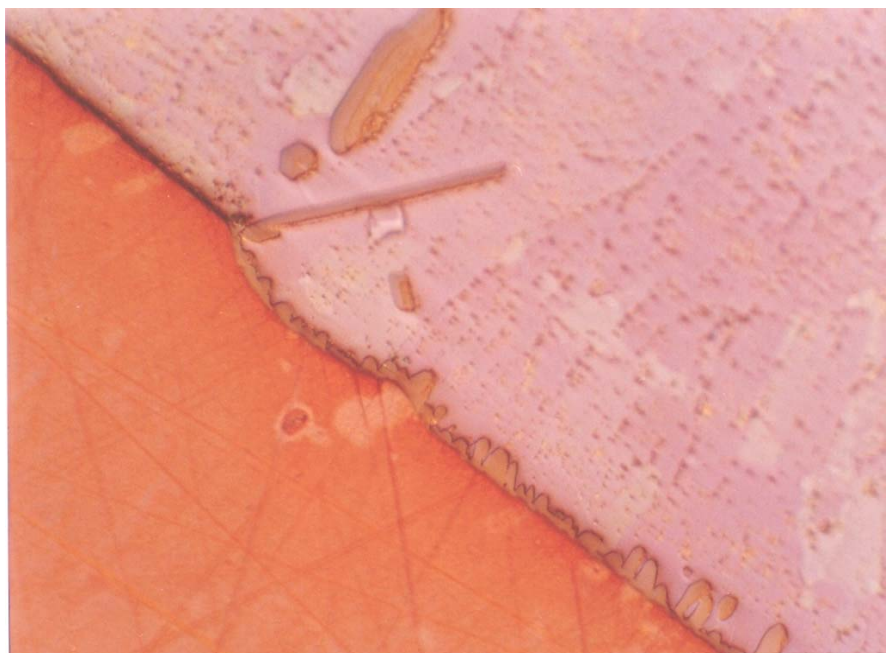
SnCu1/Cu couple
230°C; 5 min
NE: mag. 25×



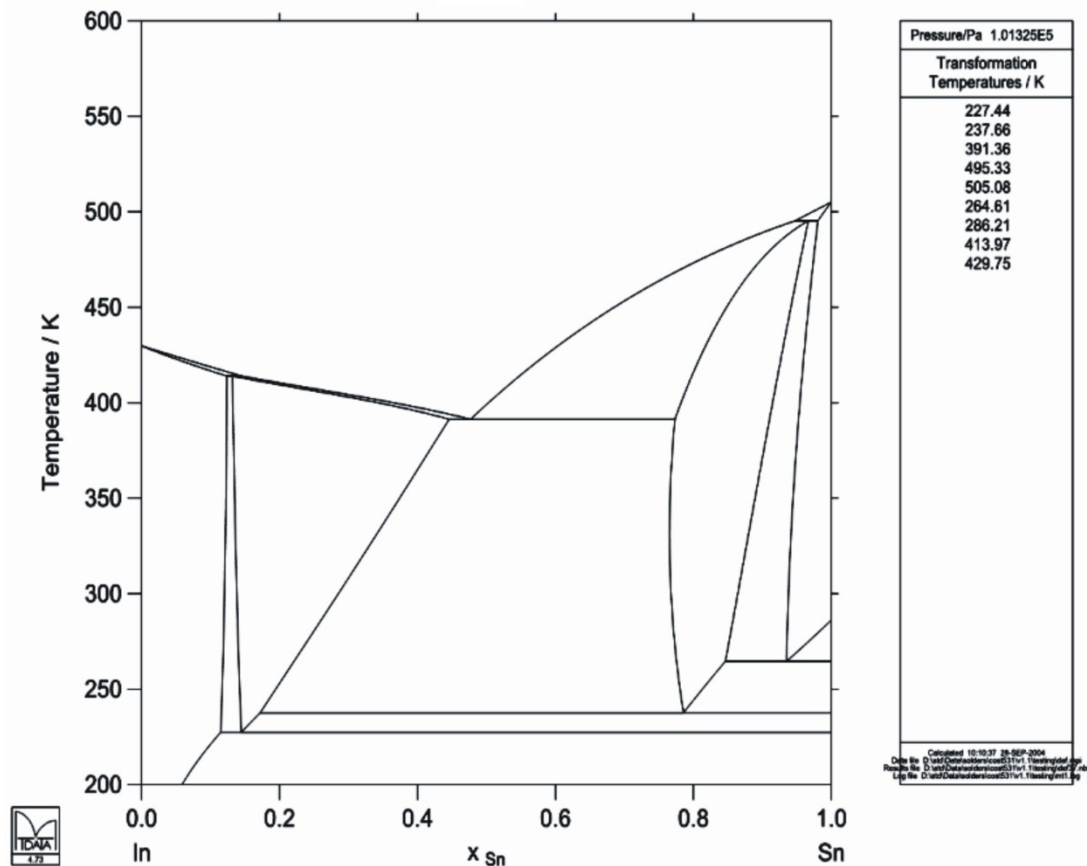
SnCu1/Cu couple
230°C; 5 min
NE: mag. 100×



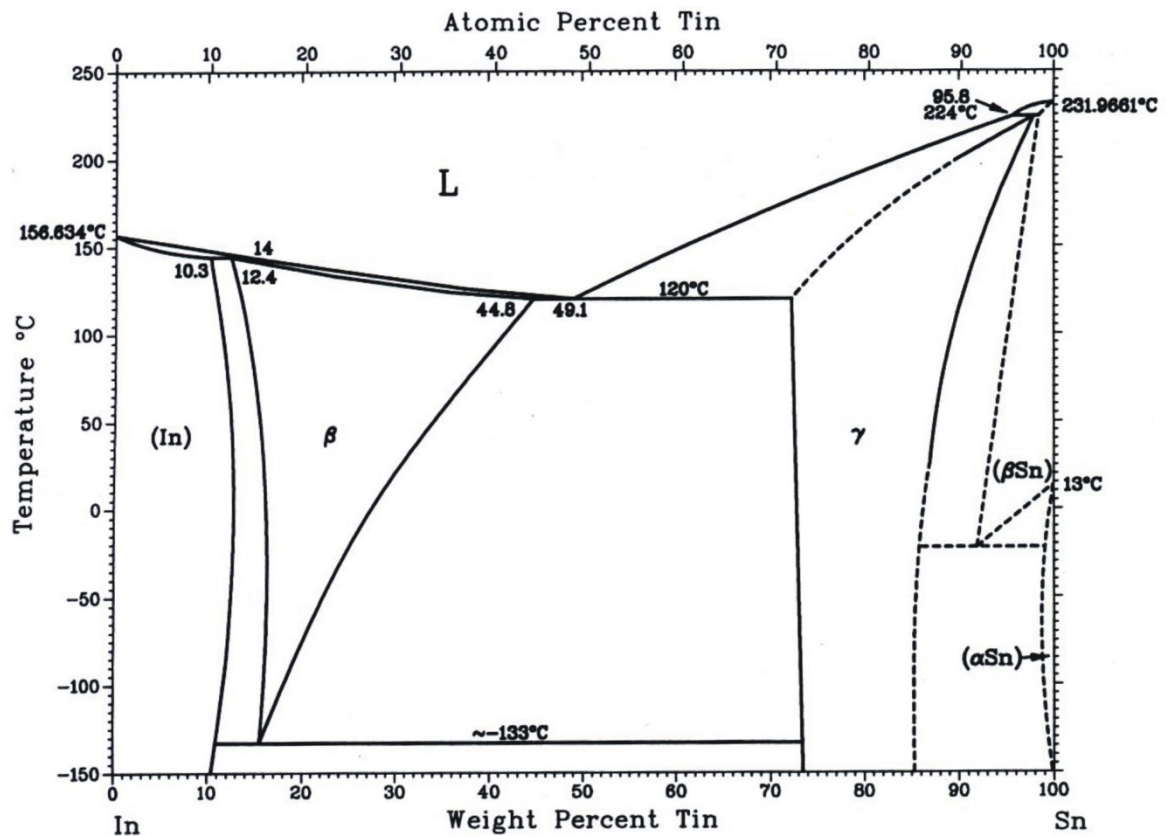
SnCu1/Cu couple
230°C; 5 min
NE: mag. 250×



Sn – In



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•260)

H. Okamoto, 1992

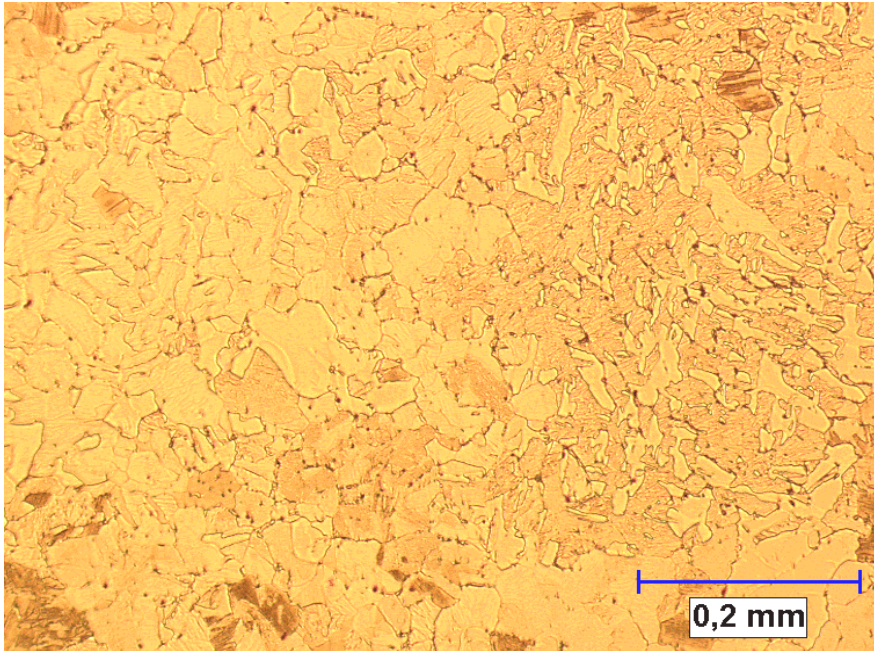
Phase	Composition, wt% Sn	Pearson symbol	Space group
(In)	0 to 12.4	<i>tI2</i>	<i>I4/mmm</i>
β	12.4 to 44.8	<i>tI2</i>	<i>I4/mmm</i>
γ	73 to ?	<i>hP5</i>	<i>P6/mmm</i>
(β Sn)	? to 100	<i>tI4</i>	<i>I4₁/and</i>
(α Sn)	100	<i>cF8</i>	<i>Fd$\bar{3}m$</i>

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•260)

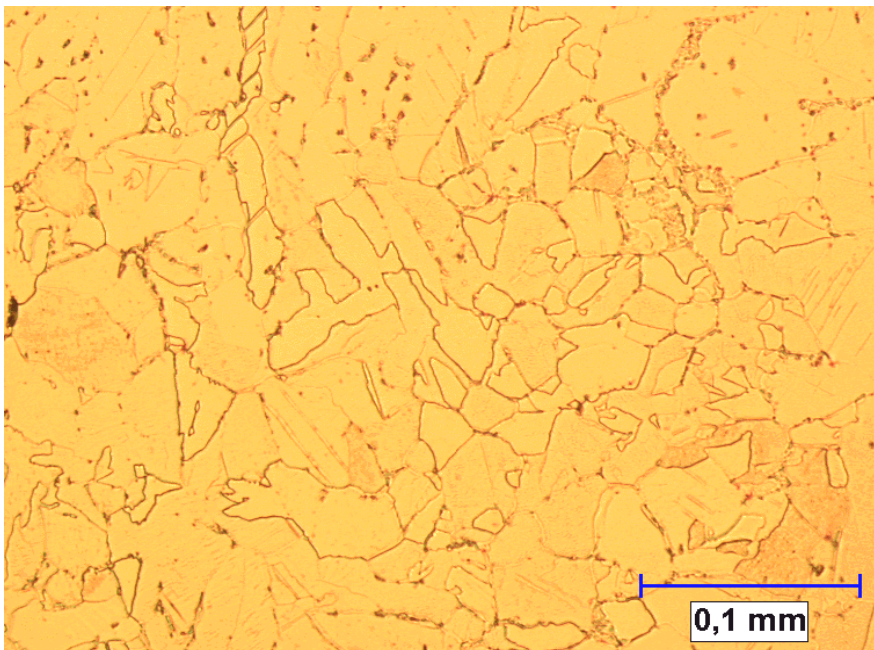
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
Sn / In	190°C, 5 min, flux	$\sim 0^\circ$	*
Sn / In	180°C, 30 min, flux	$\sim 0^\circ$	*

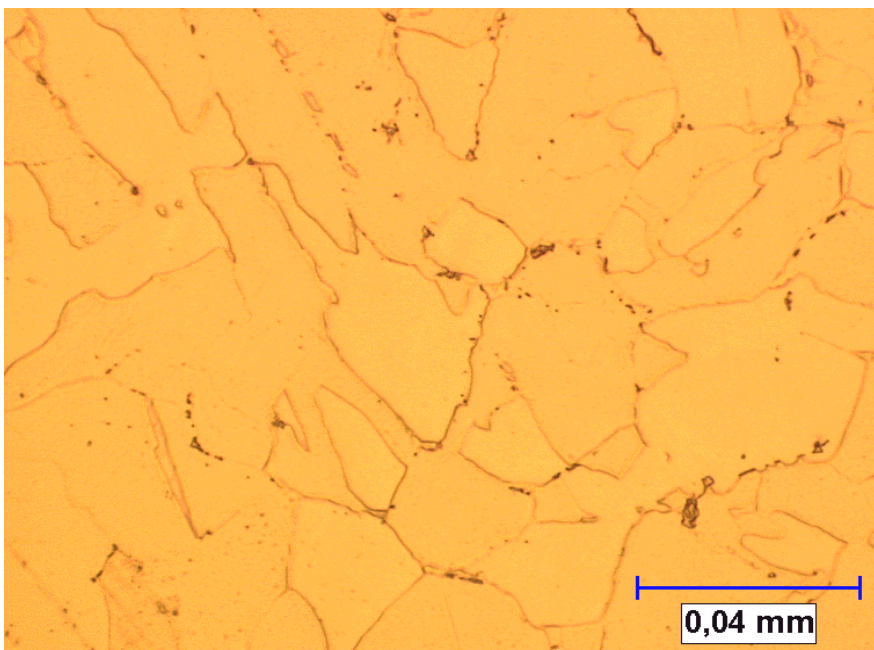
* impossible to measure due to a low contact angle



SnIn5 alloy (AC)
E: mag. 100×
CL

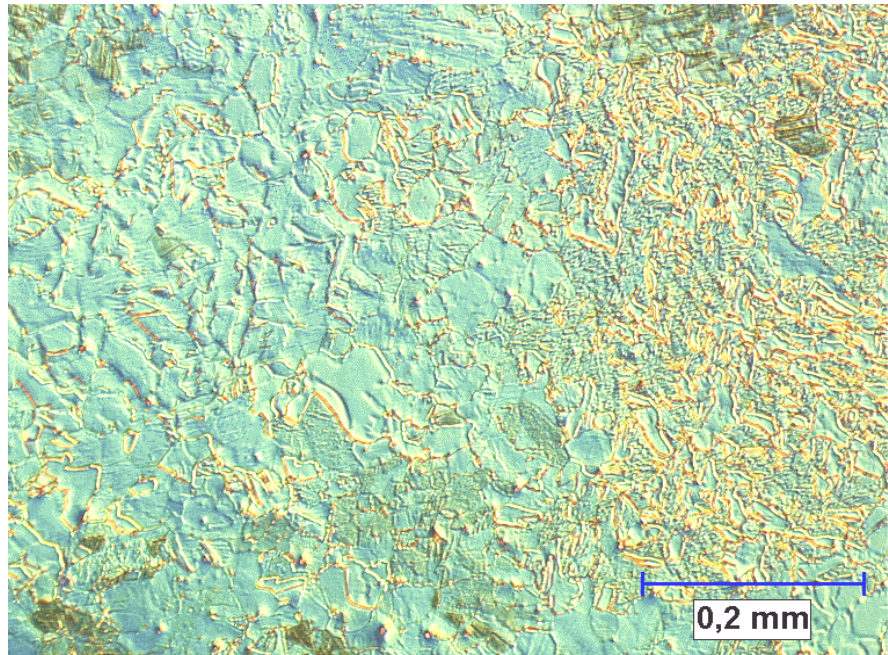


SnIn5 alloy (AC)
E: mag. 200×
CL

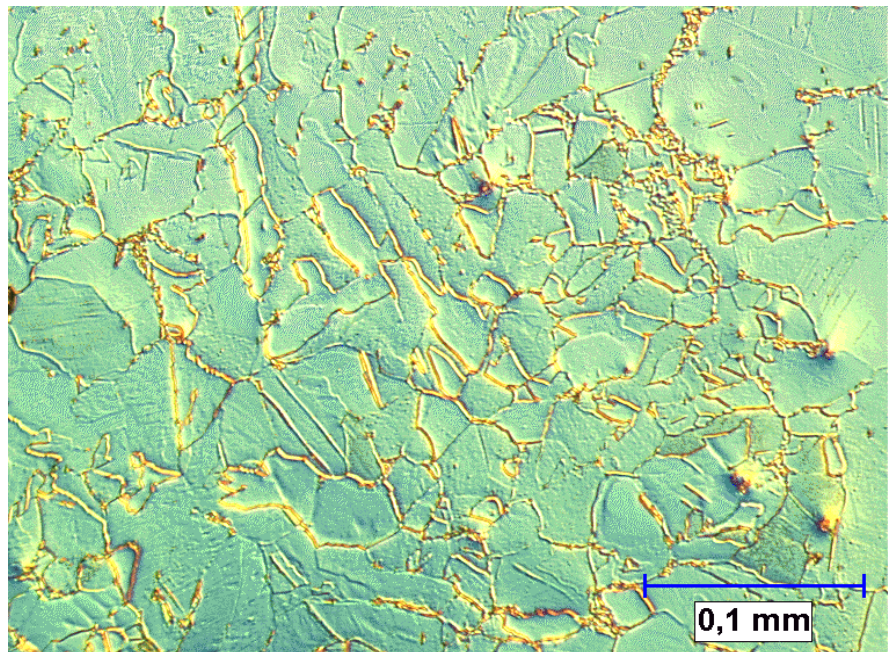


SnIn5 alloy (AC)
E: mag. 500×
CL

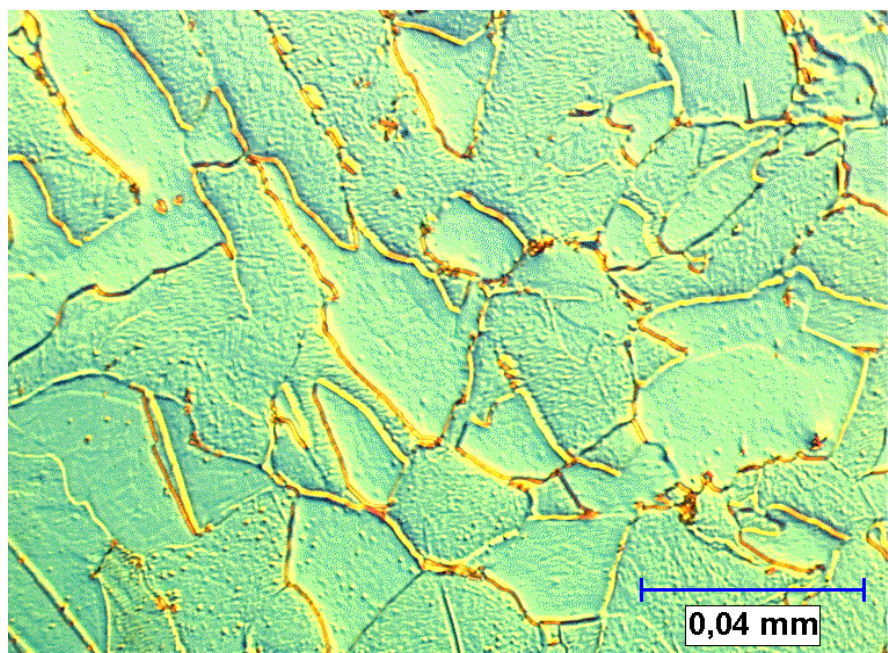
SnIn5 alloy (AC)
E: mag. 100×
PC

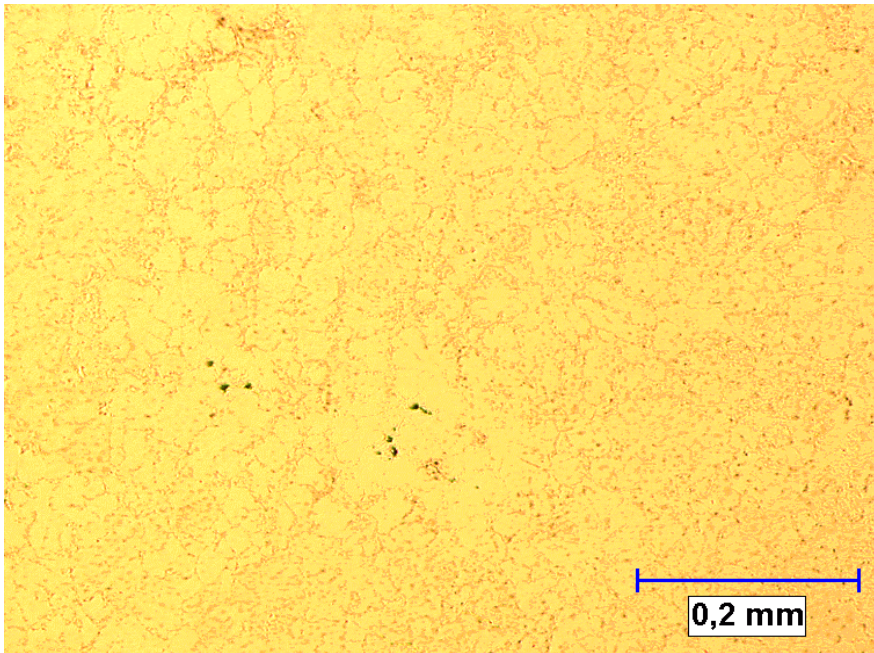


SnIn5 alloy (AC)
E: mag. 200×
PC

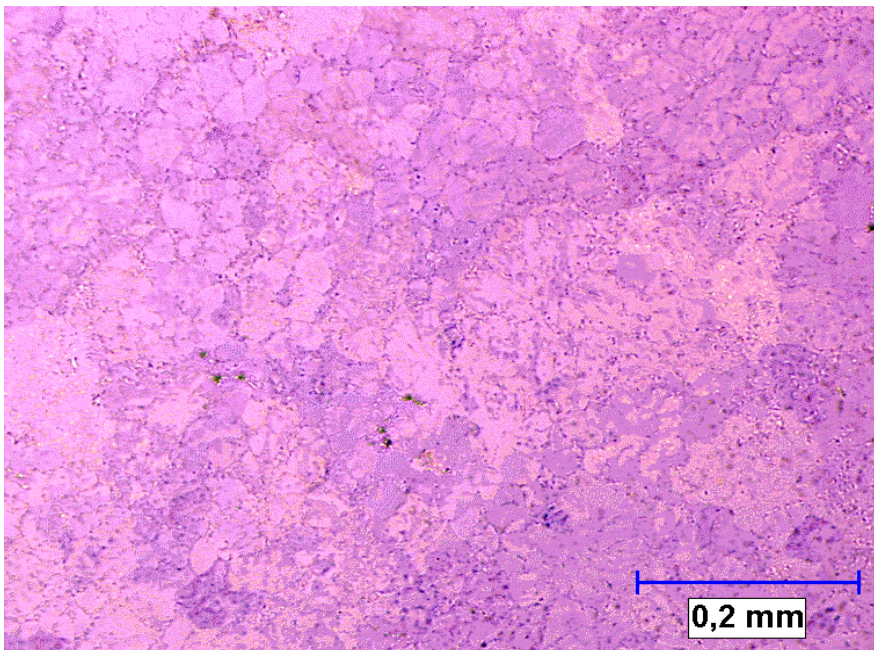


SnIn5 alloy (AC)
E: mag. 500×
PC

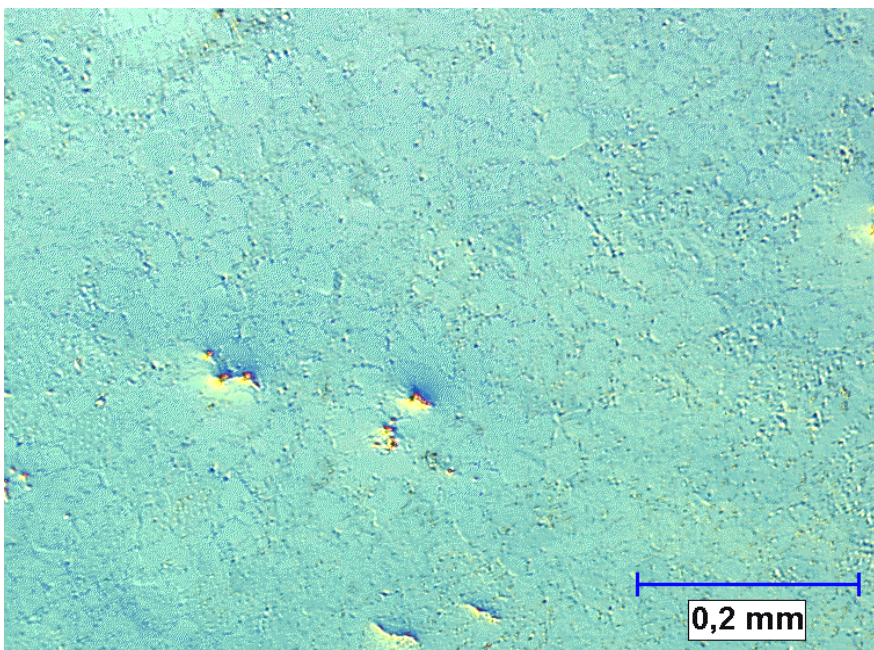




SnIn10 alloy (AC)
E: mag. 100×
CL

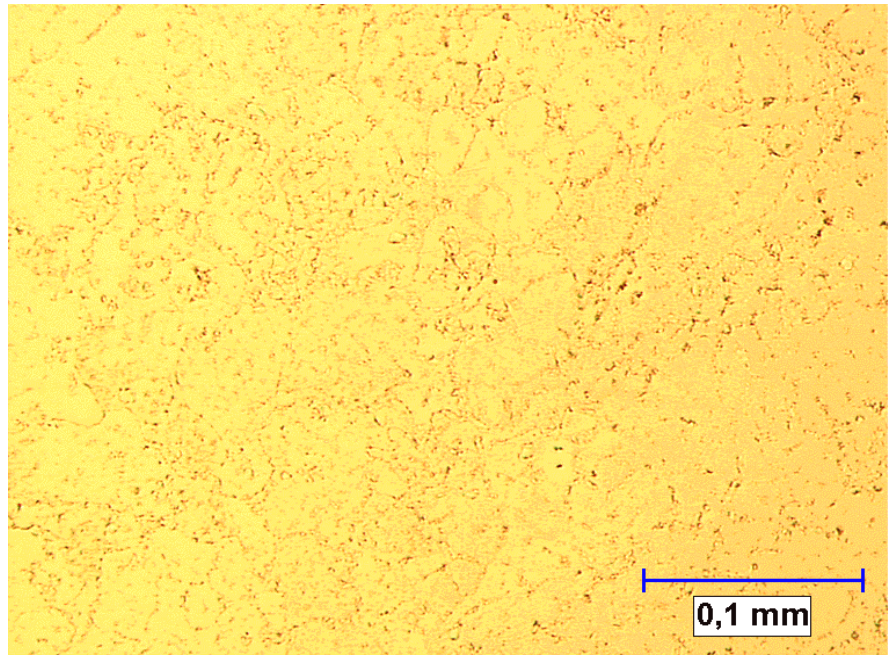


SnIn10 alloy (AC)
E: mag. 100×
PL

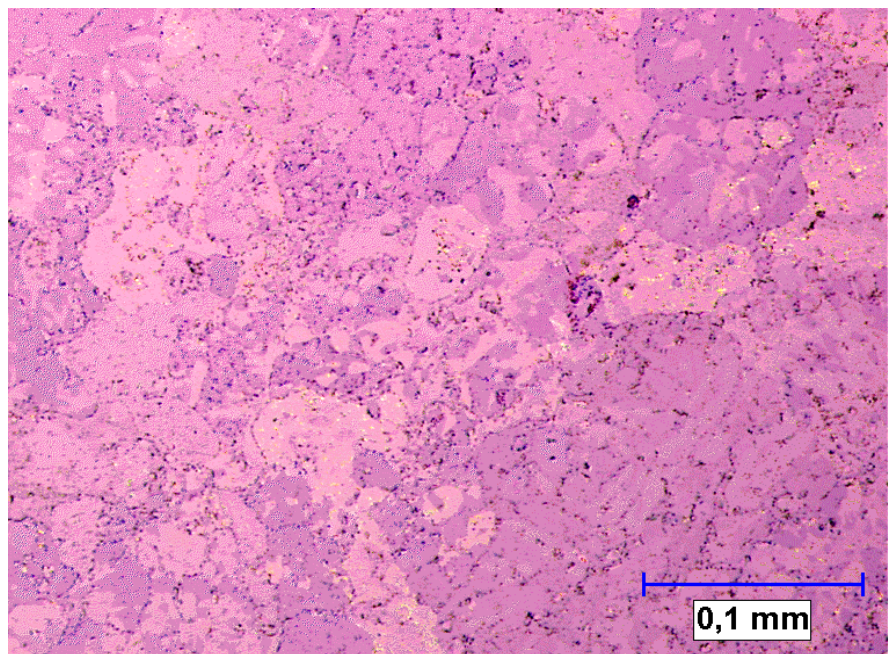


SnIn10 alloy (AC)
E: mag. 100×
PC

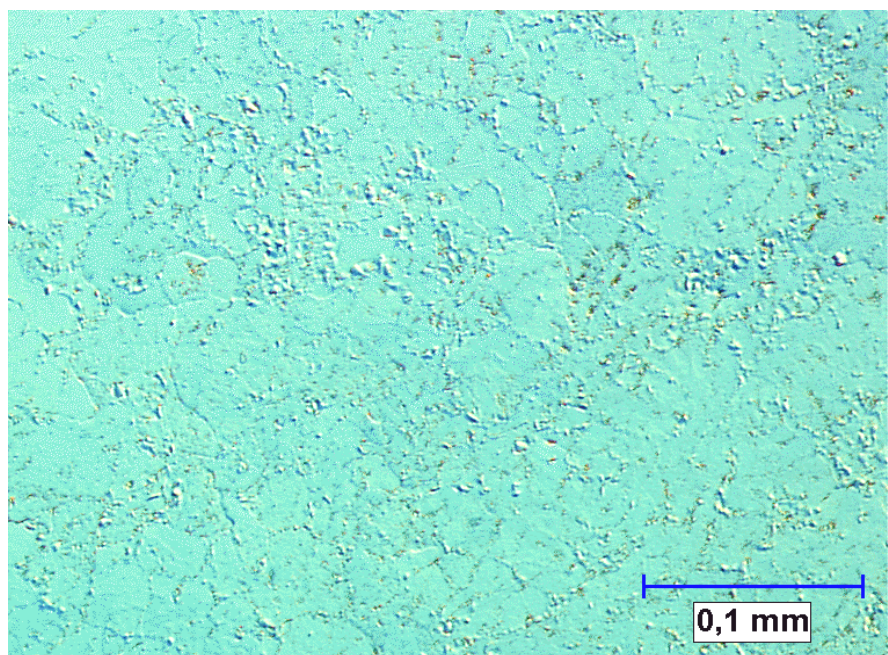
SnIn10 alloy (AC)
E: mag. 200×
CL

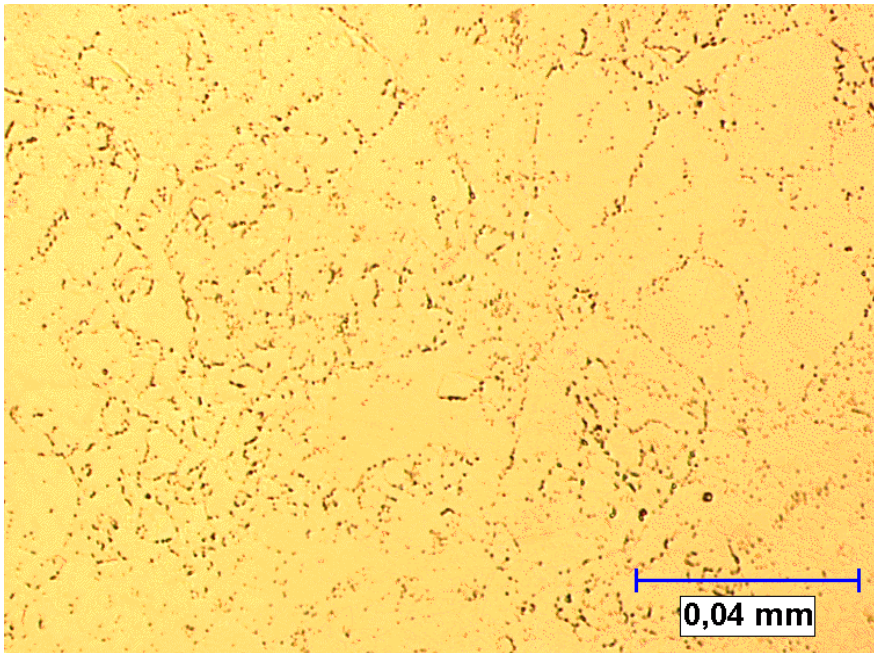


SnIn10 alloy (AC)
E: mag. 200×
PL



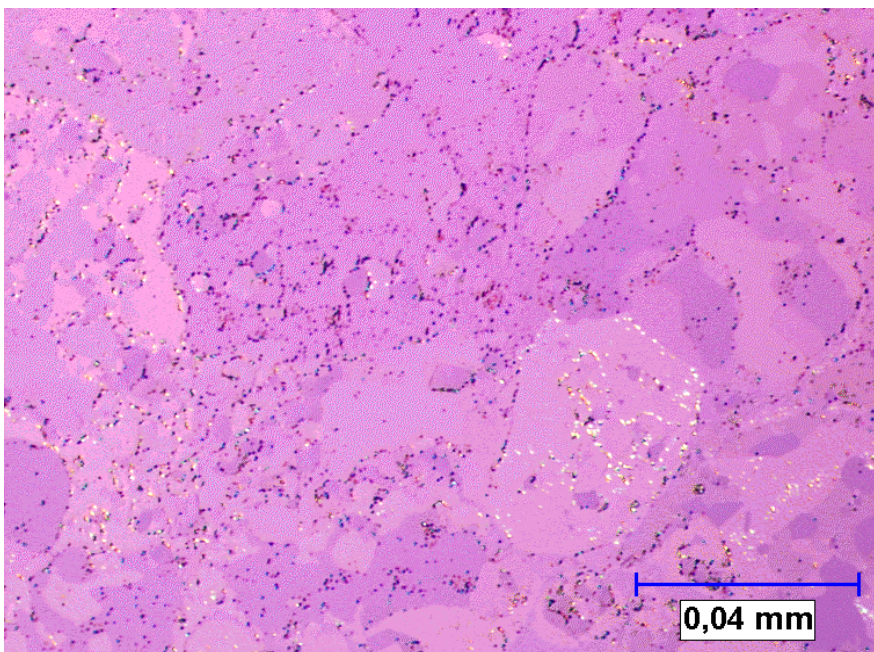
SnIn10 alloy (AC)
E: mag. 200×
PC



**SnIn10 alloy (AC)**

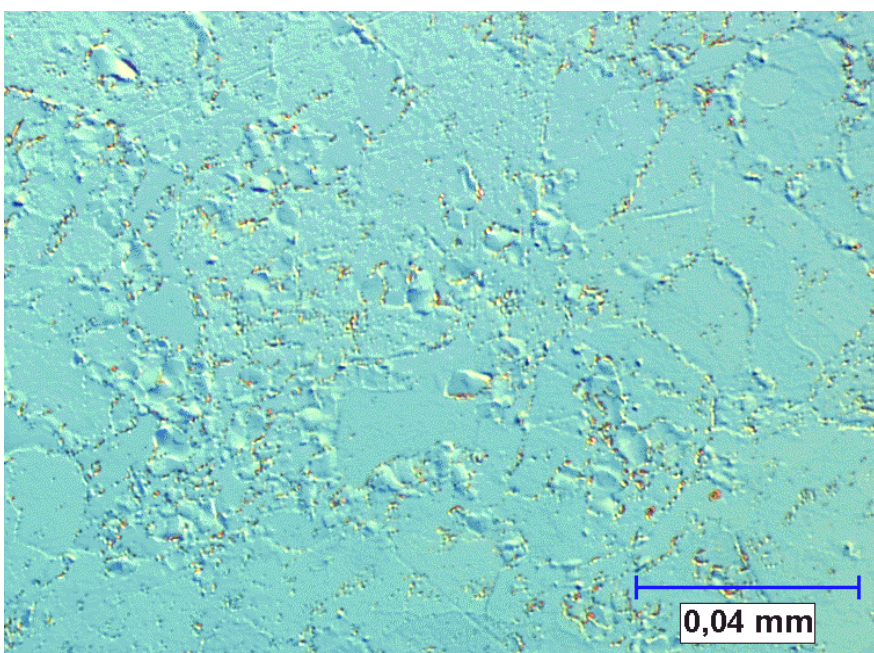
E: mag. 500×

CL

**SnIn10 alloy (AC)**

E: mag. 500×

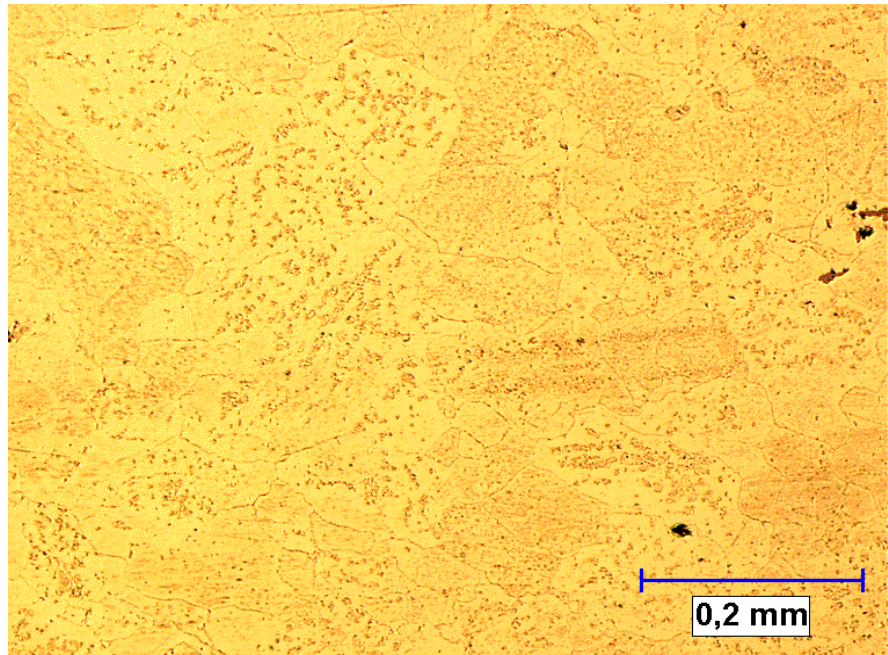
PL

**SnIn10 alloy (AC)**

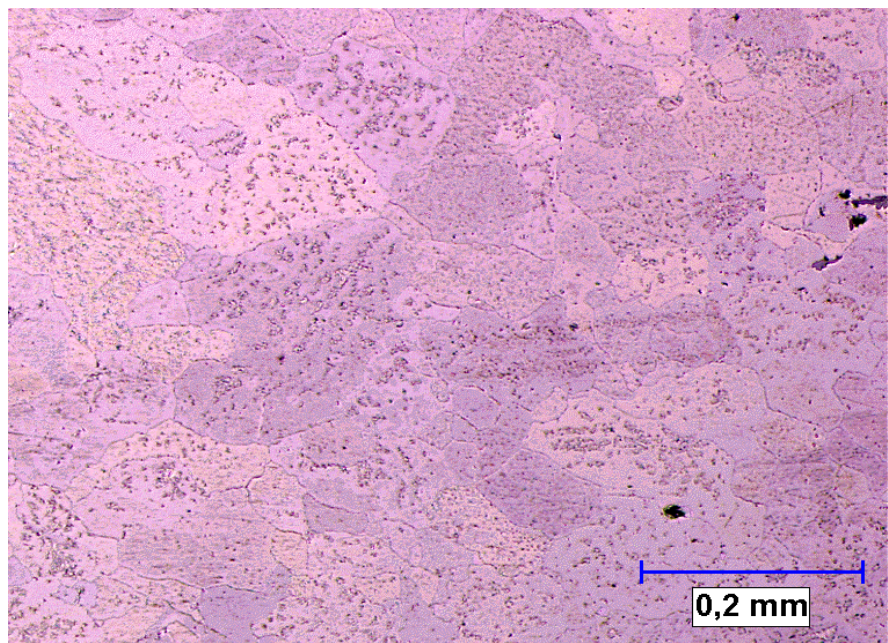
E: mag. 500×

PC

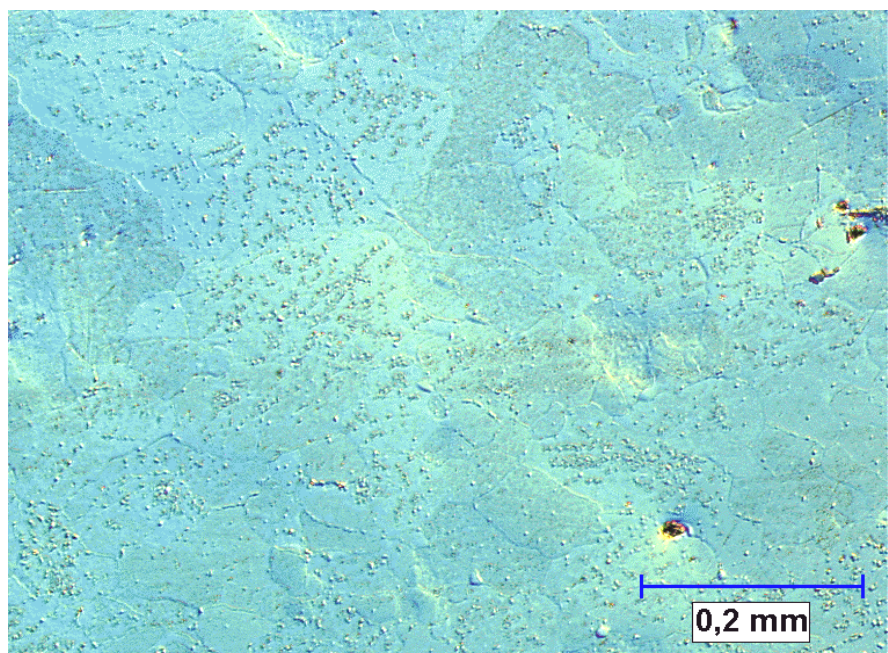
SnIn15 alloy (AC)
E: mag. 100×
CL

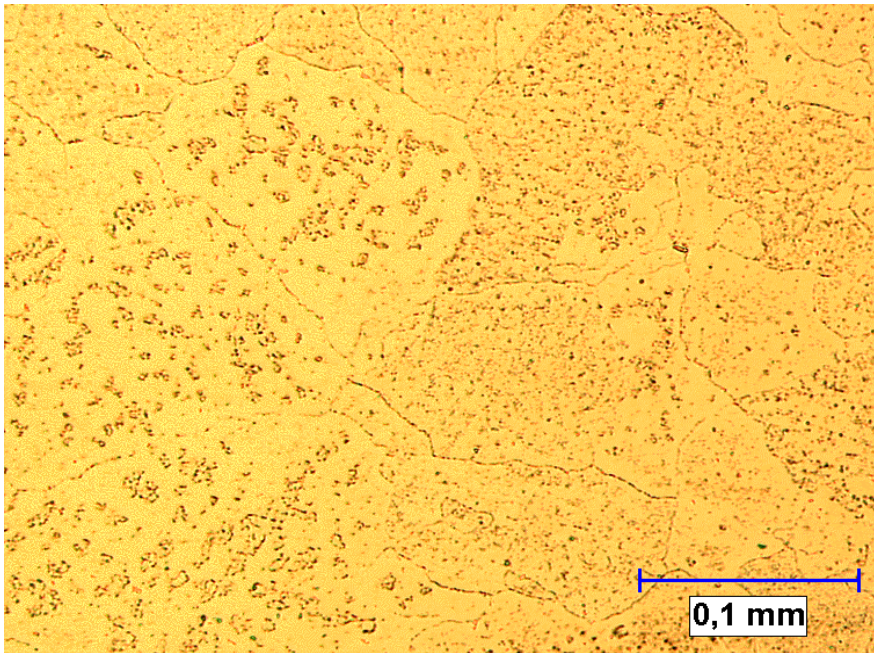


SnIn15 alloy (AC)
E: mag. 100×
PL



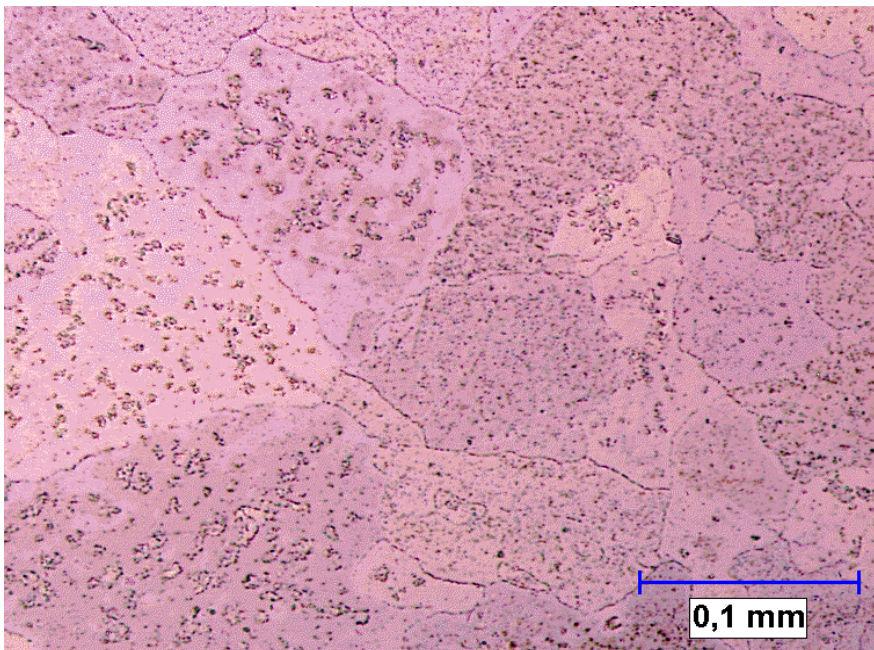
SnIn15 alloy (AC)
E: mag. 100×
PC



**SnIn15 alloy (AC)**

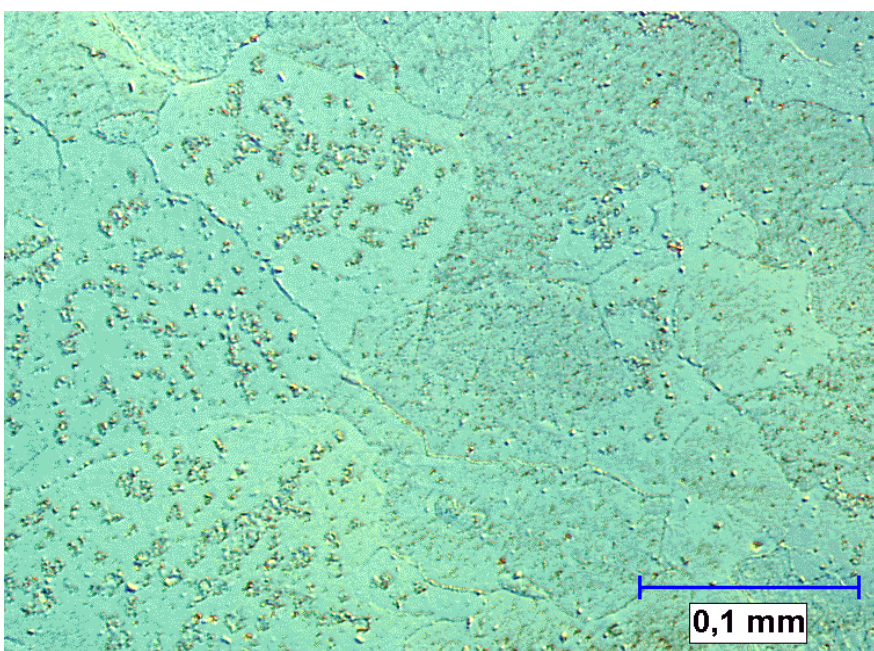
E: mag. 200×

CL

**SnIn15 alloy (AC)**

E: mag. 200×

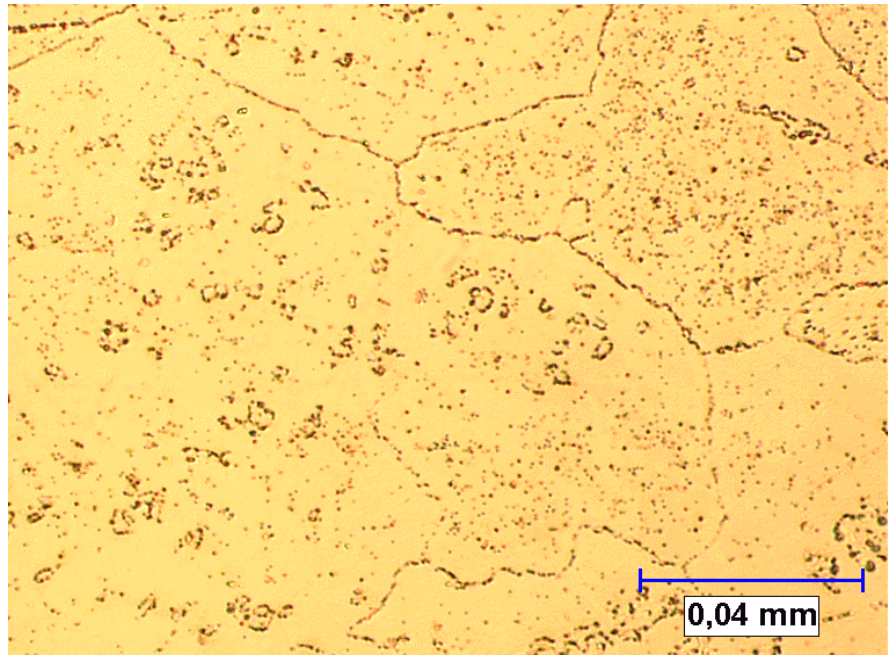
PL

**SnIn15 alloy (AC)**

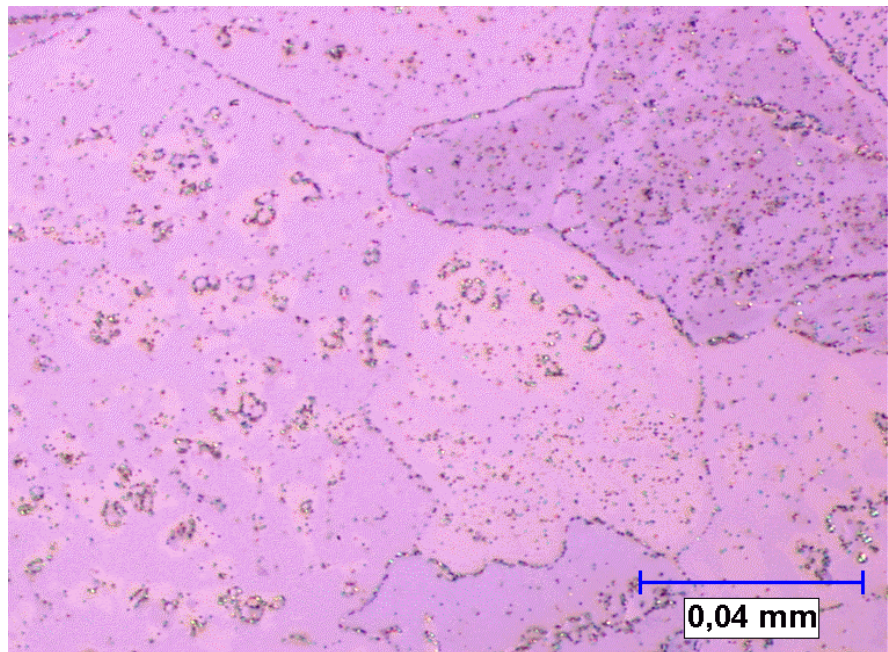
E: mag. 200×

PC

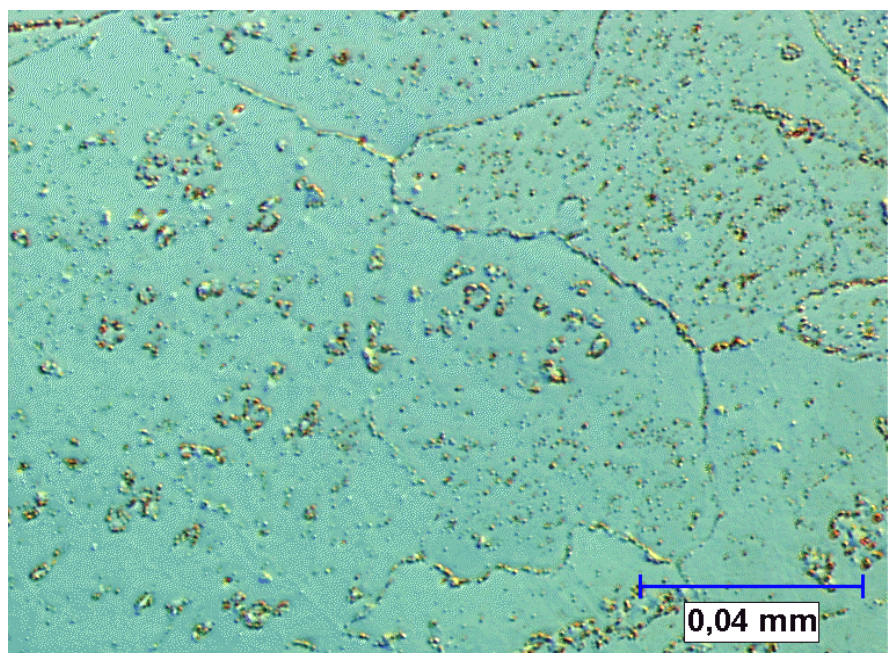
SnIn15 alloy (AC)
E: mag. 500×
CL

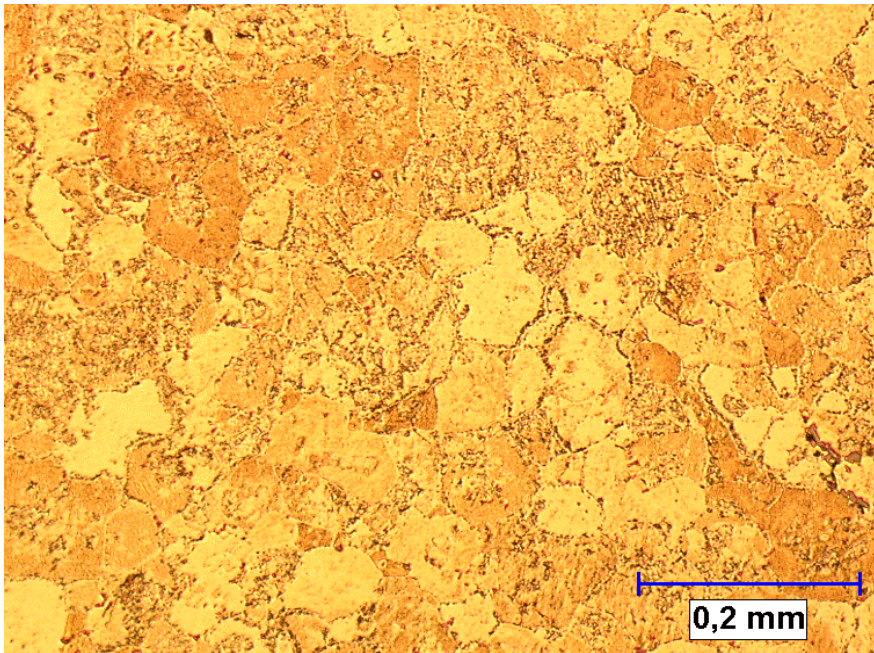


SnIn15 alloy (AC)
E: mag. 500×
PL



SnIn15 alloy (AC)
E: mag. 500×
PC

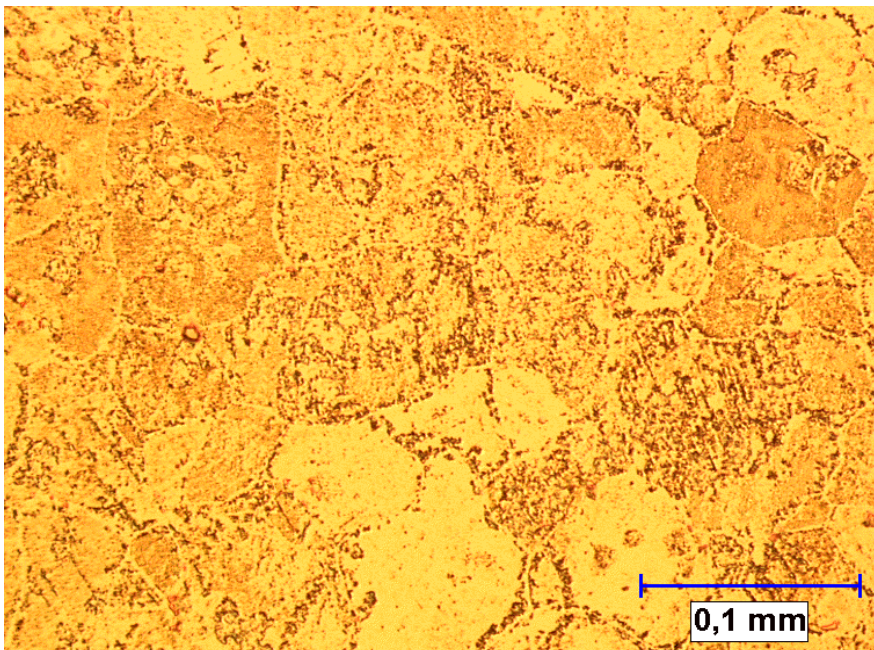




SnIn20 alloy (AC)

E: mag. 100×

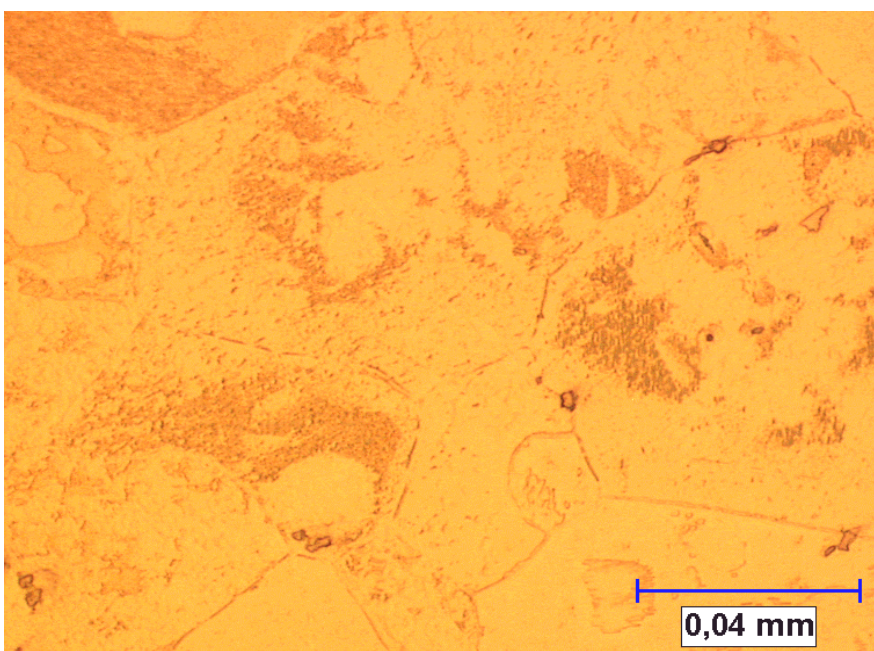
CL



SnIn20 alloy (AC)

E: mag. 200×

CL

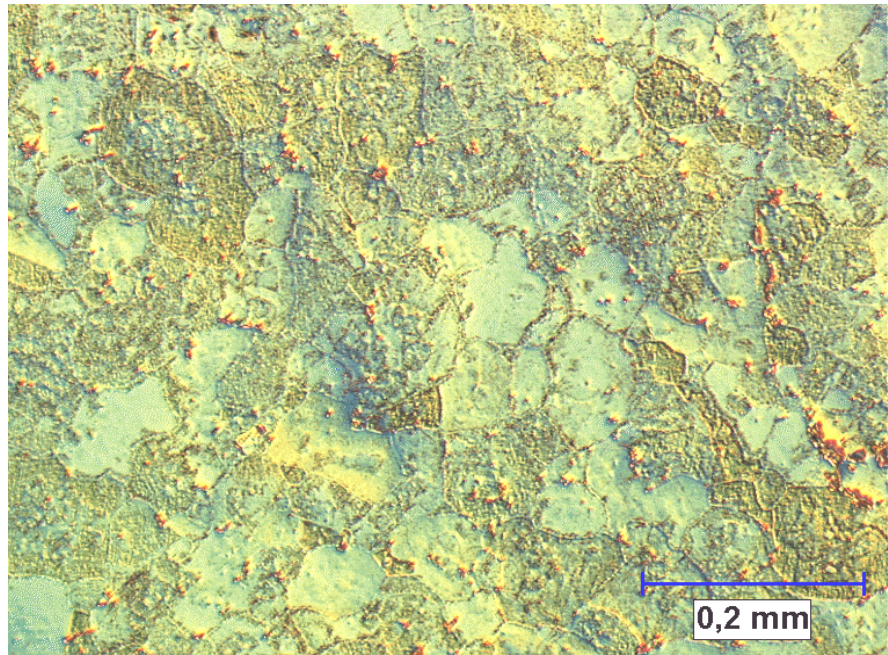


SnIn20 alloy (AC)

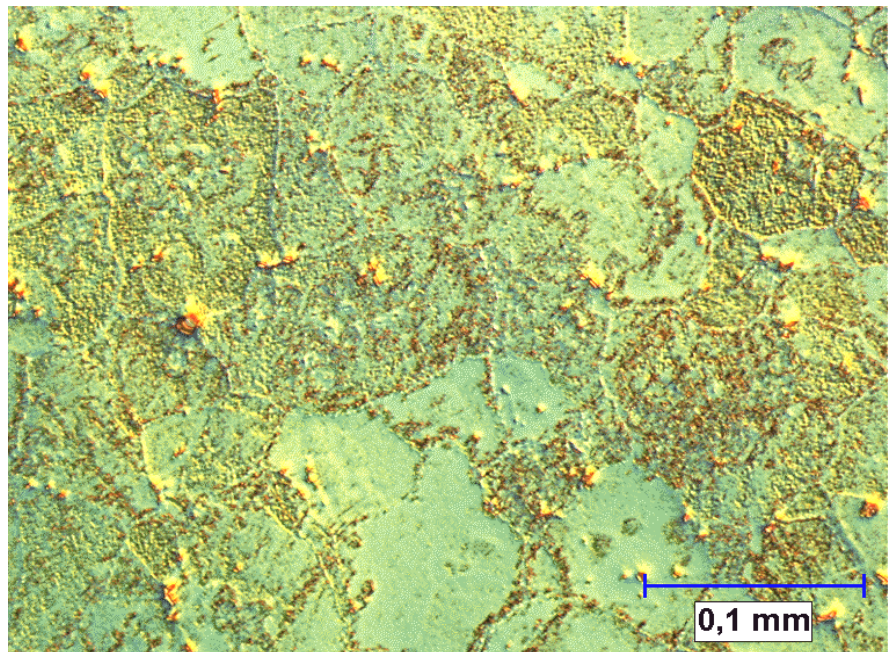
E: mag. 500×

CL

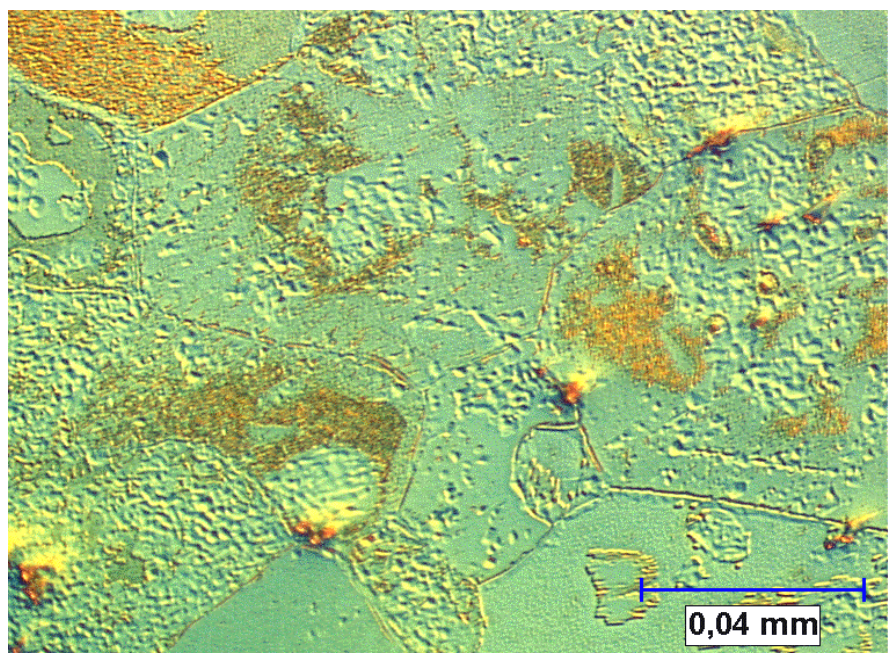
SnIn20 alloy (AC)
E: mag. 100×
PC

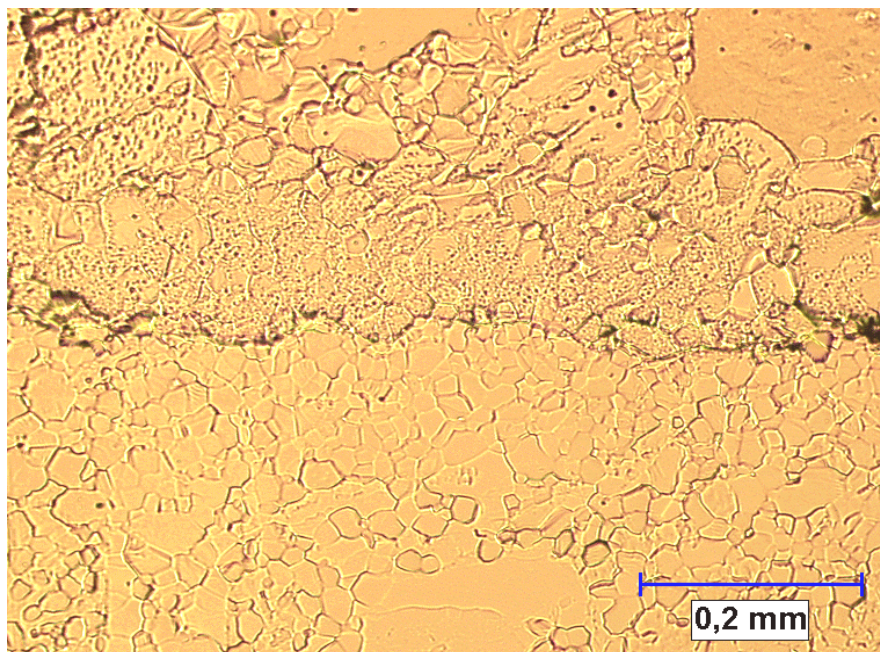


SnIn20 alloy (AC)
E: mag. 200×
PC

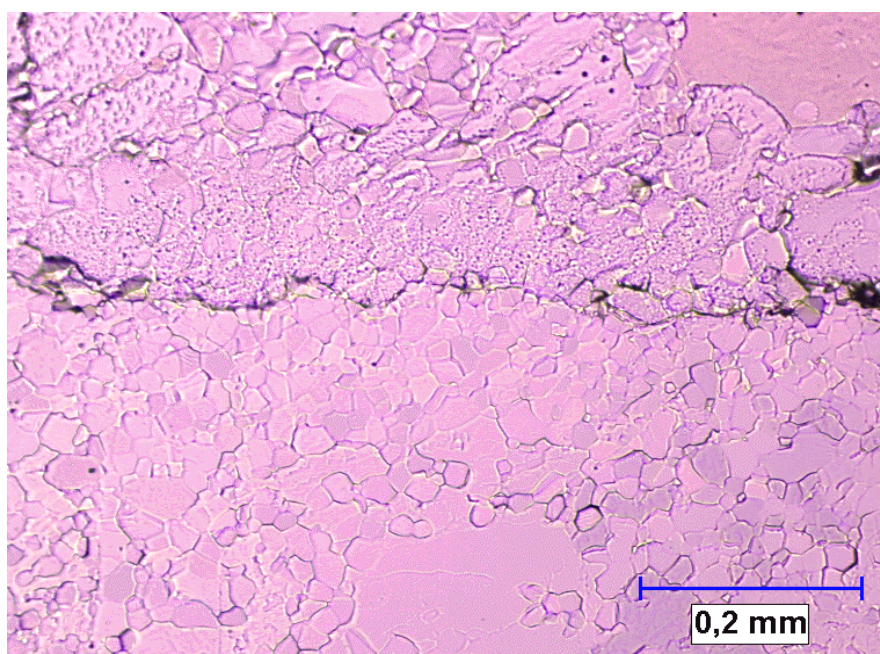


SnIn20 alloy (AC)
E: mag. 500×
PC

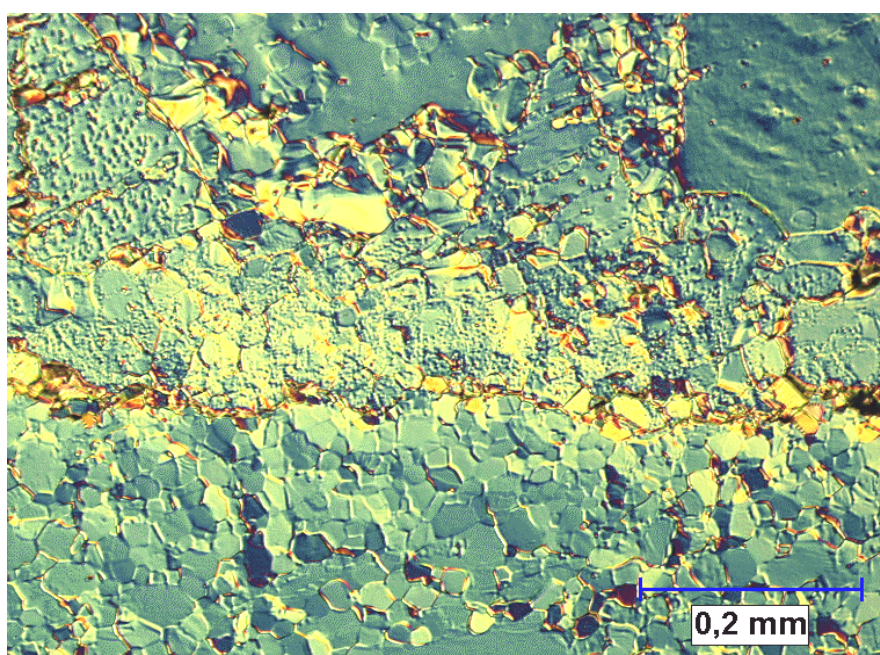




Sn/In couple
180°C; 30 min
E: mag. 100×
CL

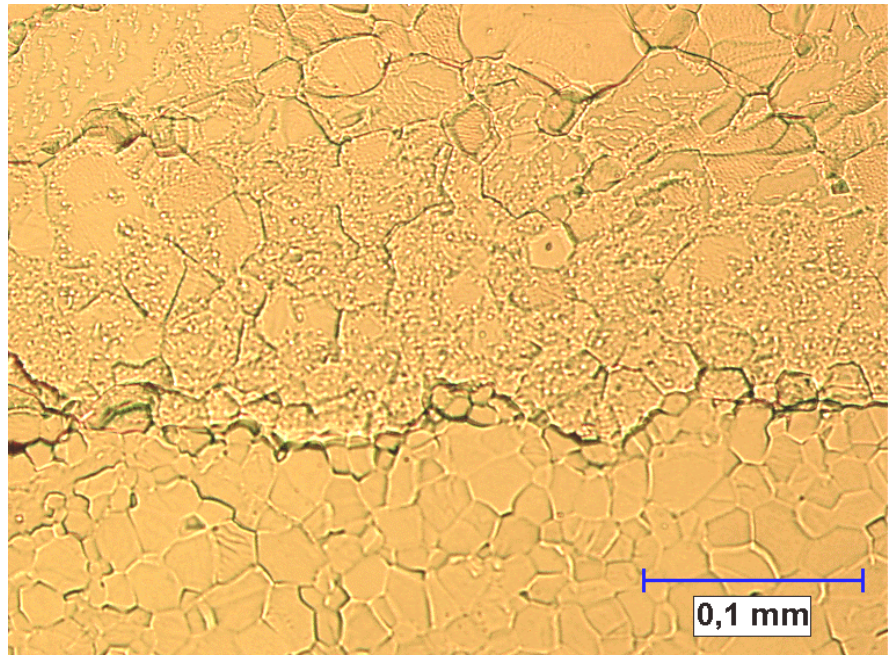


Sn/In couple
180°C; 30 min
E: mag. 100×
PL

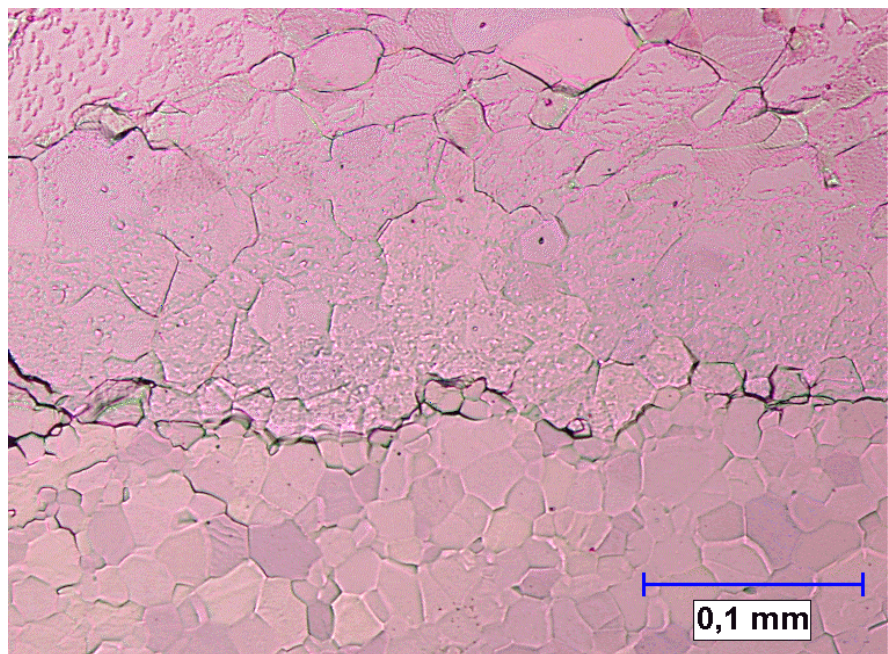


Sn/In couple
180°C; 30 min
E: mag. 100×
PC

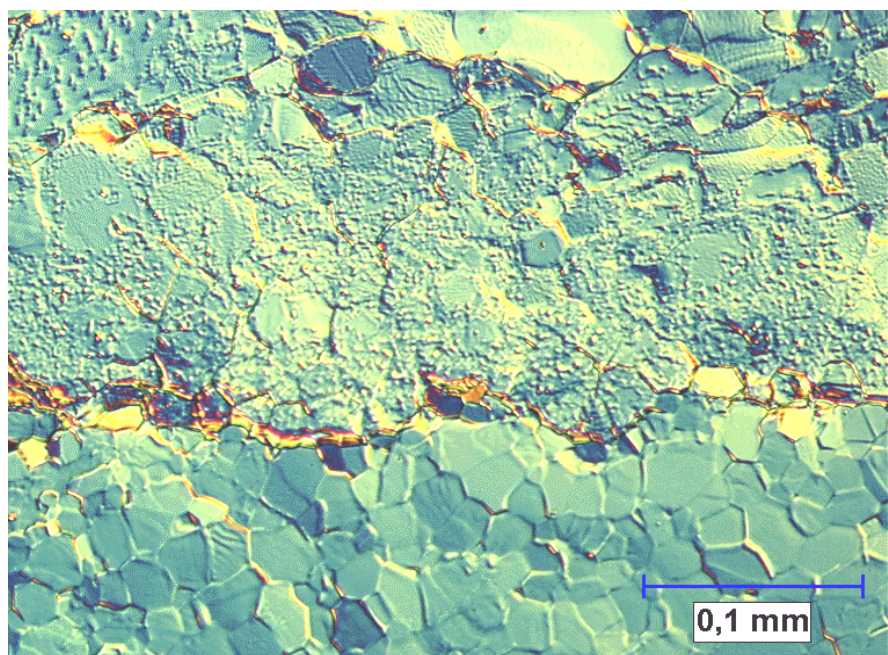
Sn/In couple
180°C; 30 min
E: mag. 200×
CL

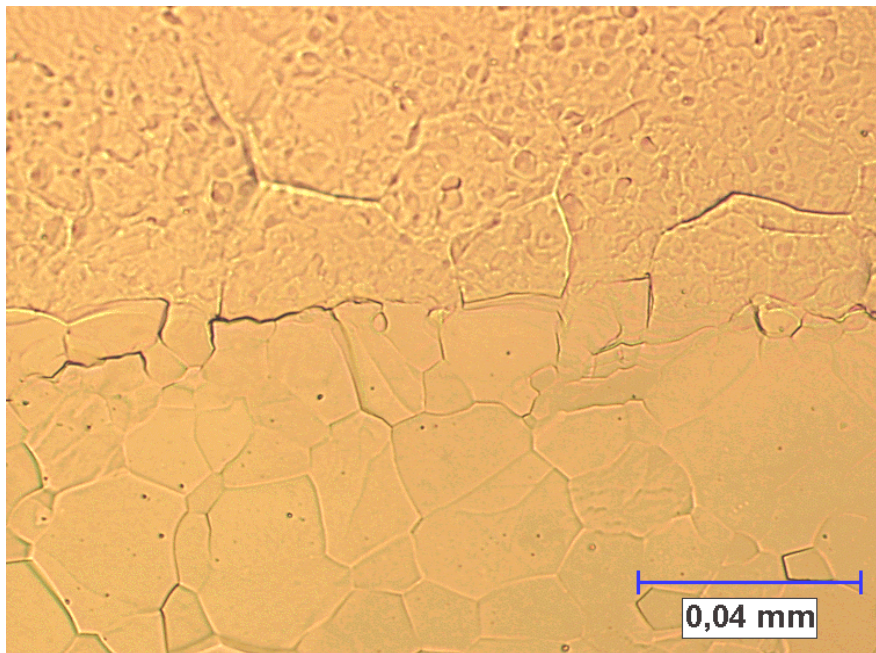


Sn/In couple
180°C; 30 min
E: mag. 200×
PL

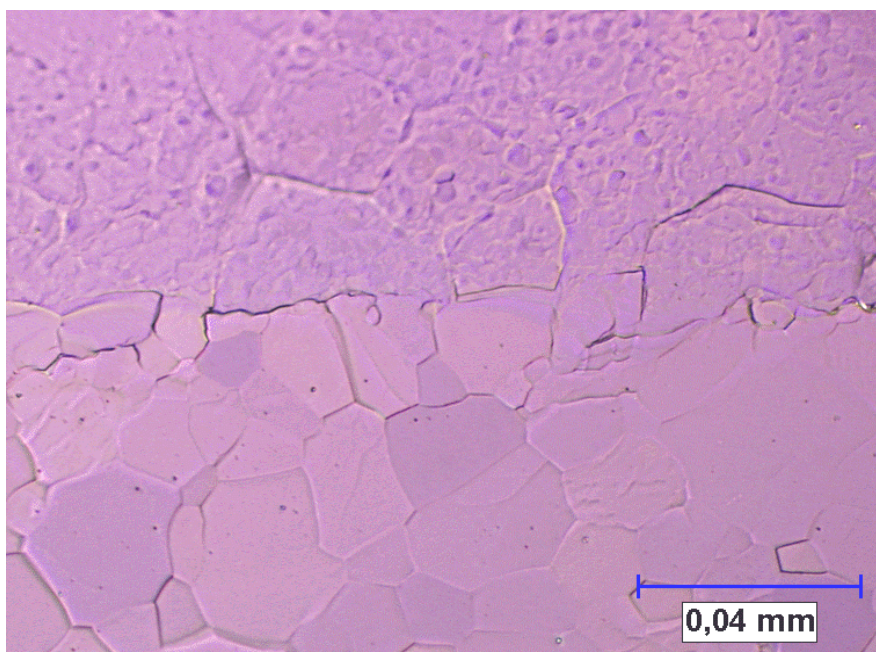


Sn/In couple
180°C; 30 min
E: mag. 200×
PC

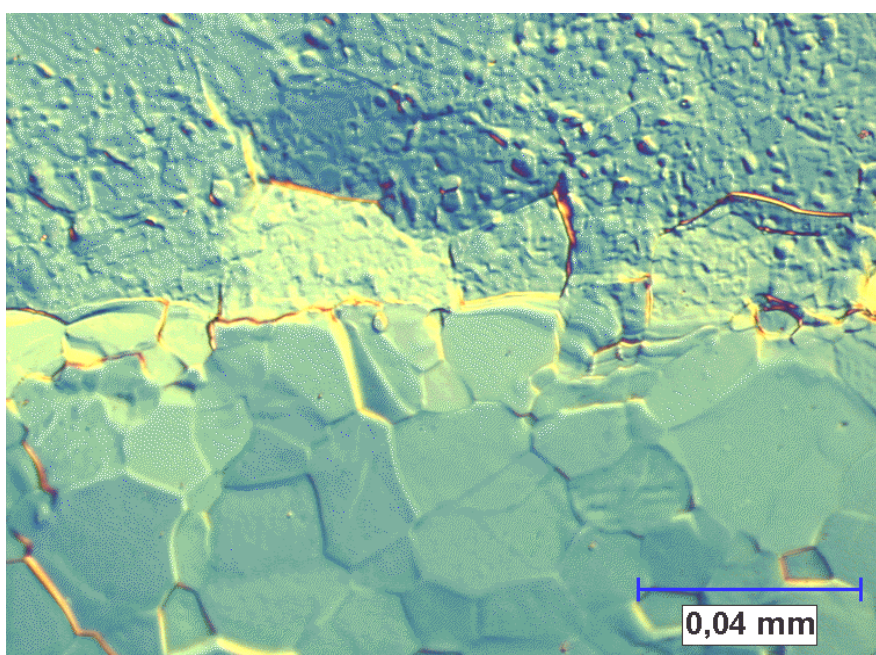




Sn/In couple
180°C; 30 min
E: mag. 500×
CL

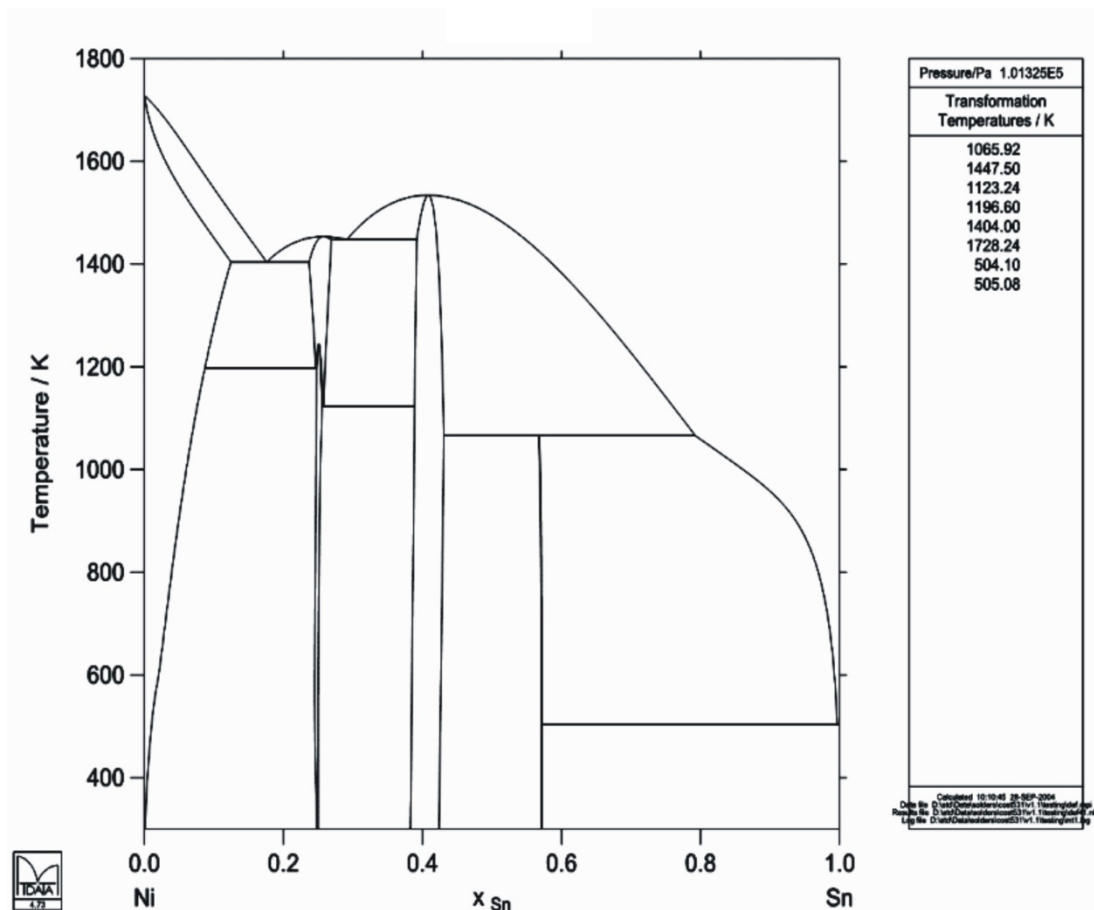


Sn/In couple
180°C; 30 min
E: mag. 500×
PL

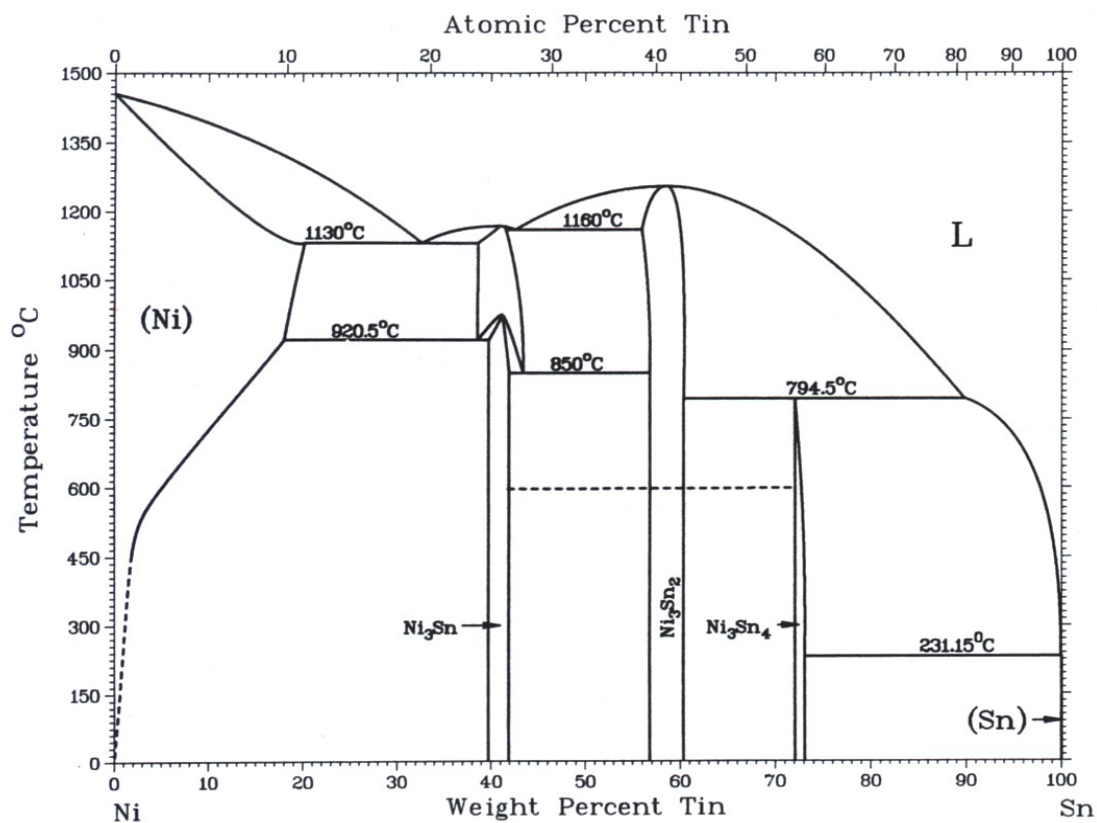


Sn/In couple
180°C; 30 min
E: mag. 500×
PC

Sn – Ni



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•318)

P. Nash and A. Nash, 1991

Phase	Composition, wt% Sn	Pearson symbol	Space group
(Ni)	0 to 19.3	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
Ni ₃ Sn(HT)	37.9 to 43.0	(a)	...
Ni ₃ Sn(LT)	39 to 41.7	<i>hP8</i>	<i>P6₃/mmc</i>
Ni ₃ Sn ₂ (HT)	54.8 to 57.9	(a)	...
		(b)	...
Ni ₃ Sn ₂ (LT)	55.9 to 59.9	<i>hP4</i>	<i>P6₃/mmc</i>
Ni ₃ Sn ₄	71.6 to 73	<i>mC14</i>	<i>C2/m</i>
(β Sn)	~100	<i>tI4</i>	<i>I4₁/amd</i>
Metastable phase			
Ni ₃ Sn	40	<i>oP8</i>	<i>Pmmn</i>

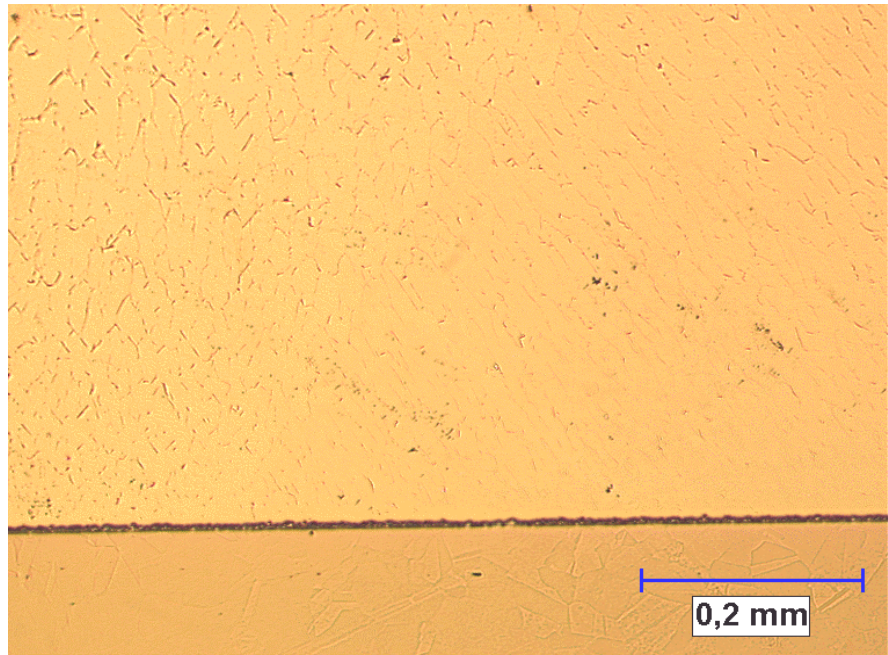
(a) Hexagonal. (b) Orthorhombic

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•318)

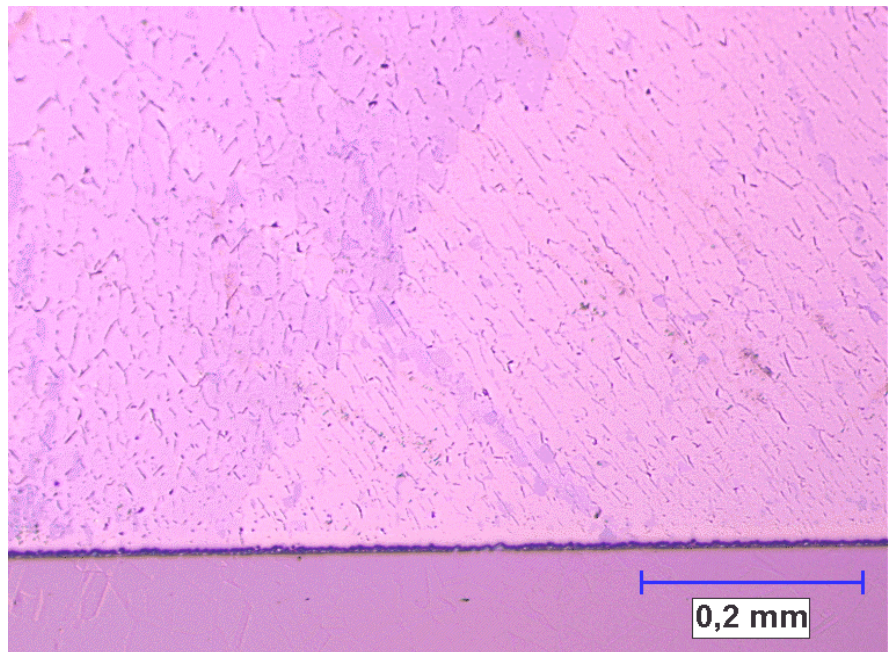
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
Sn / Ni	230°C, 5 min, flux	58°	19
Sn / Ni	230°C, 30 min, flux	37°	23

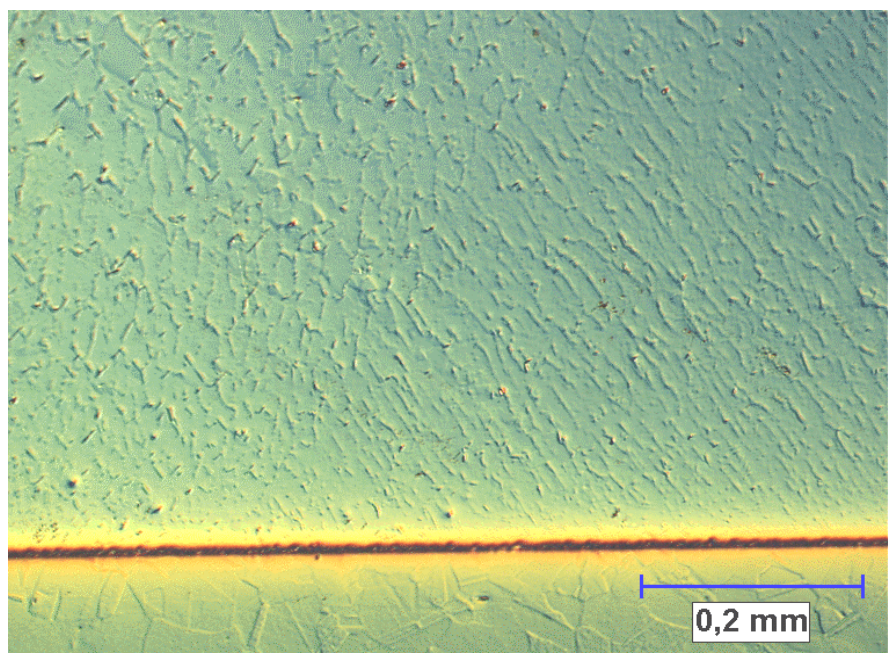
Sn/Ni couple
230°C; 5 min
NE: mag. 100×
CL

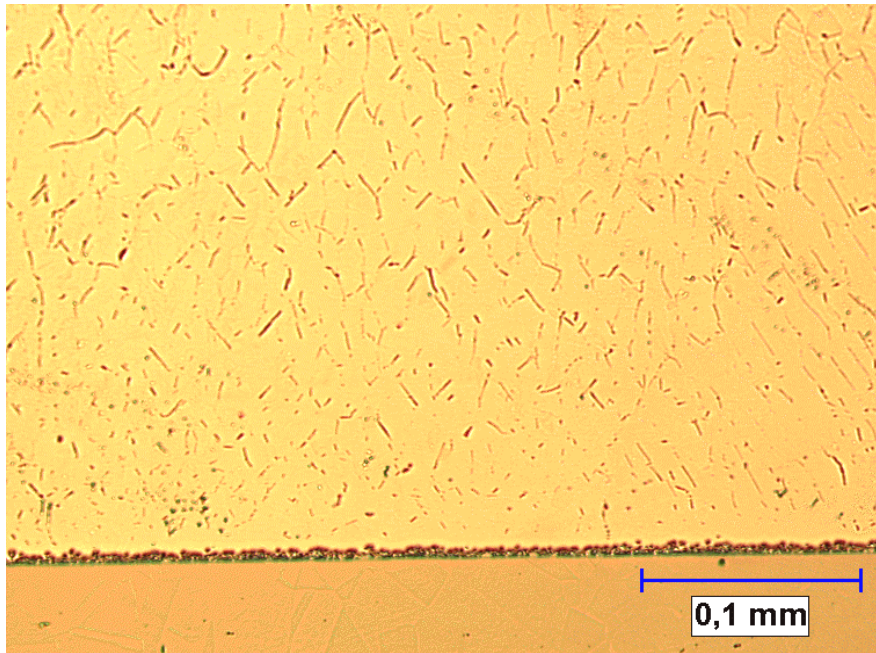


Sn/Ni couple
230°C; 5 min
NE: mag. 100×
PL

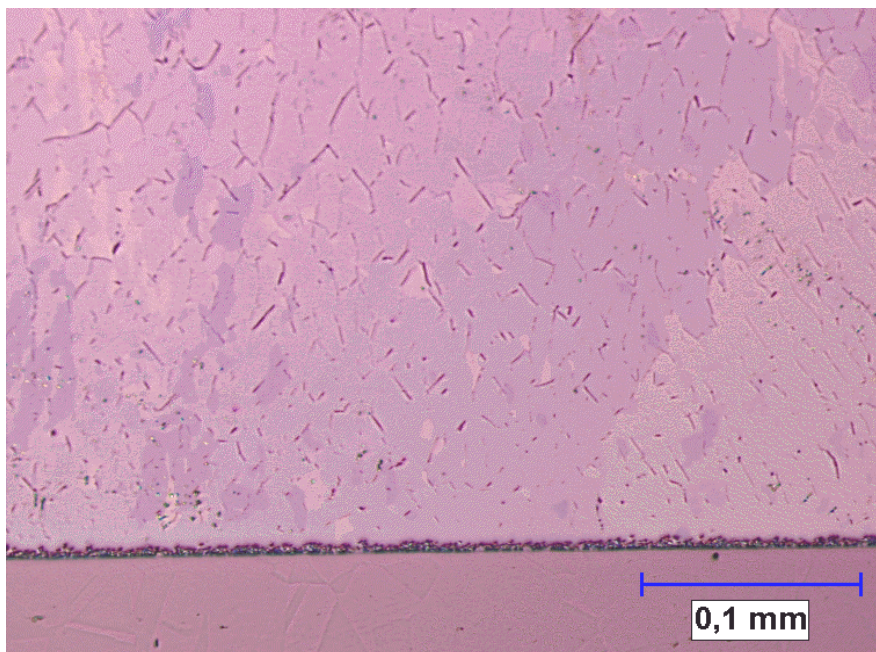


Sn/Ni couple
230°C; 5 min
NE: mag. 100×
PC

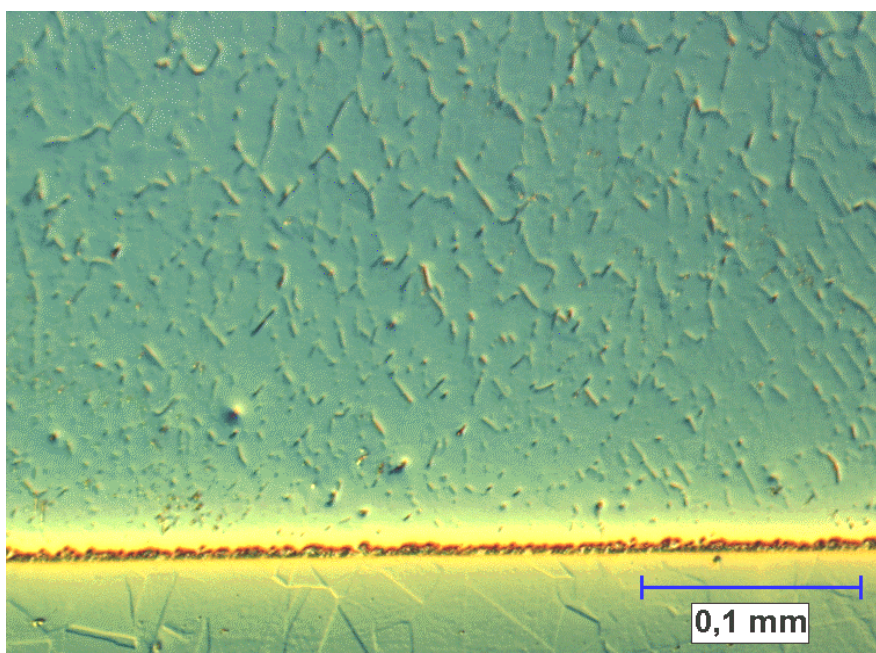




Sn/Ni couple
230°C; 5 min
NE: mag. 200×
CL

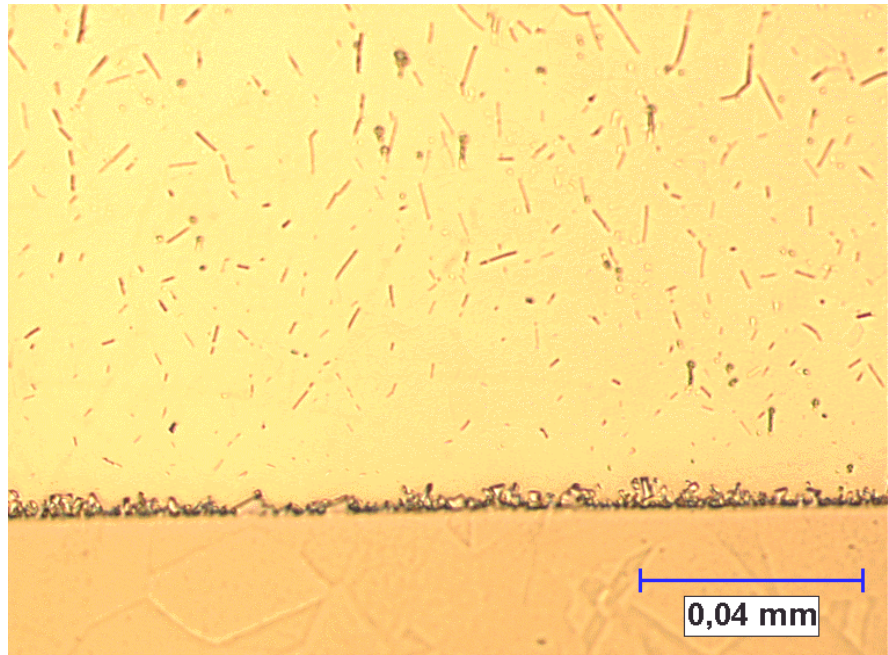


Sn/Ni couple
230°C; 5 min
NE: mag. 200×
PL

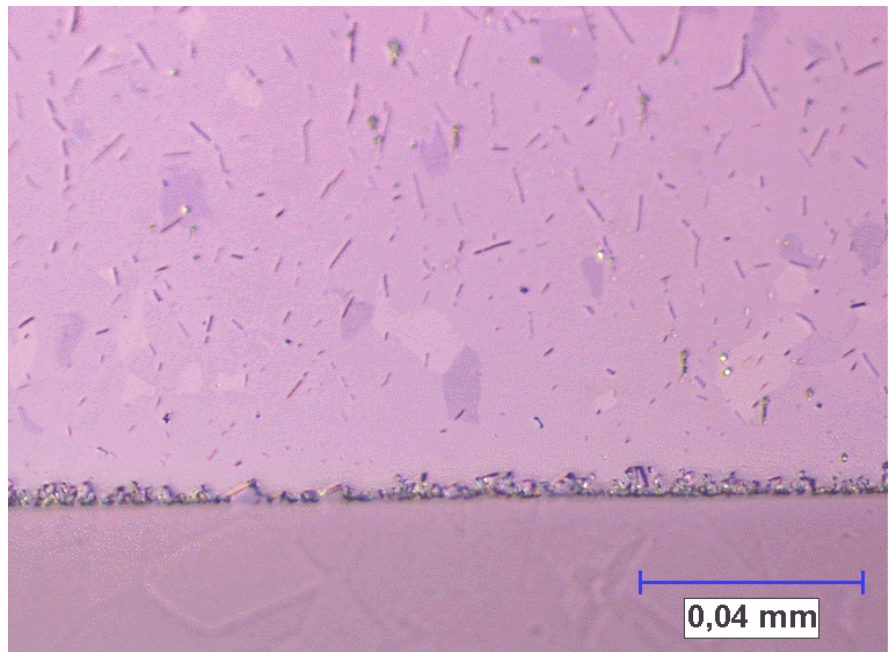


Sn/Ni couple
230°C; 5 min
NE: mag. 200×
PC

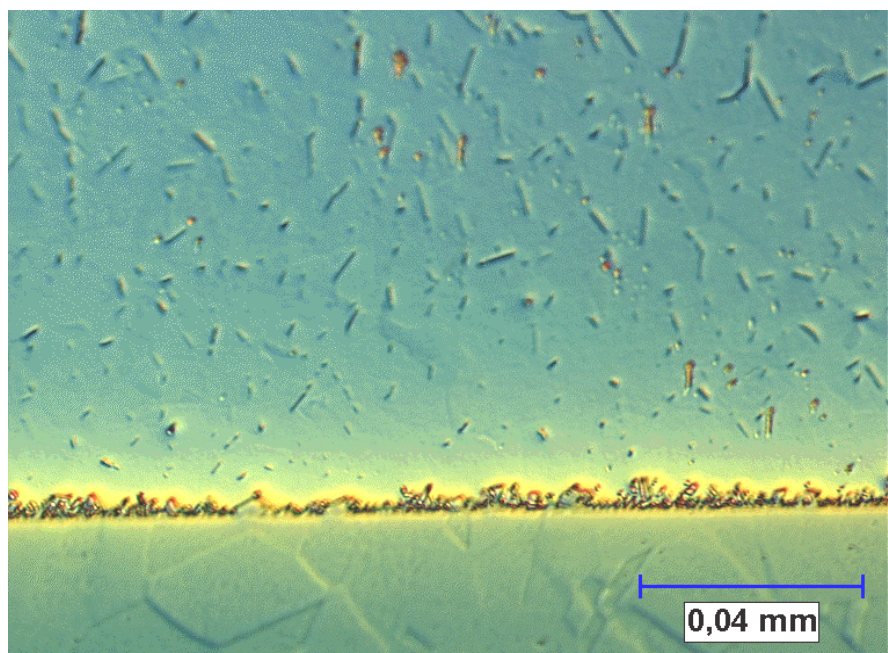
Sn/Ni couple
230°C; 5 min
NE: mag. 500×
CL

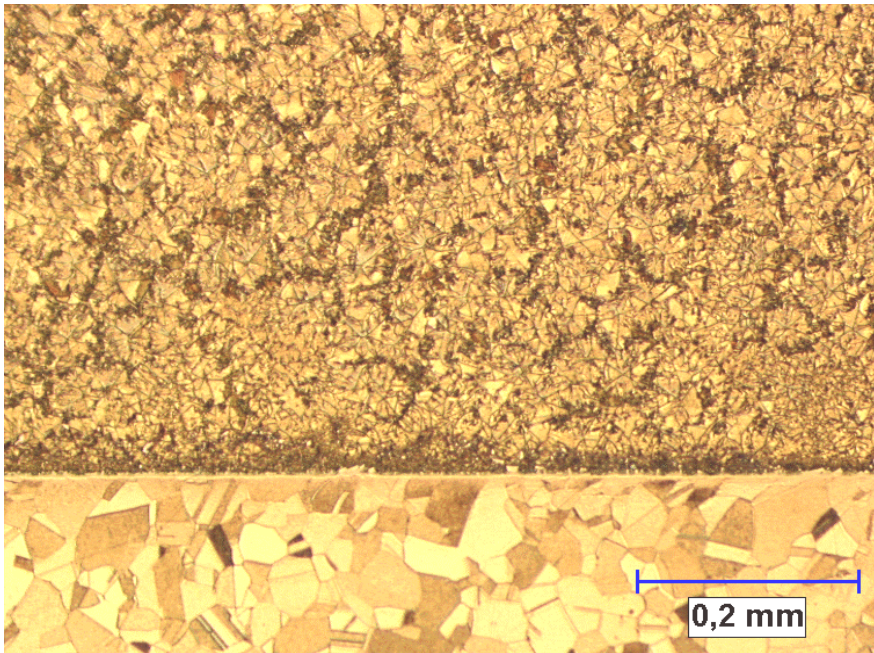


Sn/Ni couple
230°C; 5 min
NE: mag. 500×
PL

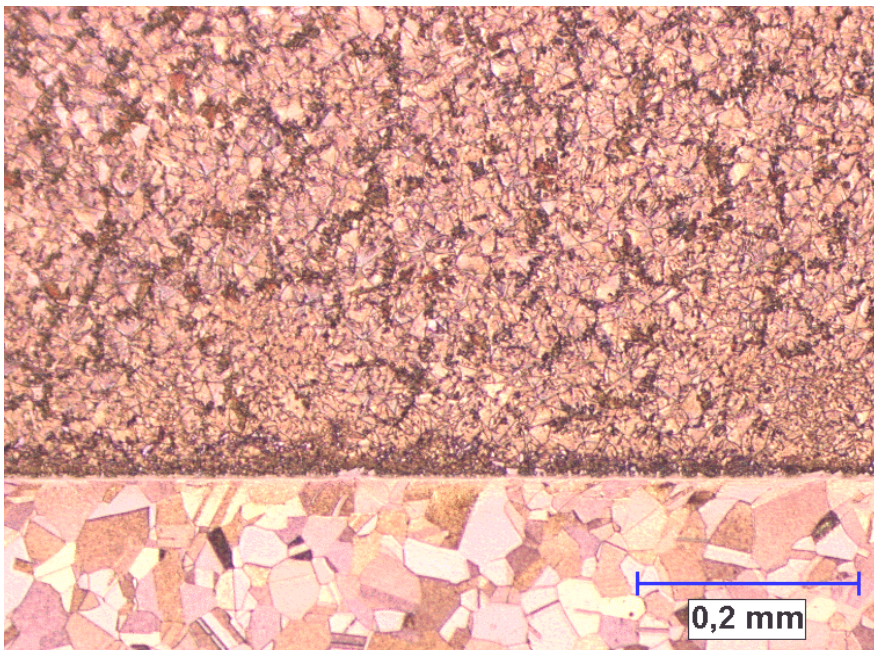


Sn/Ni couple
230°C; 5 min
NE: mag. 500×
PC

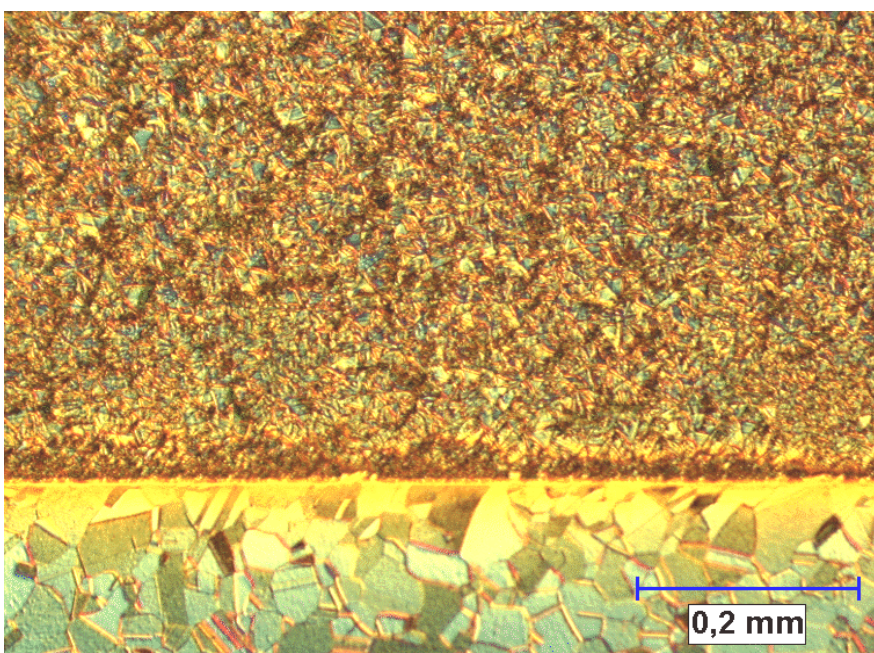




Sn/Ni couple
230°C; 30 min
E: mag. 100×
CL

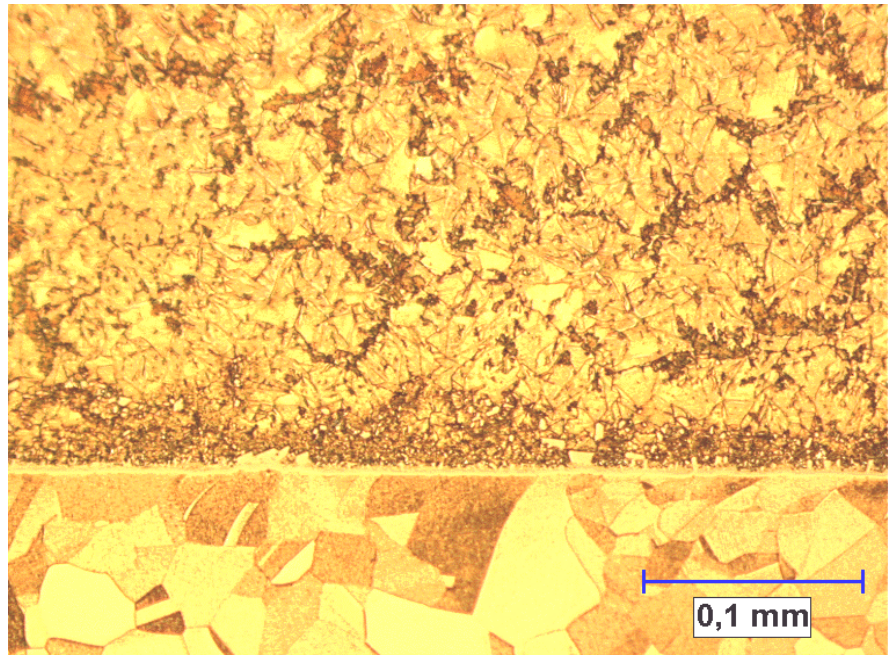


Sn/Ni couple
230°C; 30 min
E: mag. 100×
PL

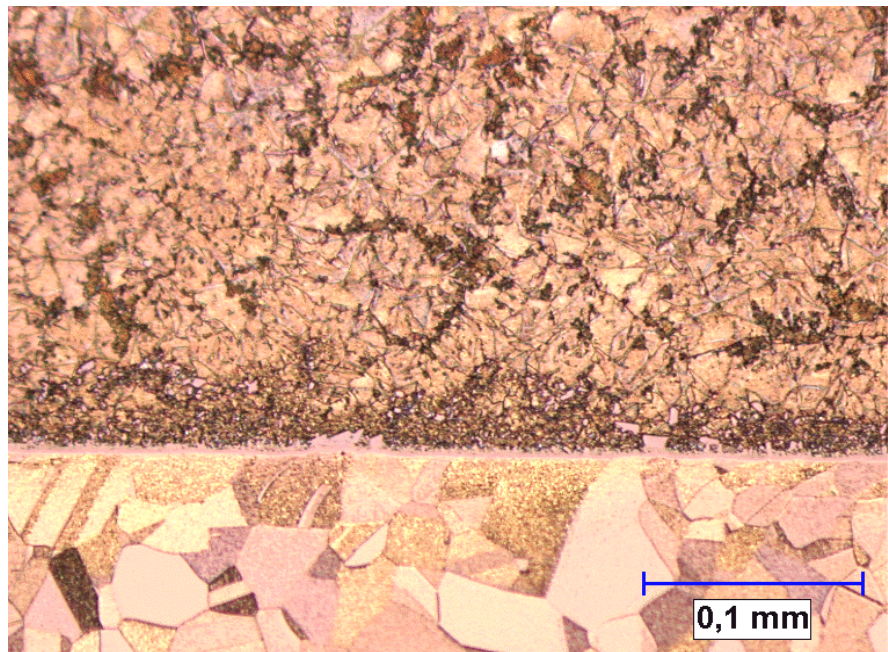


Sn/Ni couple
230°C; 30 min
E: mag. 100×
PC

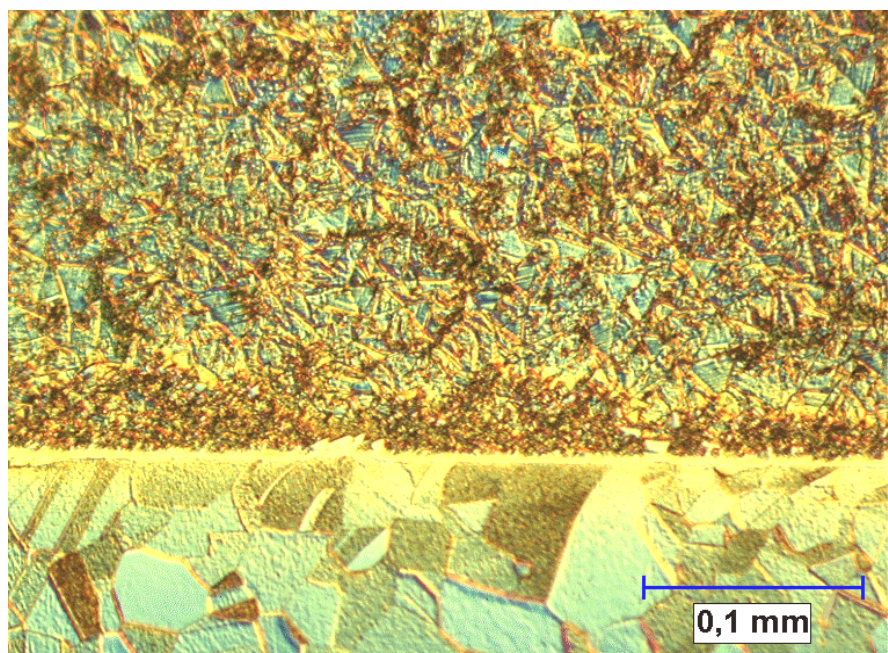
Sn/Ni couple
230°C; 30 min
E: mag. 200×
CL

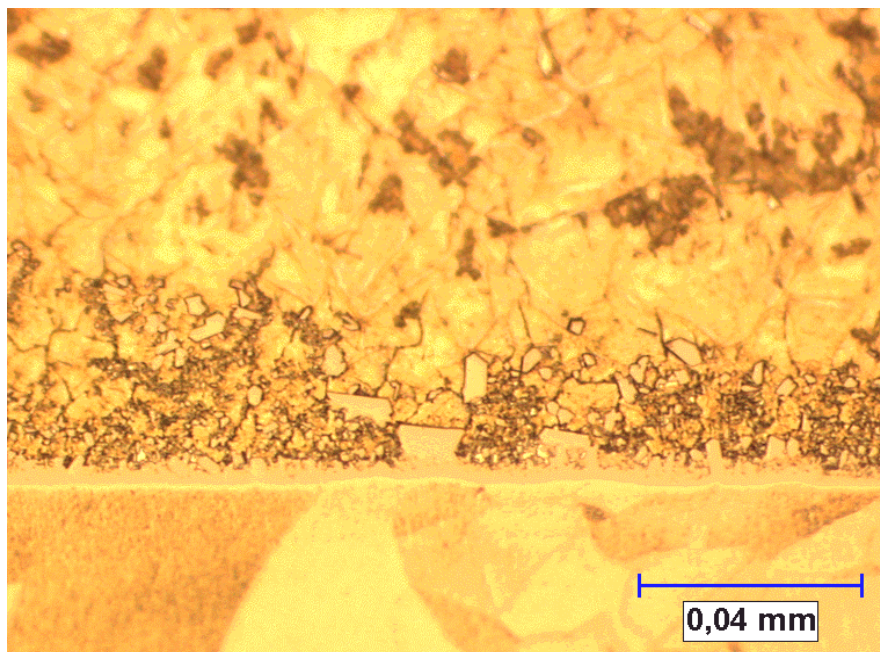


Sn/Ni couple
230°C; 30 min
E: mag. 200×
PL

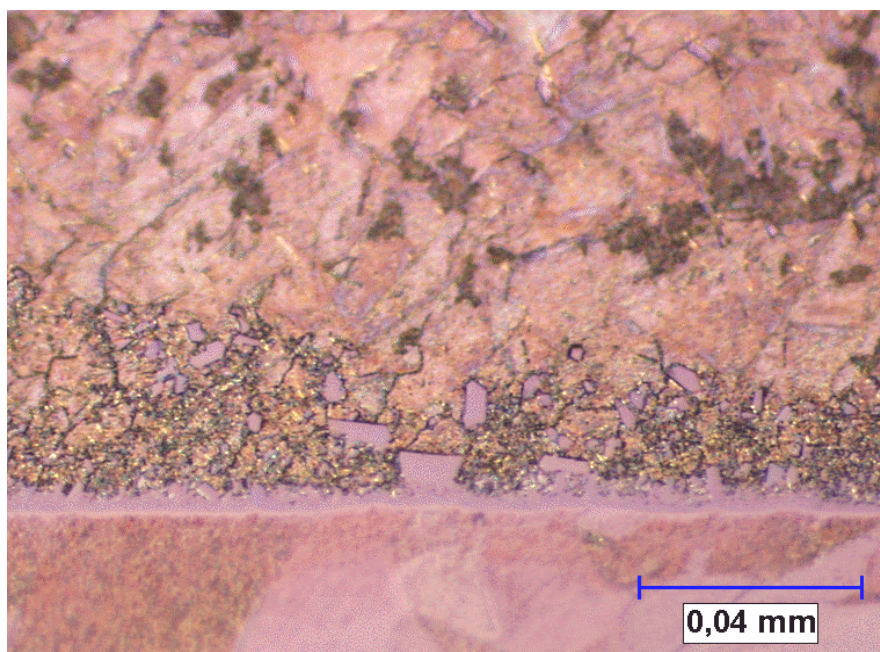


Sn/Ni couple
230°C; 30 min
E: mag. 200×
PC

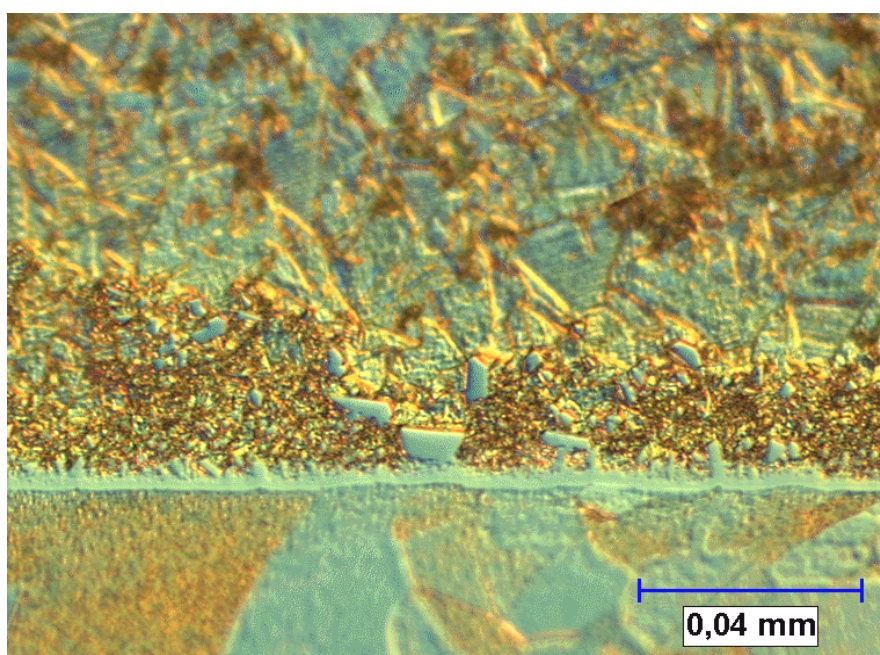




Sn/Ni couple
230°C; 30 min
E: mag. 500×
CL

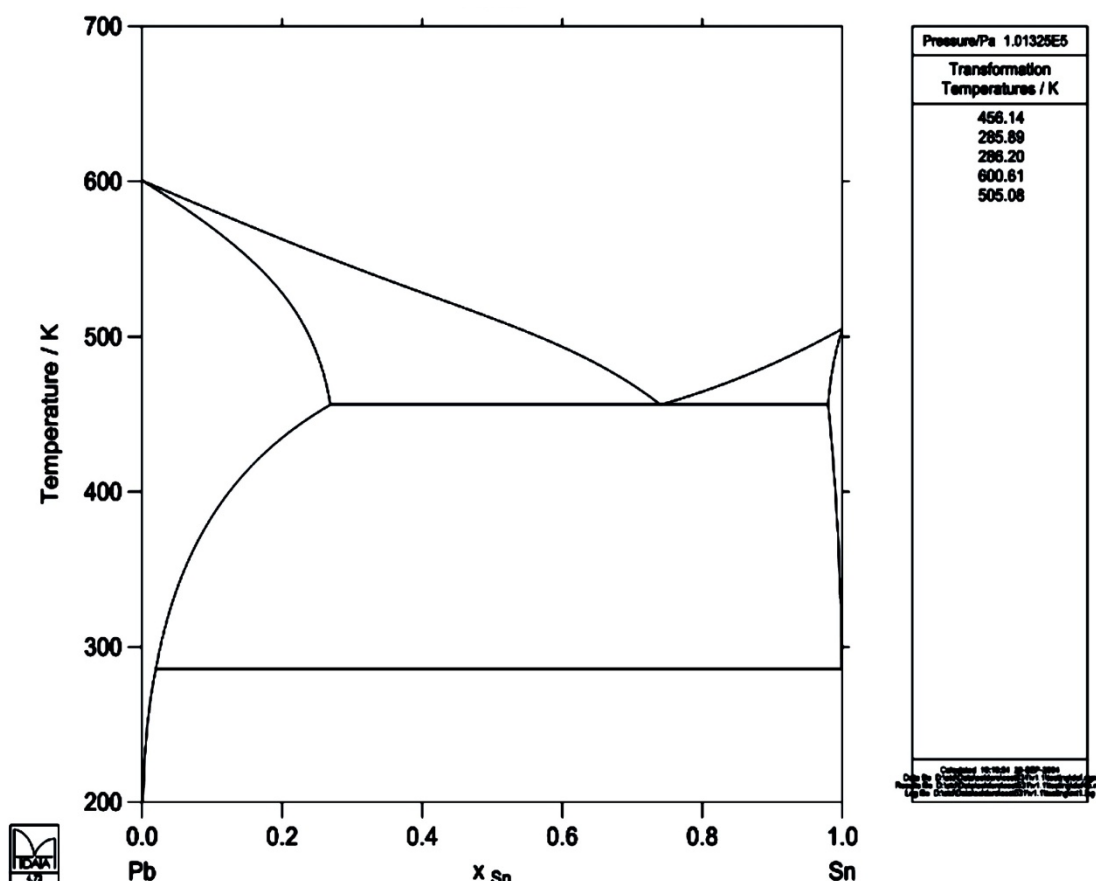


Sn/Ni couple
230°C; 30 min
E: mag. 500×
PL

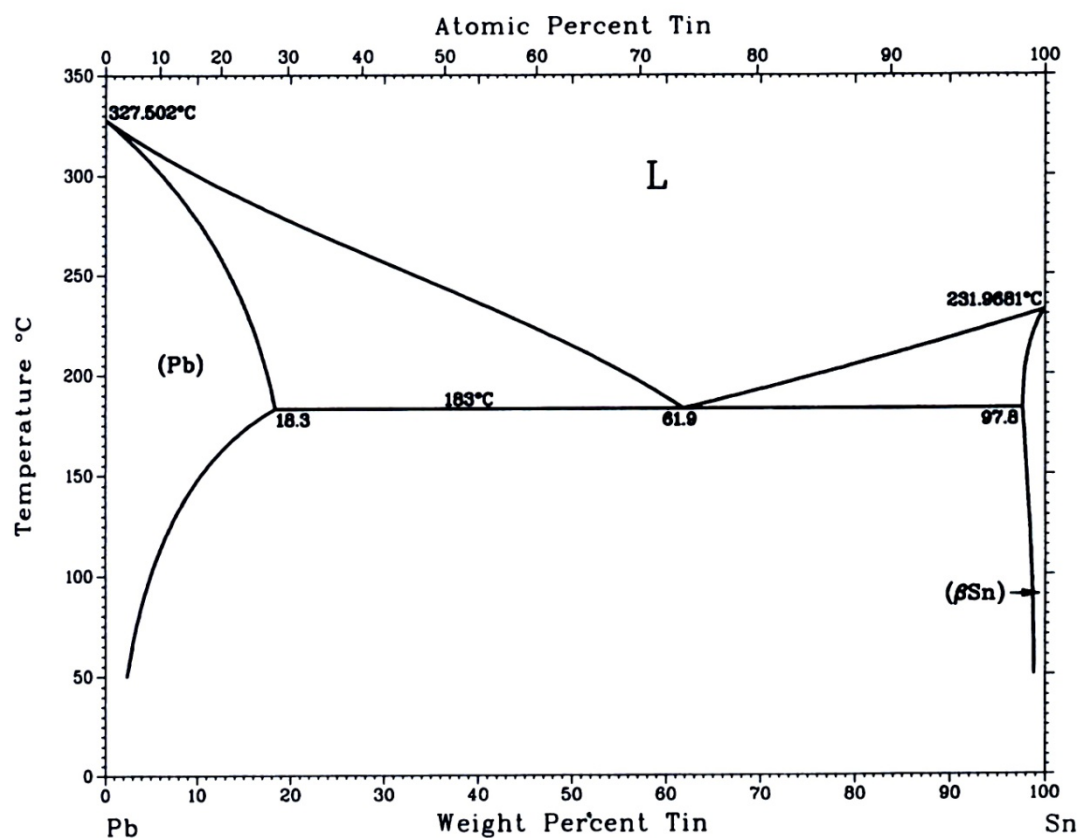


Sn/Ni couple
230°C; 30 min
E: mag. 500×
PC

Sn – Pb



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•335)

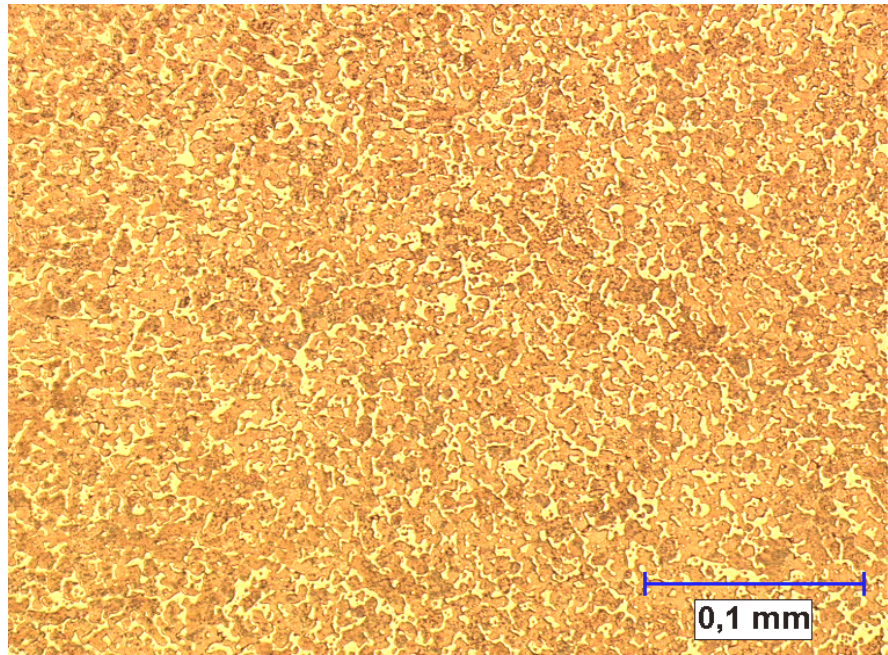
I. Karakaya and W.T. Thompson, 1988

Phase	Composition, wt% Sn	Pearson symbol	Space group
(Pb)	0 to 18.3	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
(β Sn)	97.8 to 100	<i>tI4</i>	<i>I4$_1$/<i>amd</i></i>
(α Sn)	100	<i>cF8</i>	<i>Fd$\bar{3}m$</i>
High-pressure phases			
ϵ (a)	52 to 74	<i>hP1</i>	<i>P6/<i>mmm</i></i>
ϵ' (b)	52	<i>hP2</i>	<i>P6$_3$/<i>mmc</i></i>

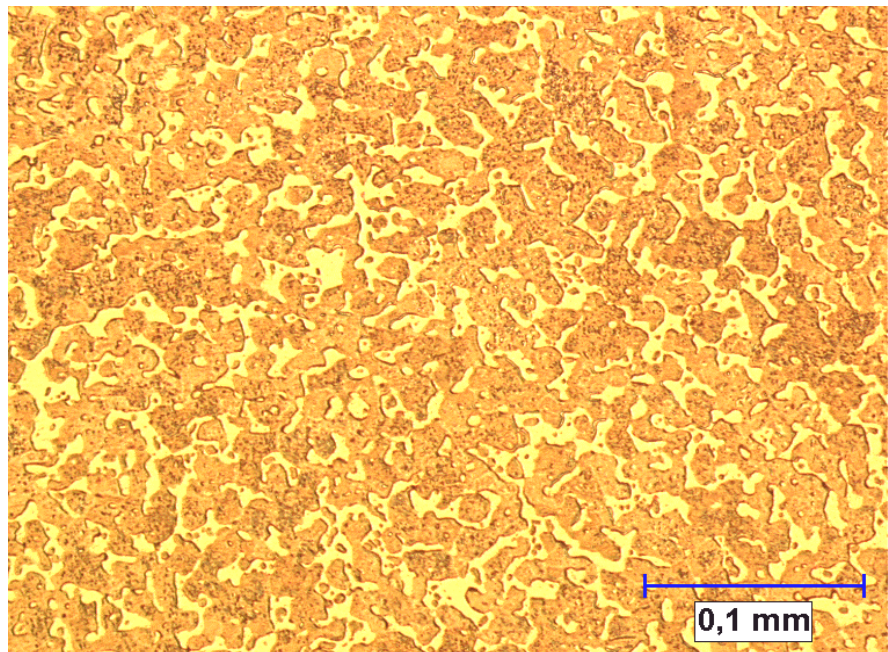
(a) From phase diagram calculated at 2500 MPa. (b) This phase was claimed for alloys at 350 °C and 5500 MPa.

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•335)

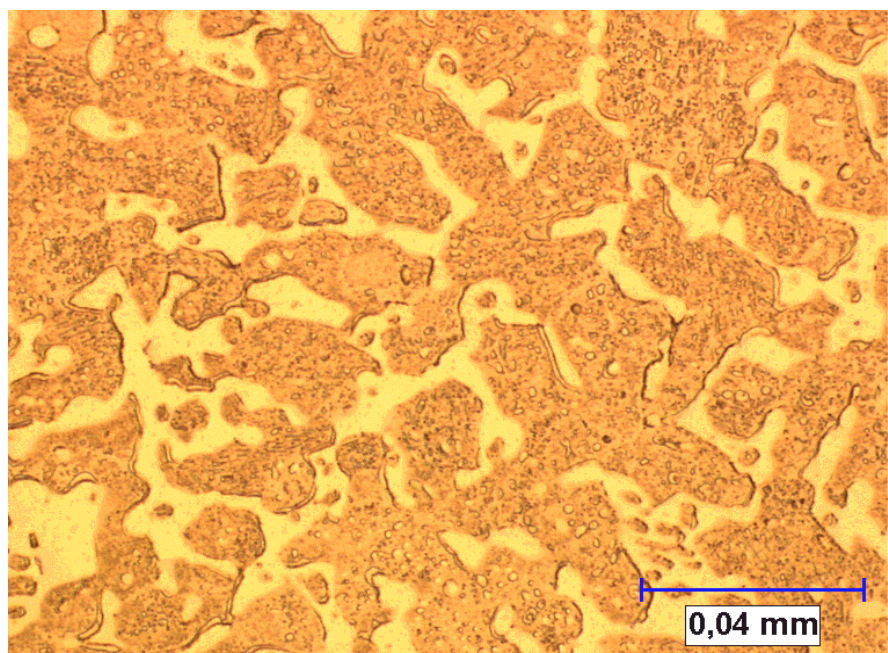
SnPb67 alloy (AC)
E: mag. 100×
CL

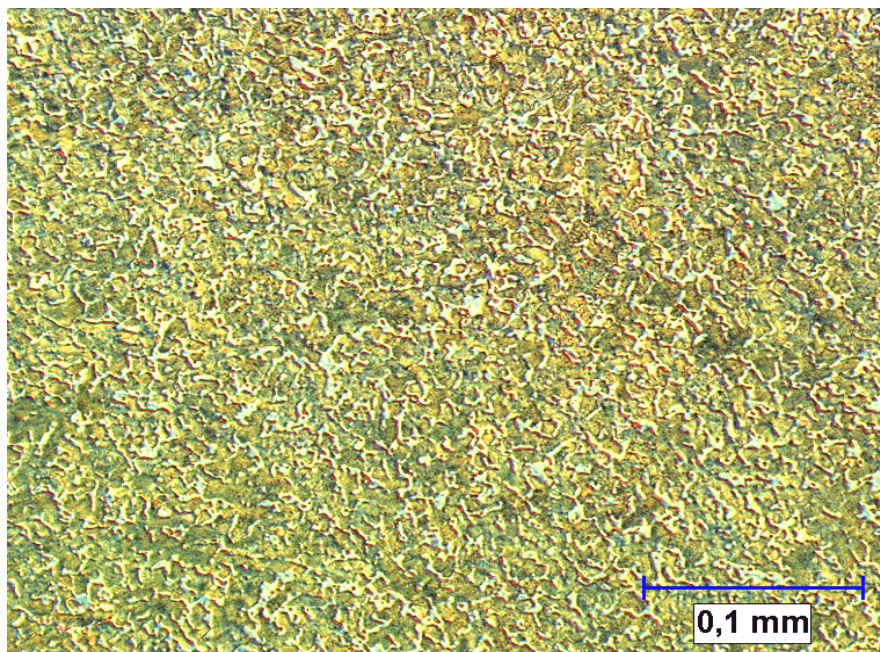
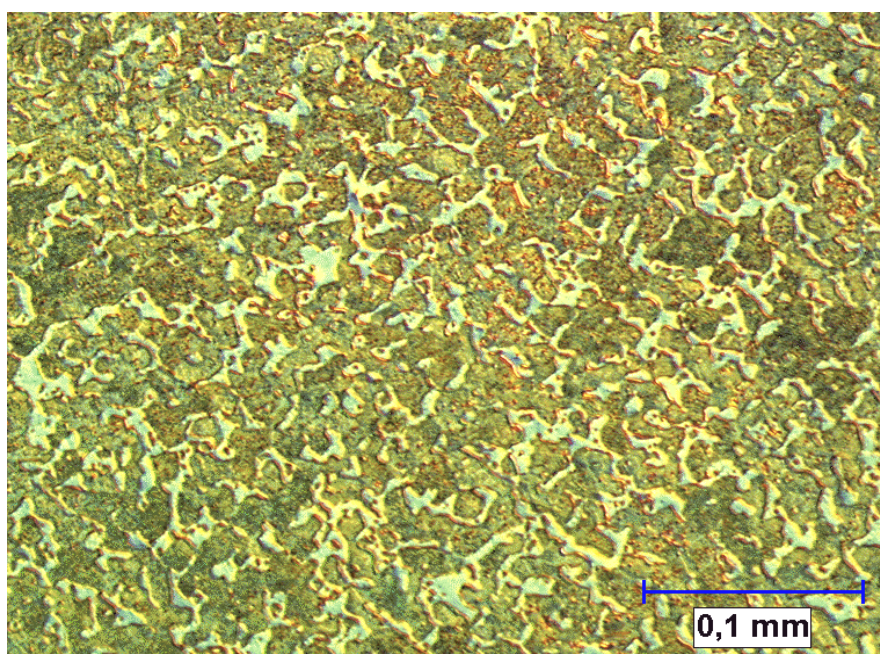
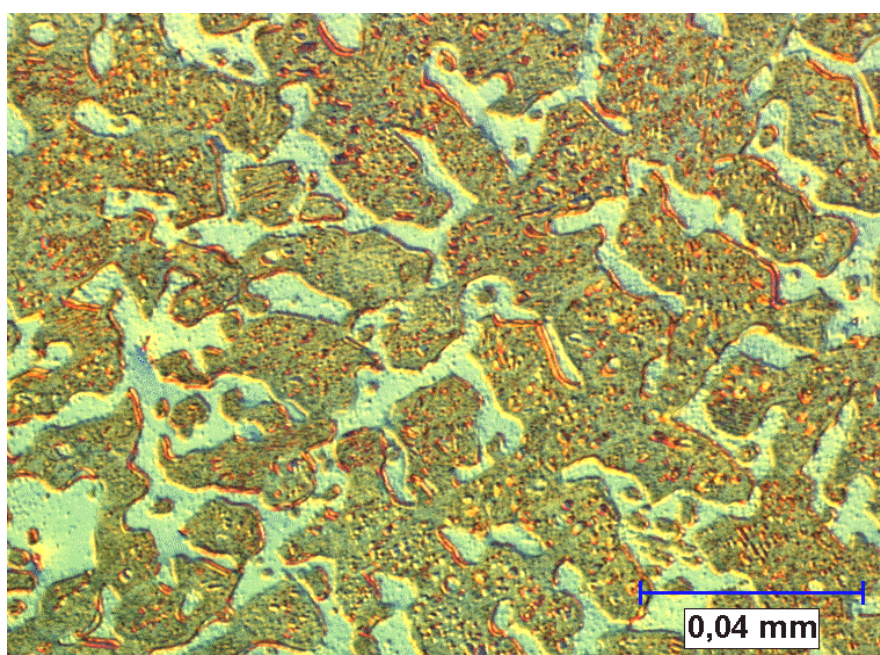


SnPb67 alloy (AC)
E: mag. 200×
CL

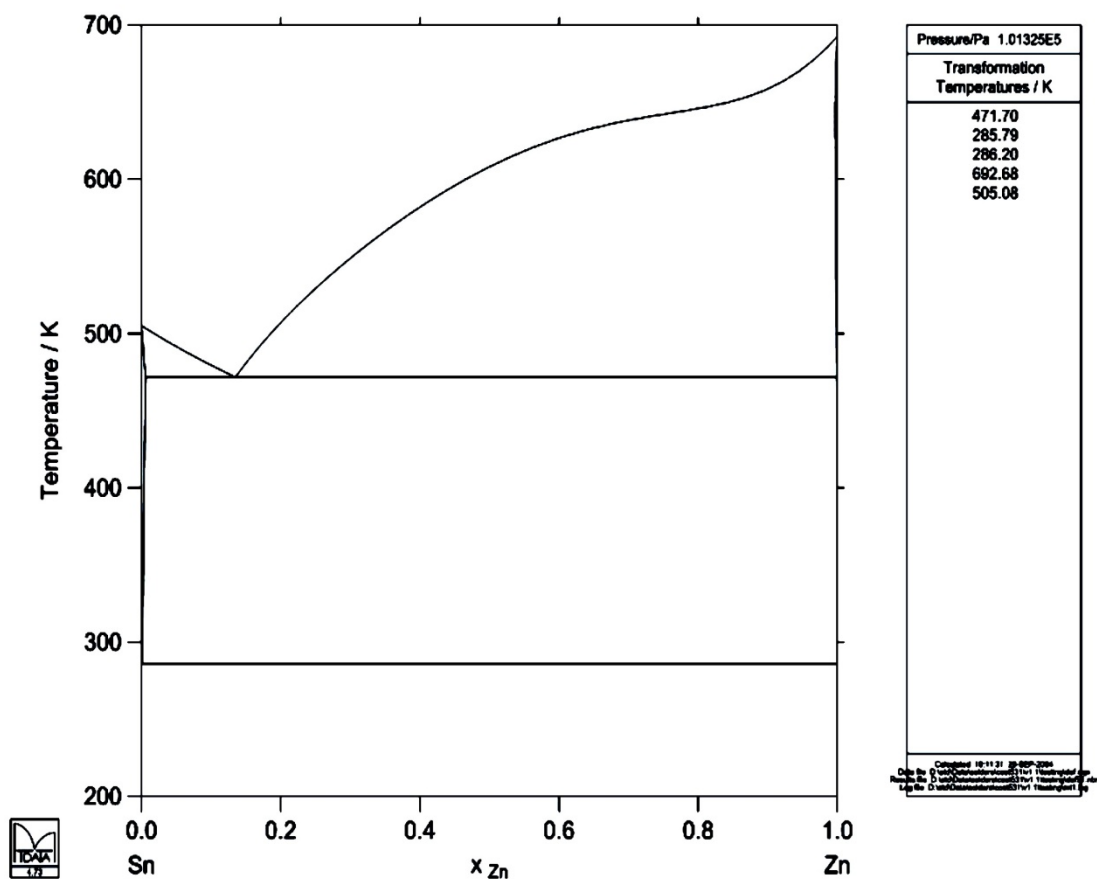


SnPb67 alloy (AC)
E: mag. 500×
CL

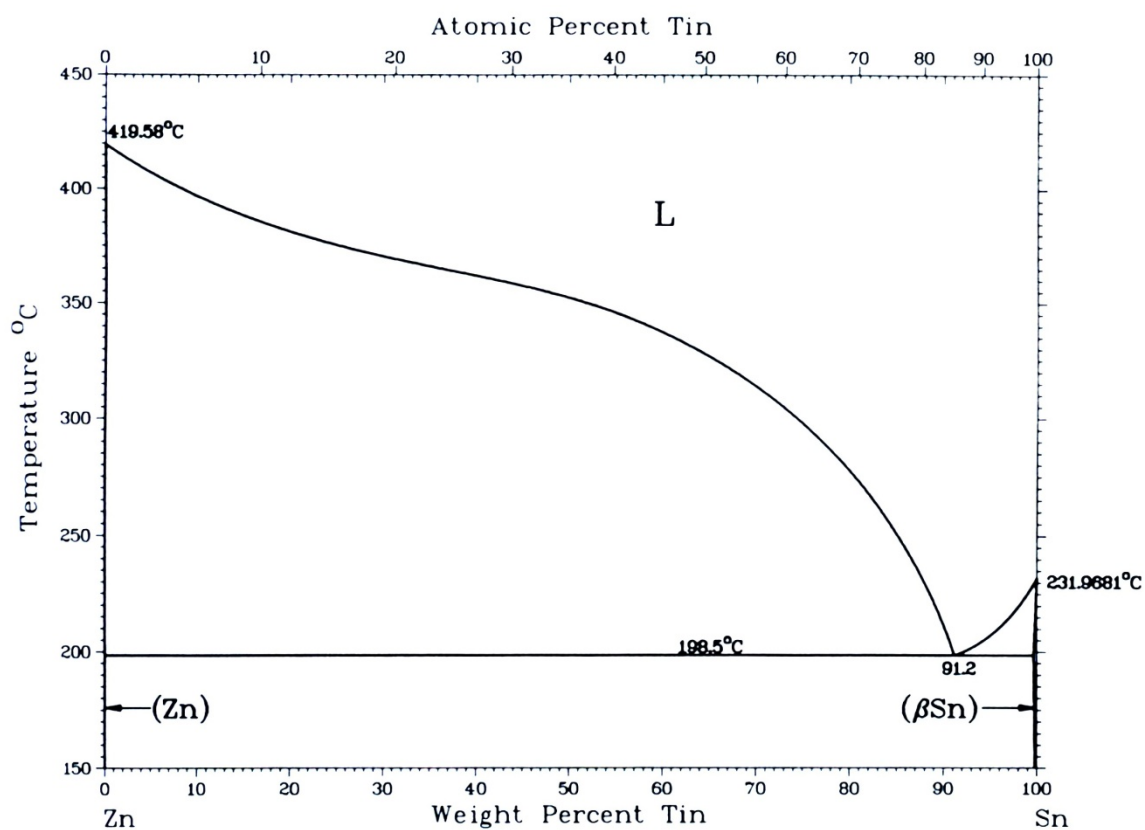


**SnPb67 alloy (AC)****E: mag. 100×****PC****SnPb67 alloy (AC)****E: mag. 200×****PC****SnPb67 alloy (AC)****E: mag. 500×****PC**

Sn – Zn



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



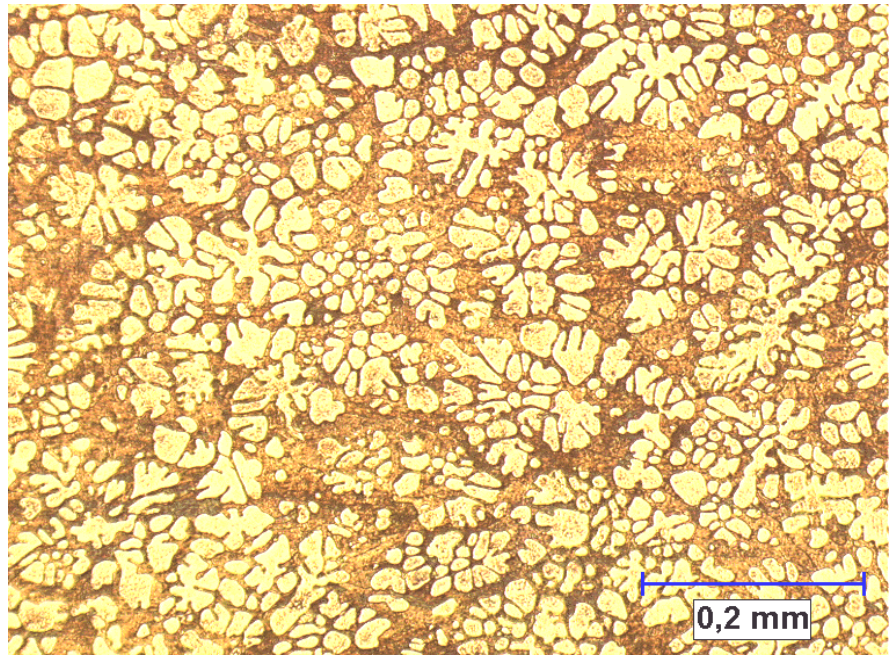
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•372)

Z. Moser, J. Dutkiewicz, W. Gasior, and J. Salawa, 1985

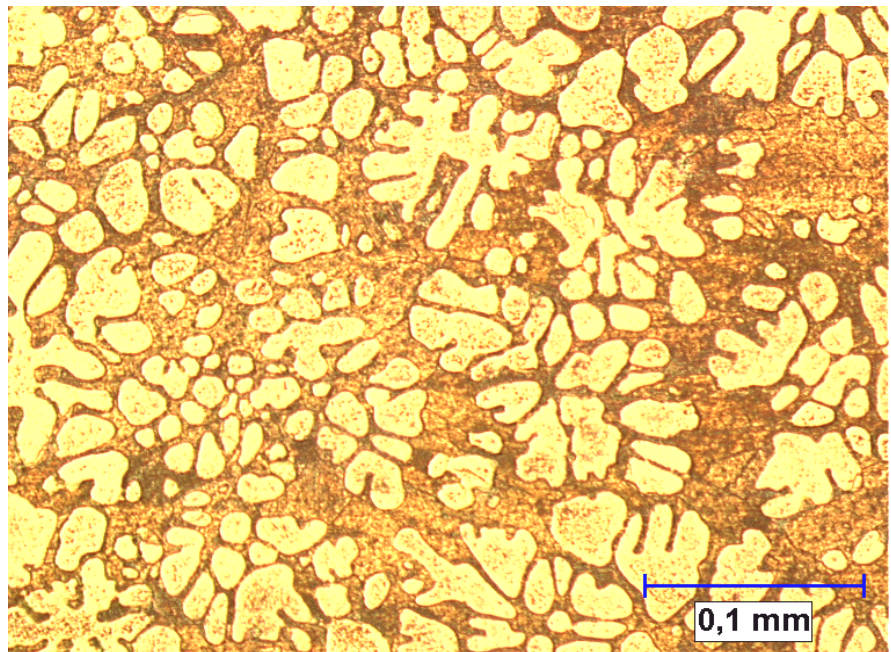
Phase	Composition, wt% Sn	Pearson symbol	Space group
(Zn)	0	<i>hP2</i>	<i>P6₃/mmc</i>
(βSn)	~100	<i>tI4</i>	<i>I4₁/amd</i>

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•372)

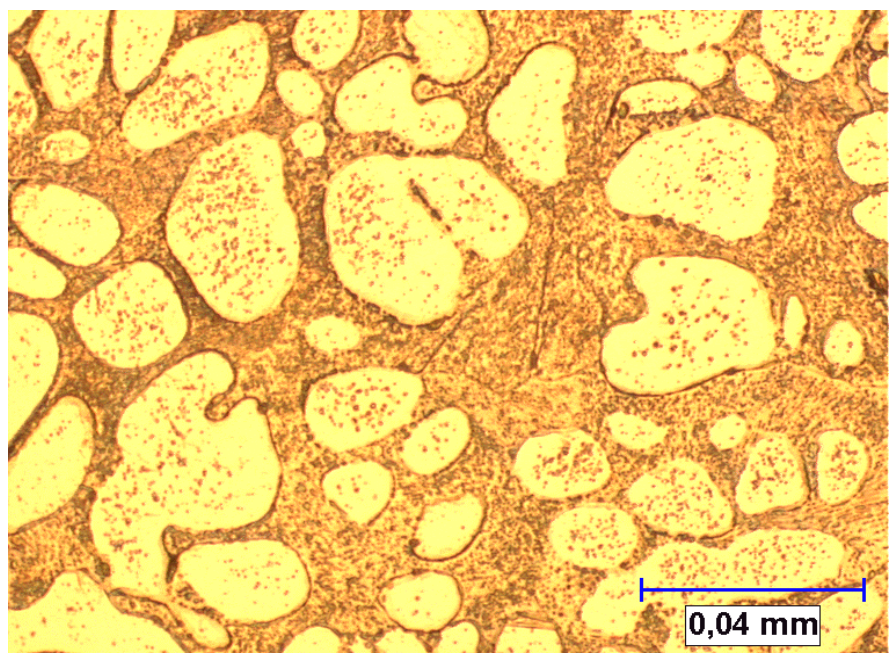
SnZn4.5 alloy (AC)
E: mag. 100×
CL

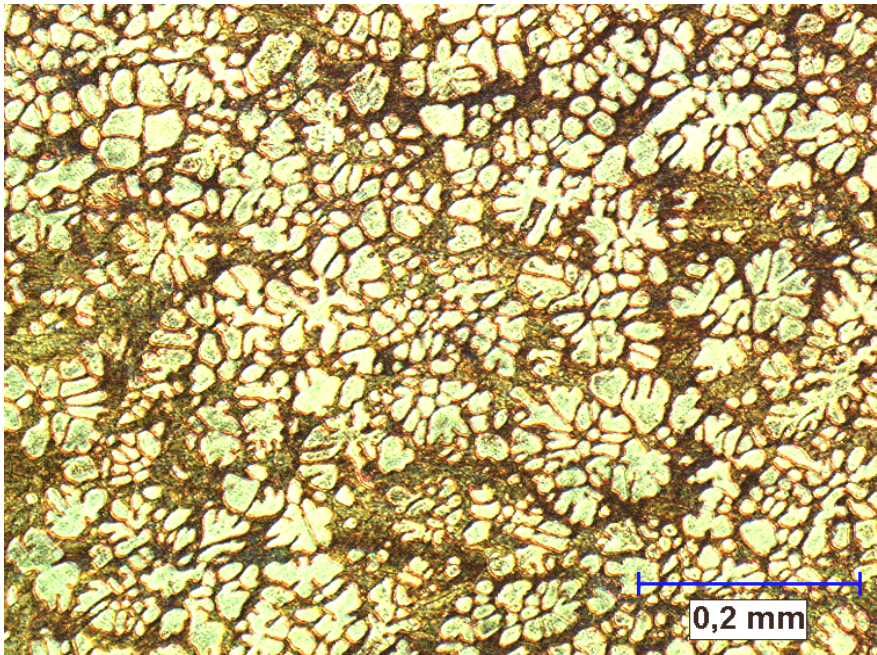


SnZn4.5 alloy (AC)
E: mag. 200×
CL

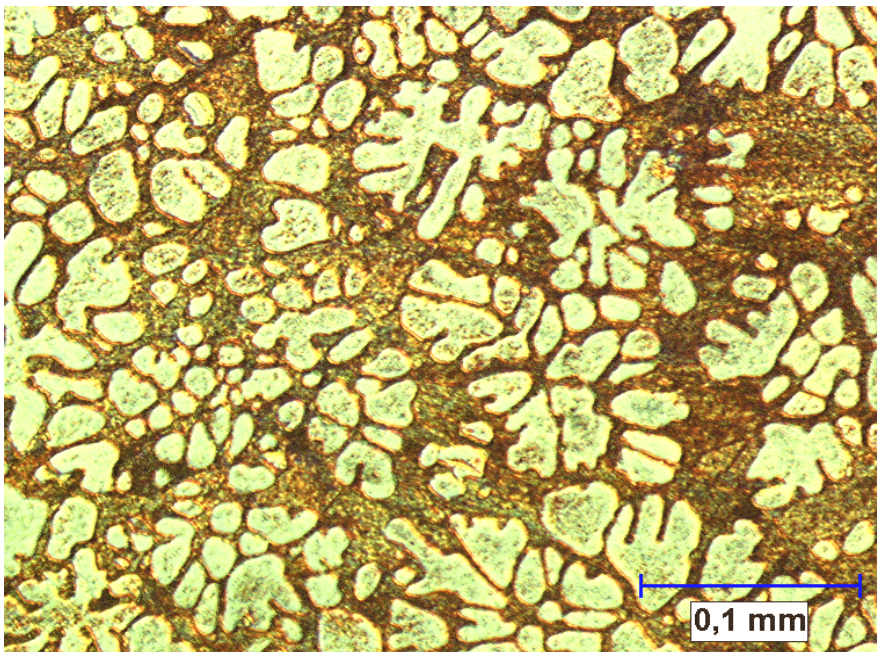


SnZn4.5 alloy (AC)
E: mag. 500×
CL

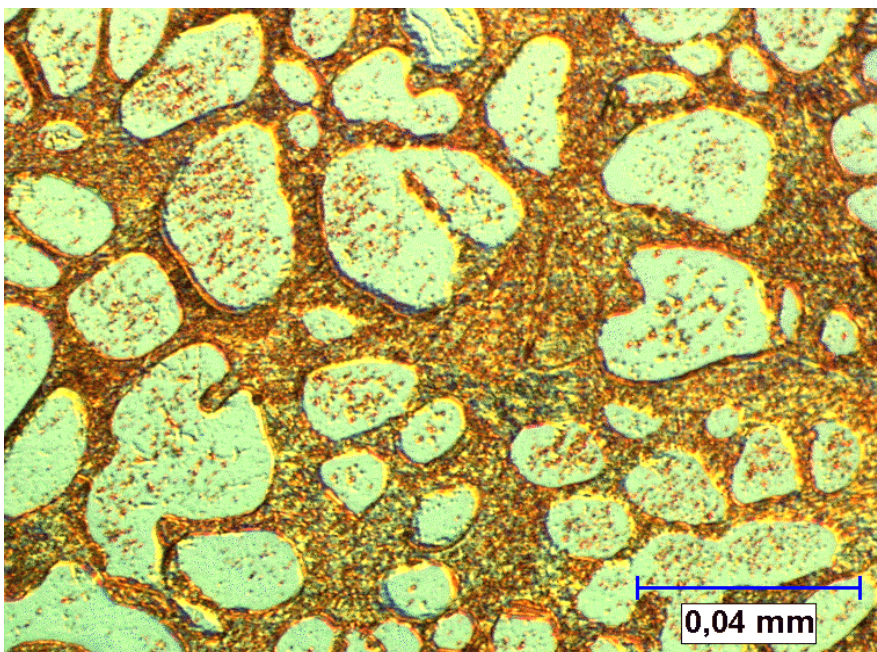




SnZn4.5 alloy
E: mag. 100×
PC

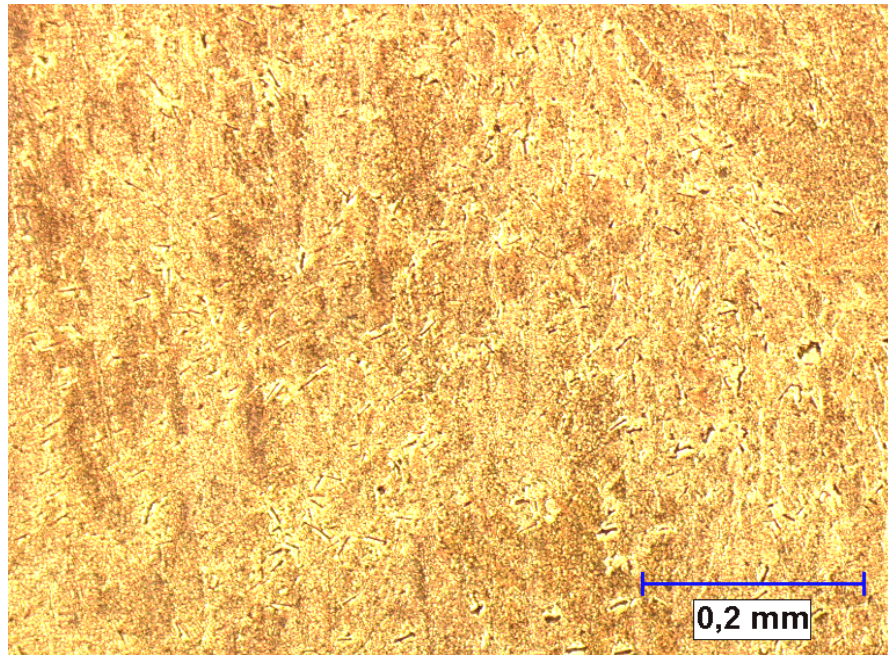


SnZn4.5 alloy
E: mag. 200×
PC

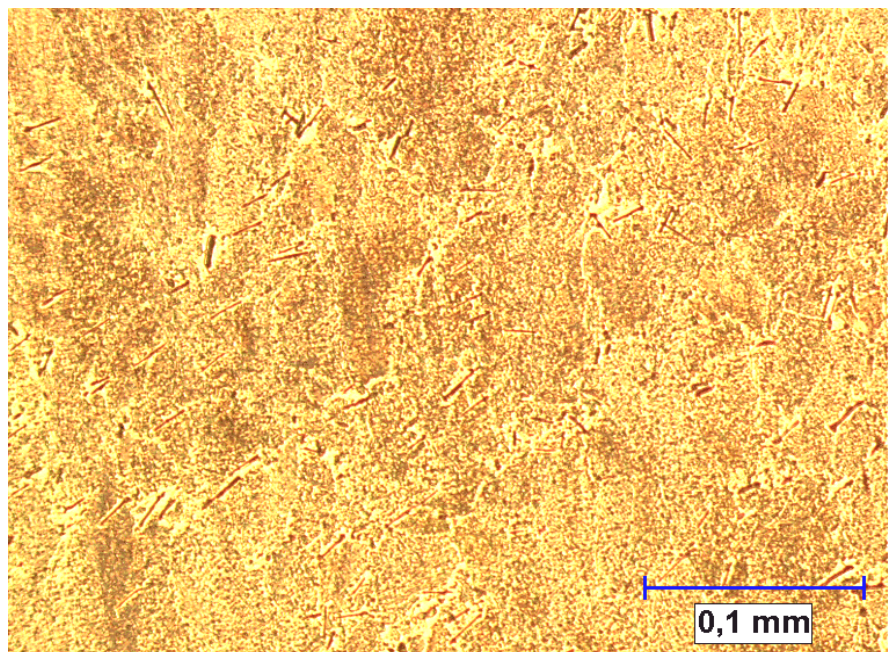


SnZn4.5 alloy
E: mag. 500×
PC

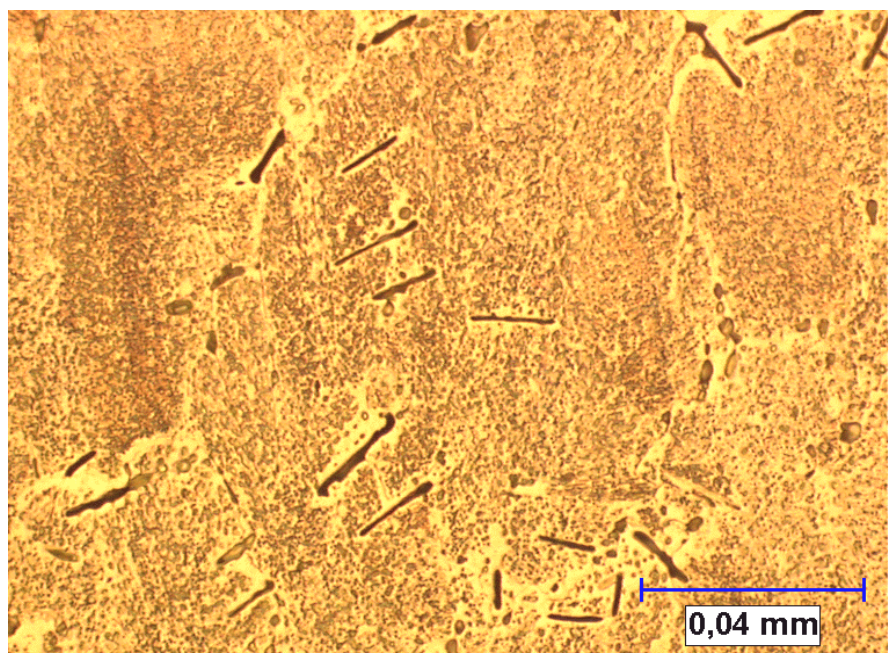
SnZn9 alloy (AC)
E: mag. 100×
CL

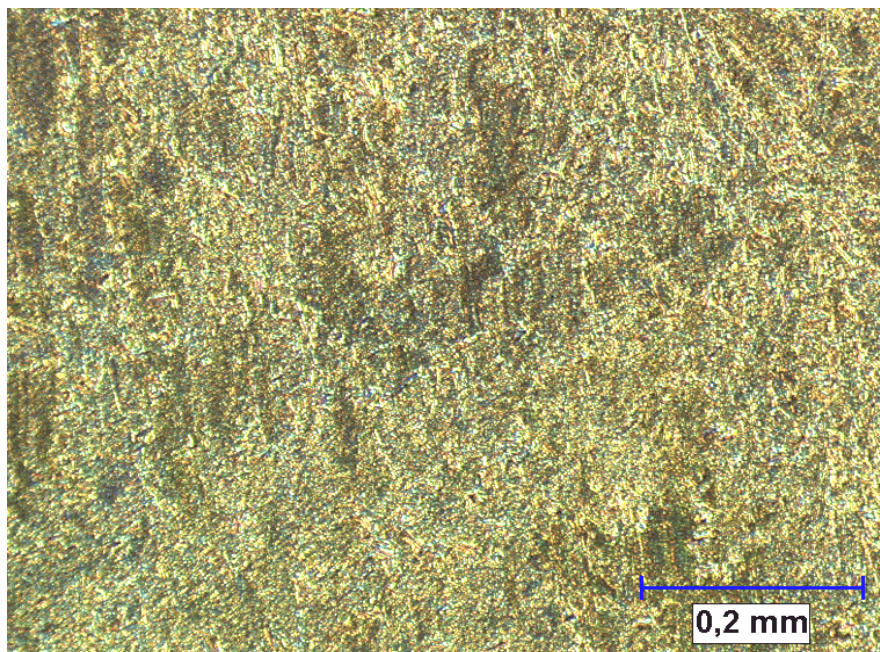
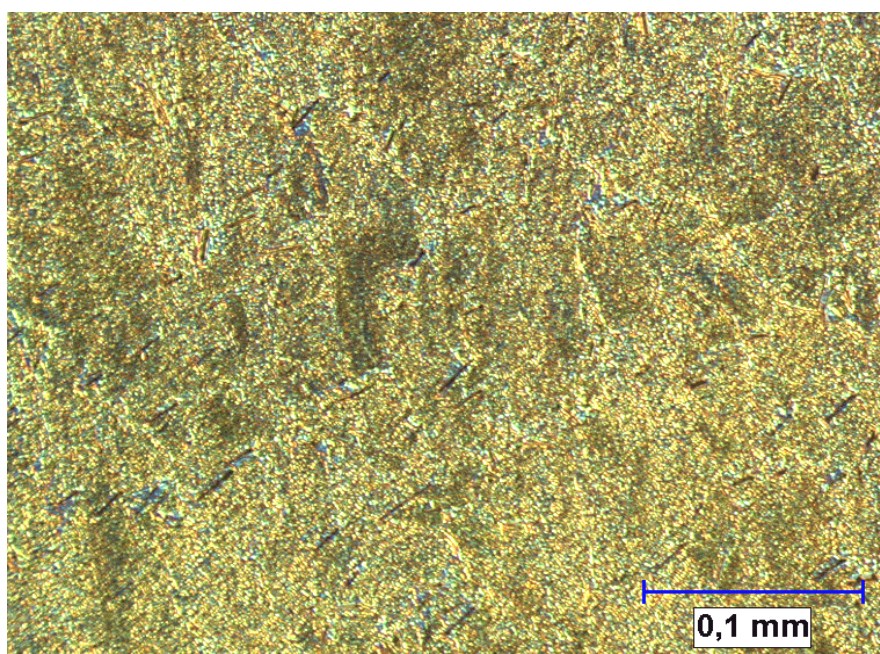
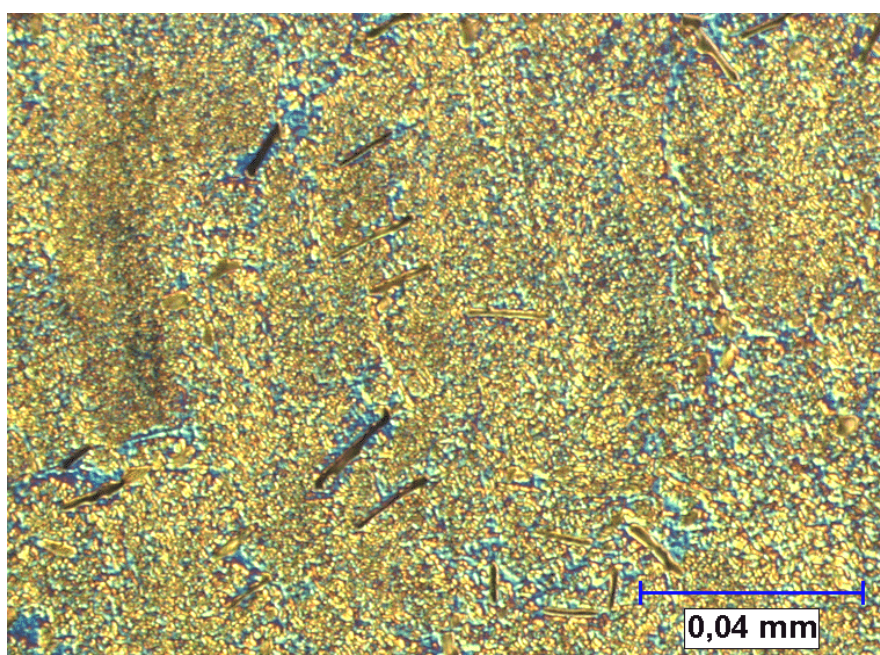


SnZn9 alloy (AC)
E: mag. 200×
CL

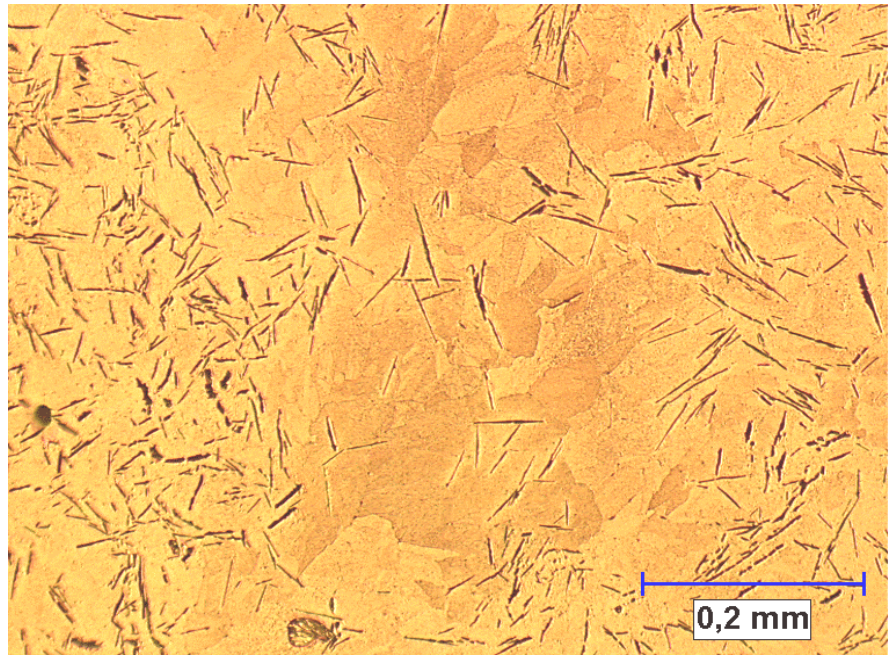


SnZn9 alloy (AC)
E: mag. 500×
CL

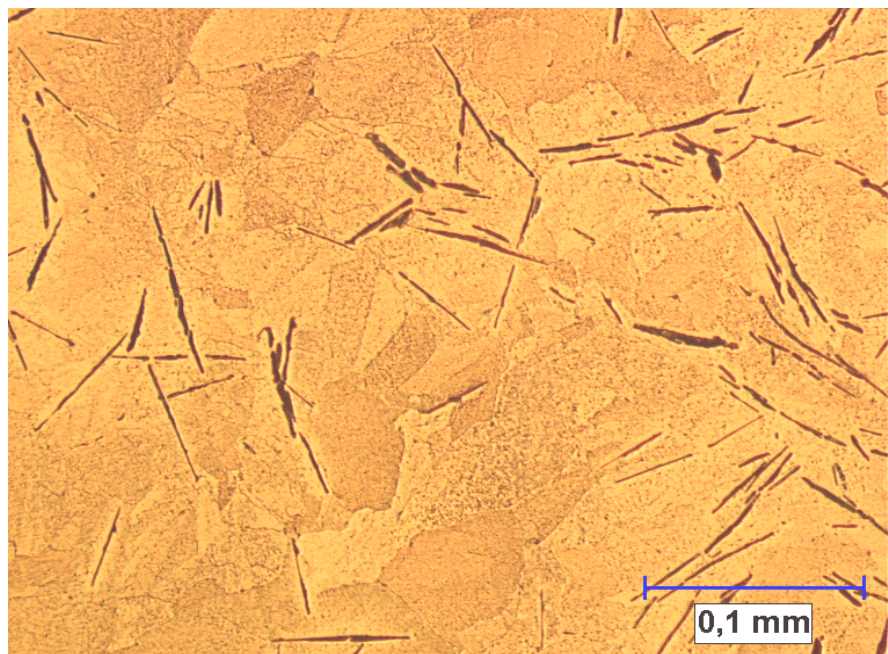


**SnZn9 alloy (AC)****E: mag. 100×****PC****SnZn9 alloy (AC)****E: mag. 200×****PC****SnZn9 alloy (AC)****E: mag. 500×****PC**

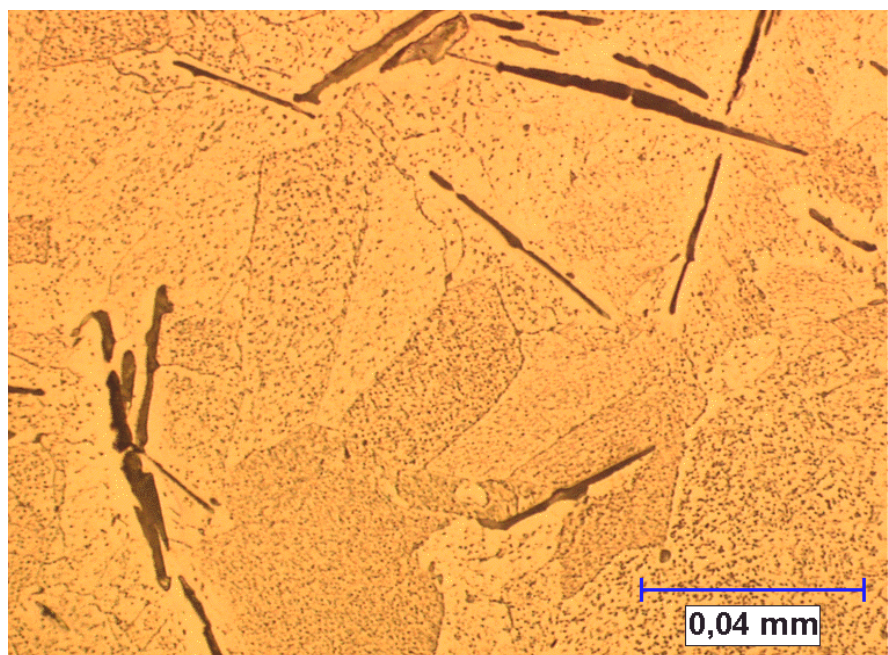
SnZn13.5 alloy
E: mag. 100×
CL

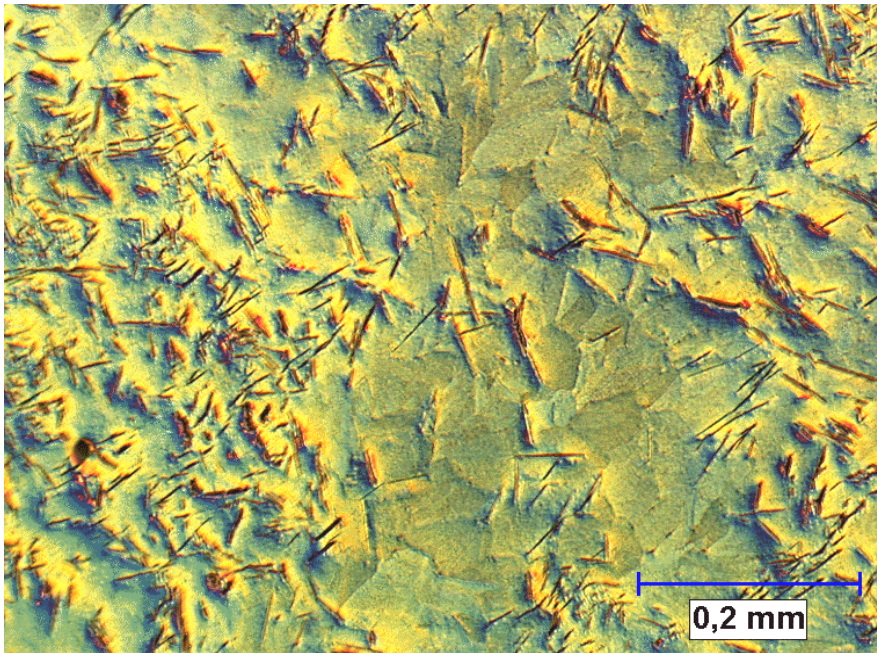


SnZn13.5 alloy
E: mag. 200×
CL

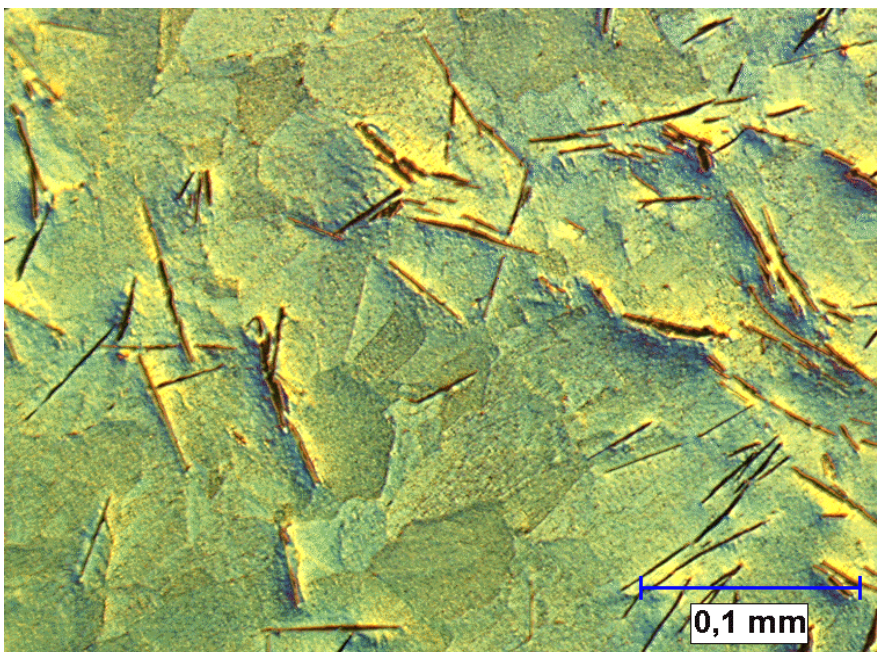


SnZn13.5 alloy
E: mag. 500×
CL

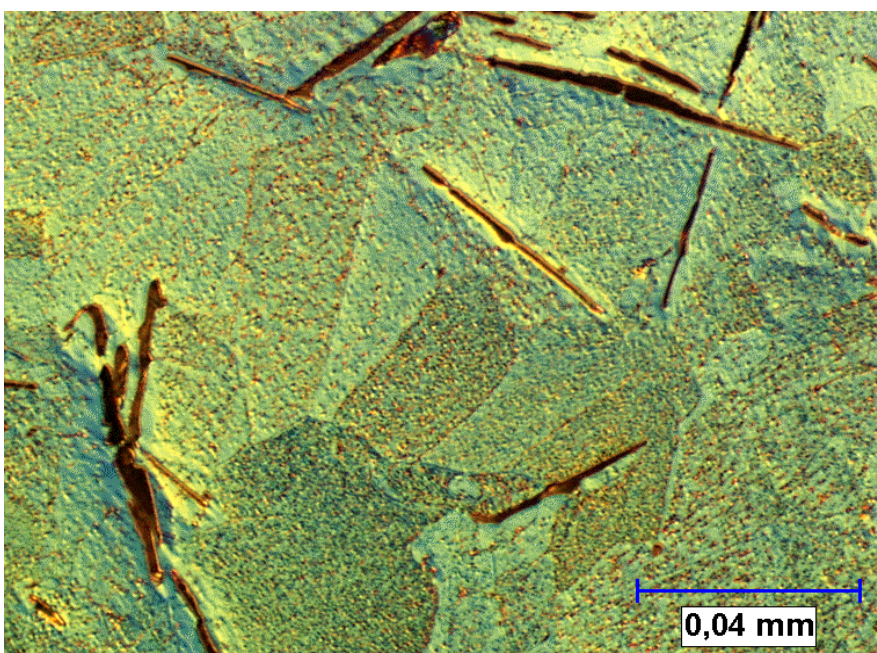




SnZn13.5 alloy
E: mag. 100×
PC

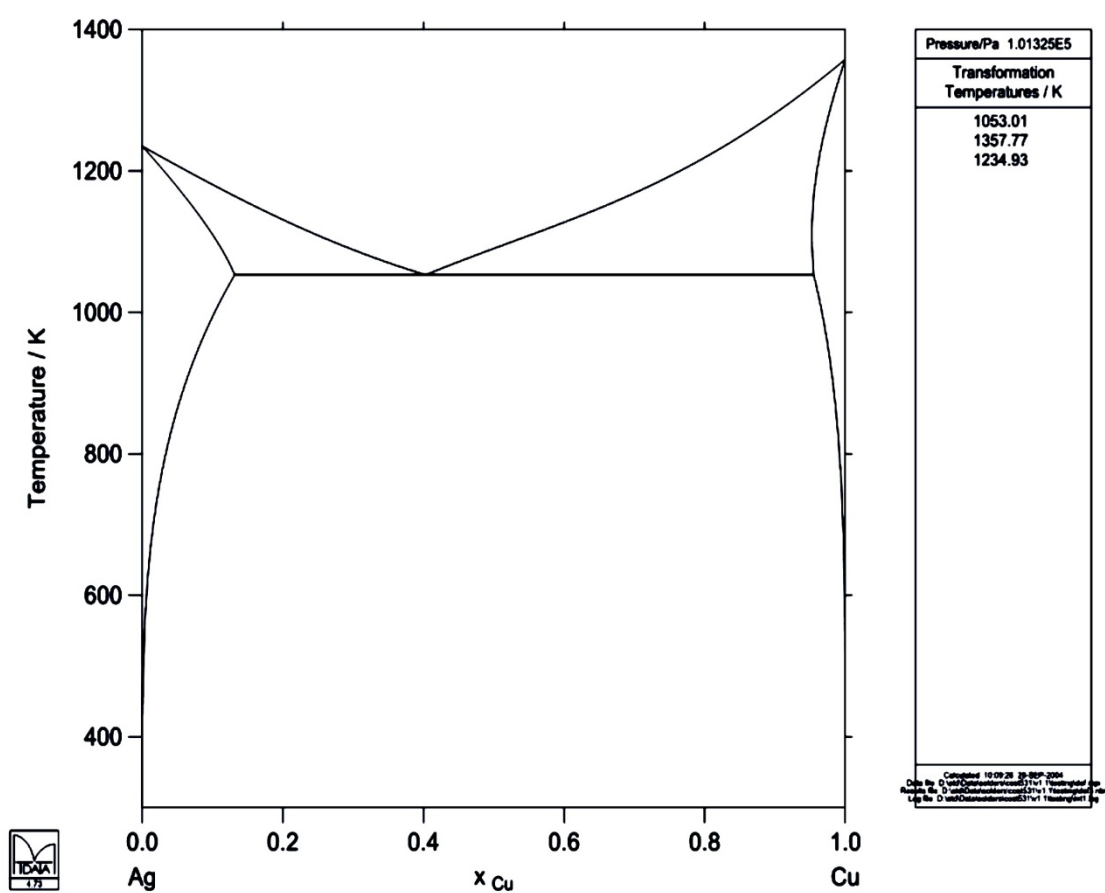


SnZn13.5 alloy
E: mag. 200×
PC

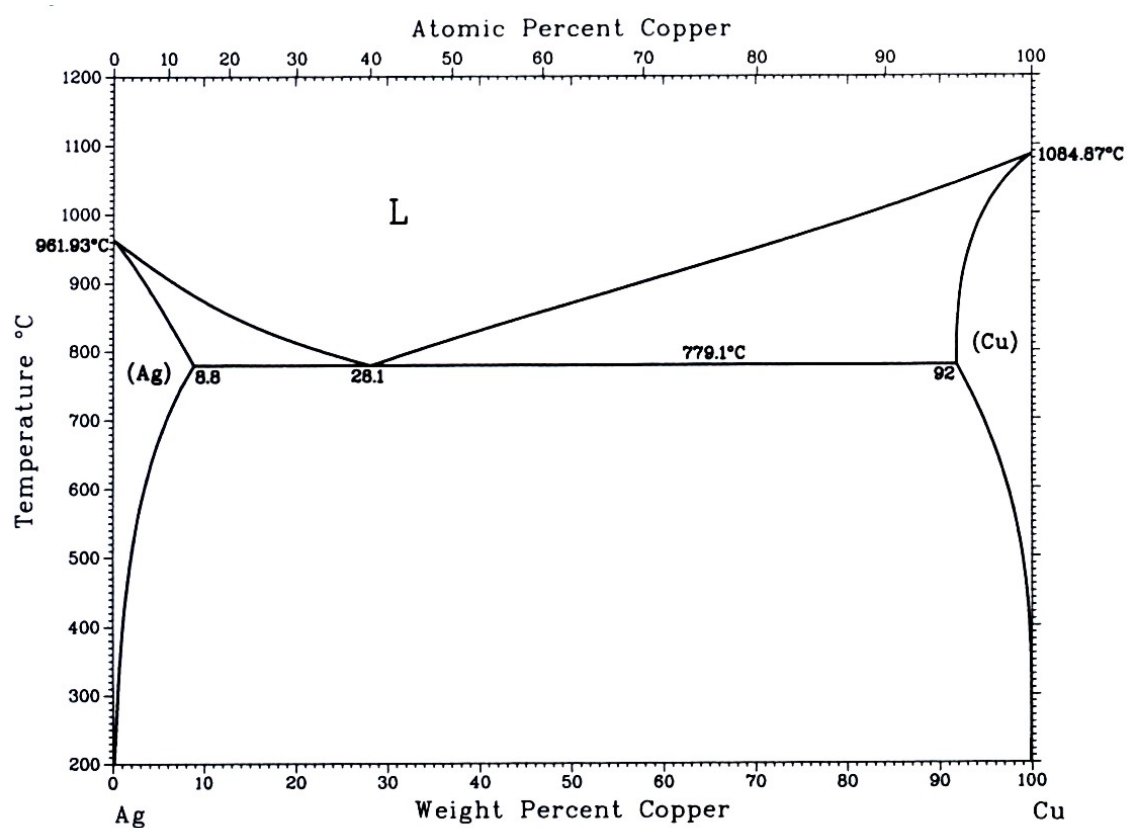


SnZn13.5 alloy
E: mag. 500×
PC

Ag – Cu



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•28)

P.R. Subramanian and J.H. Perepezko, unpublished

Phase	Composition, wt% Cu	Pearson symbol	Space group
(Ag)	0 to 8.8	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
(Cu)	92.0 to 100	<i>cF4</i>	<i>Fm$\bar{3}m$</i>

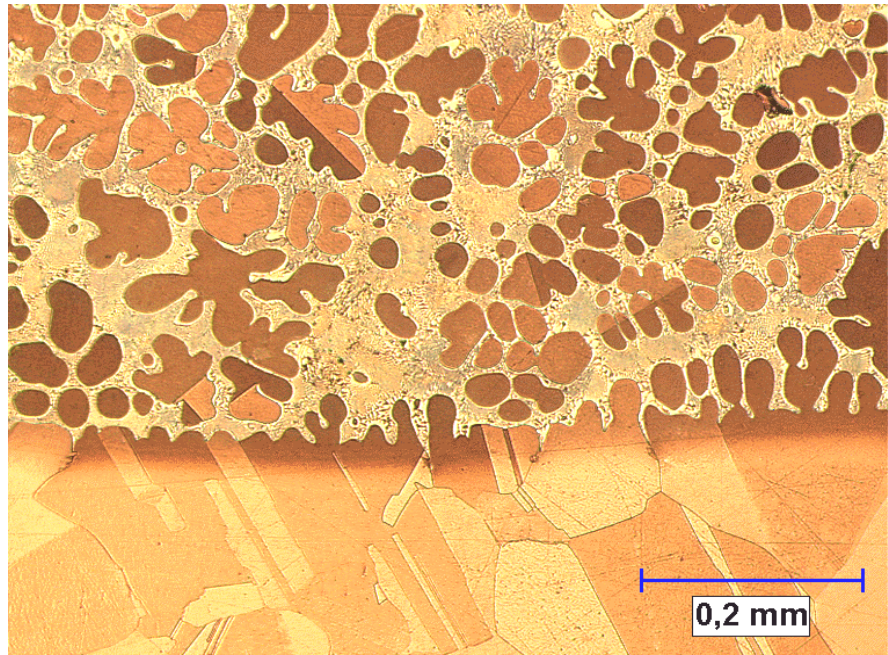
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•28)

Properties of solder/substrate couples

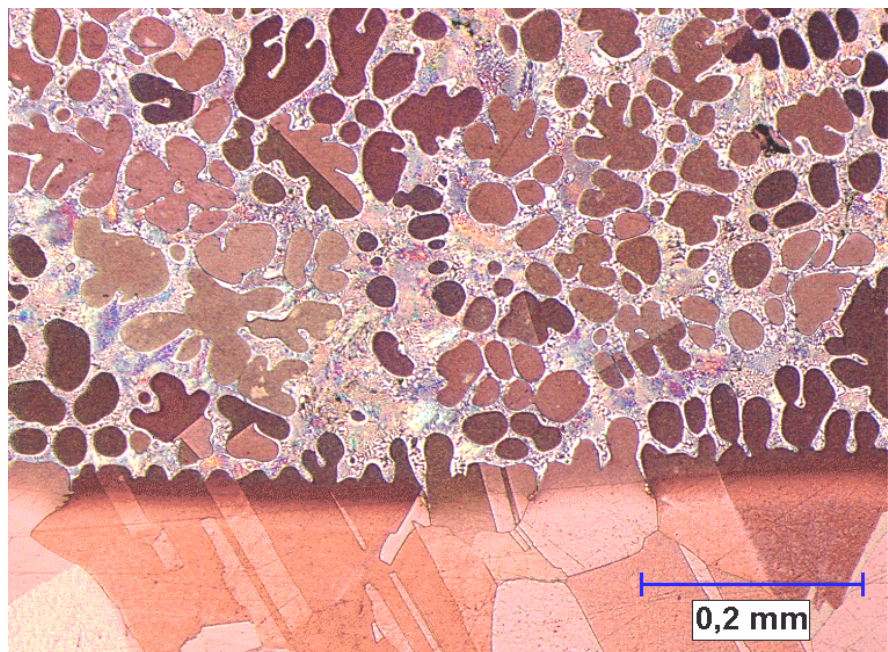
Couple	Conditions	θ , deg	τ , MPa
Ag / Cu	230°C, 5 min, flux	$\sim 0^\circ$	*
Ag / Cu	230°C, 30 min, flux	$\sim 0^\circ$	*

* impossible to measure due to a low contact angle

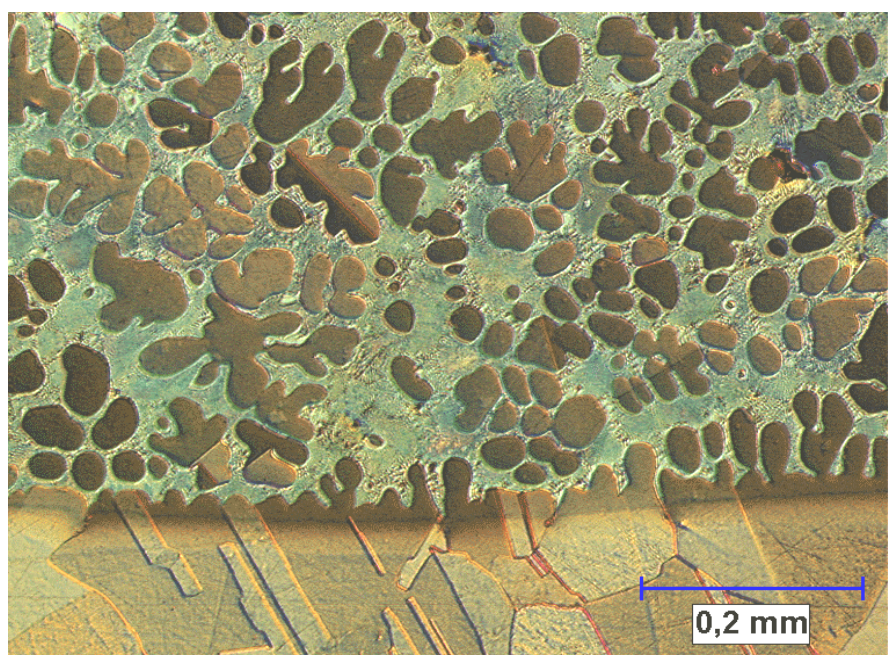
Ag/Cu couple (AC)
970°C; 30 min
E: mag. 100×
CL

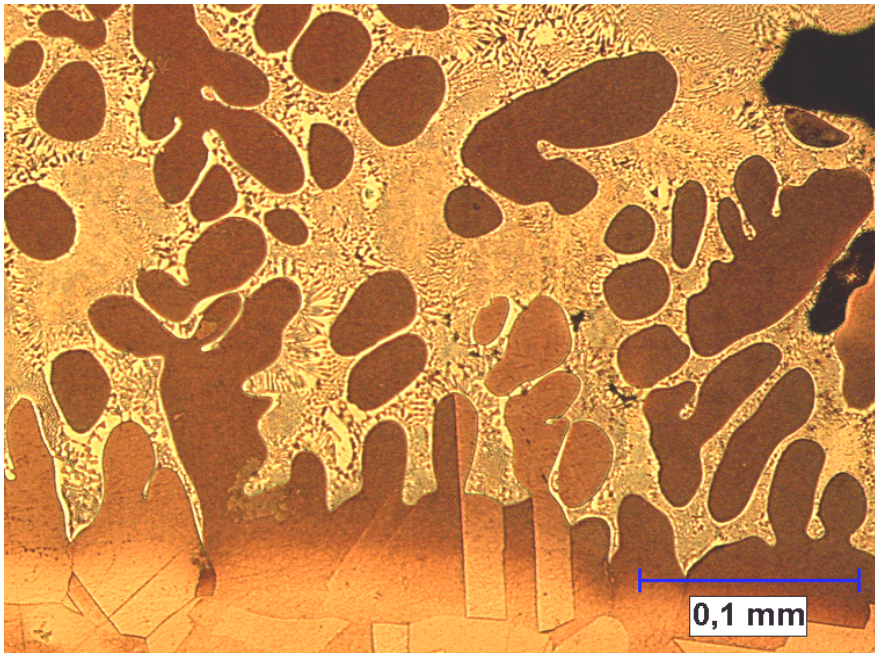


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 100×
PL

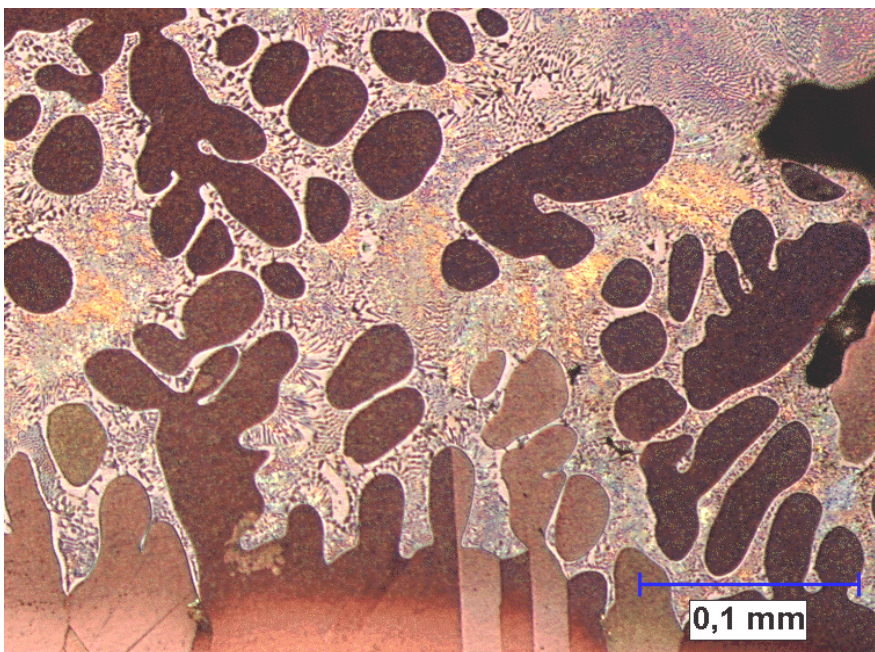


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 100×
PC

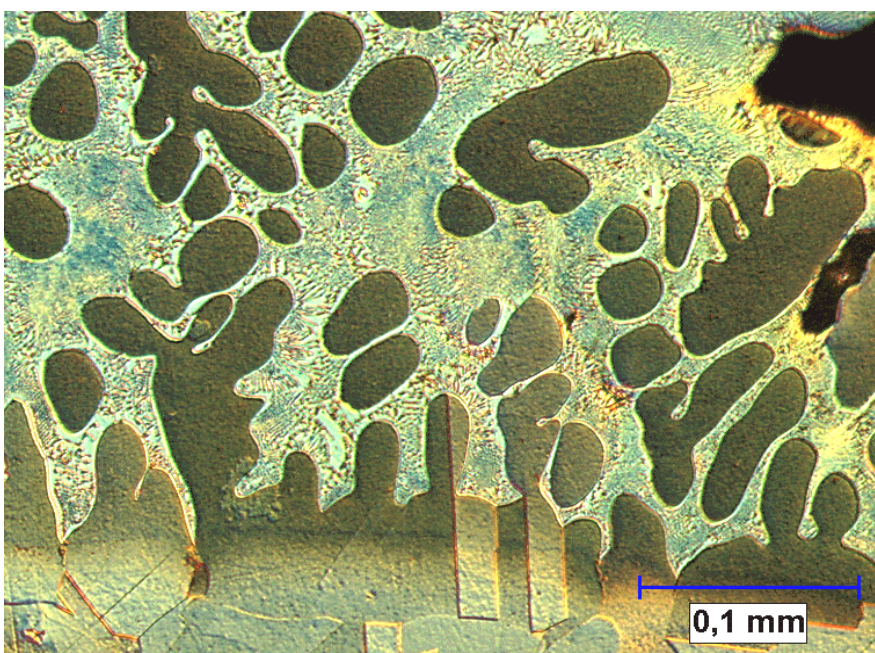




Ag/Cu couple (AC)
970°C; 30 min
E: mag. 200×
CL

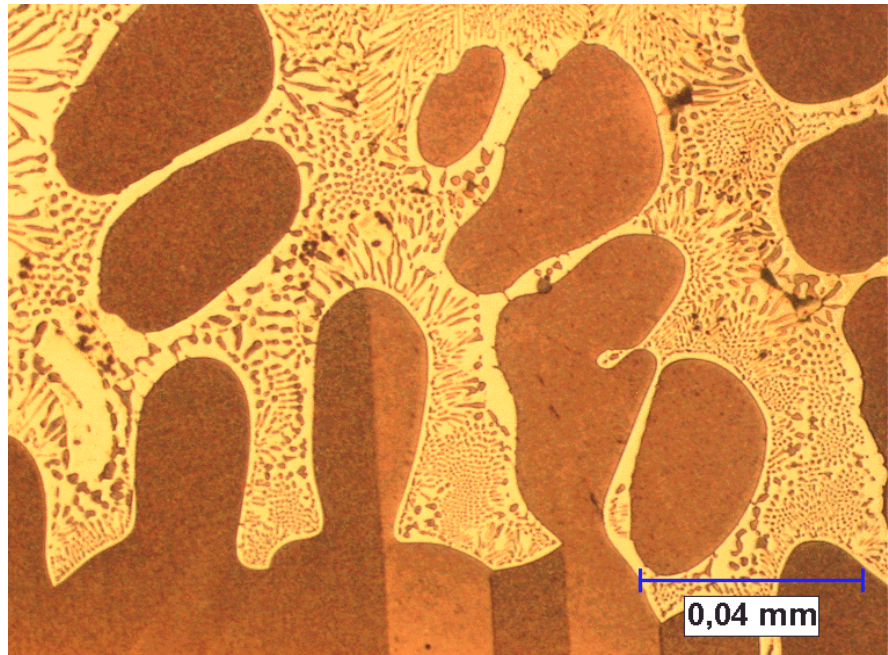


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 200×
PL

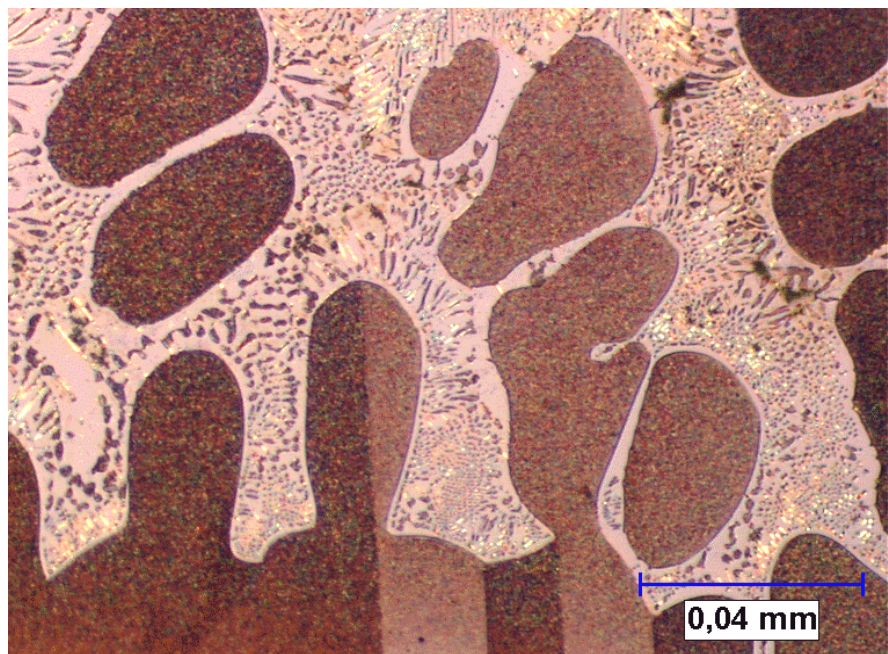


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 200×
PC

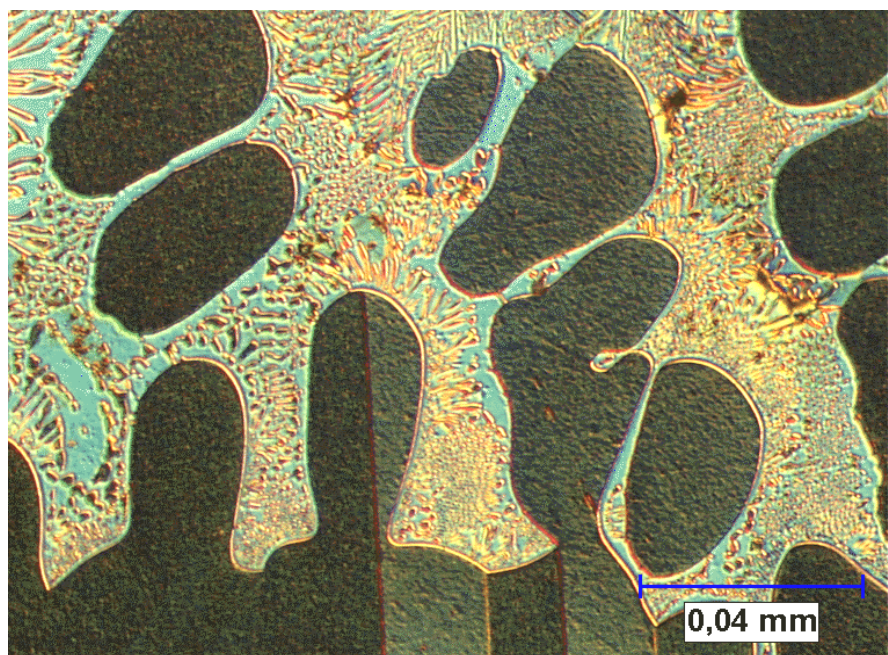
Ag/Cu couple (AC)
970°C; 30 min
E: mag. 500×
CL

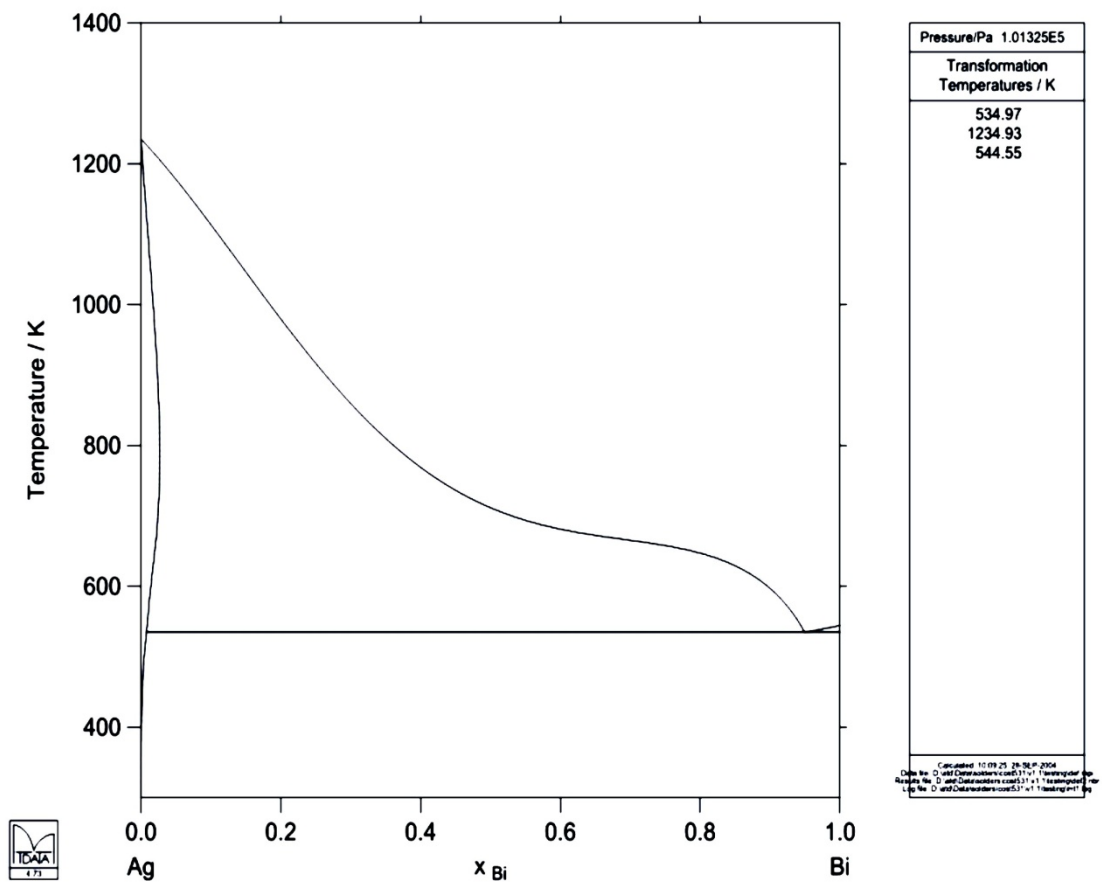


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 500×
PL

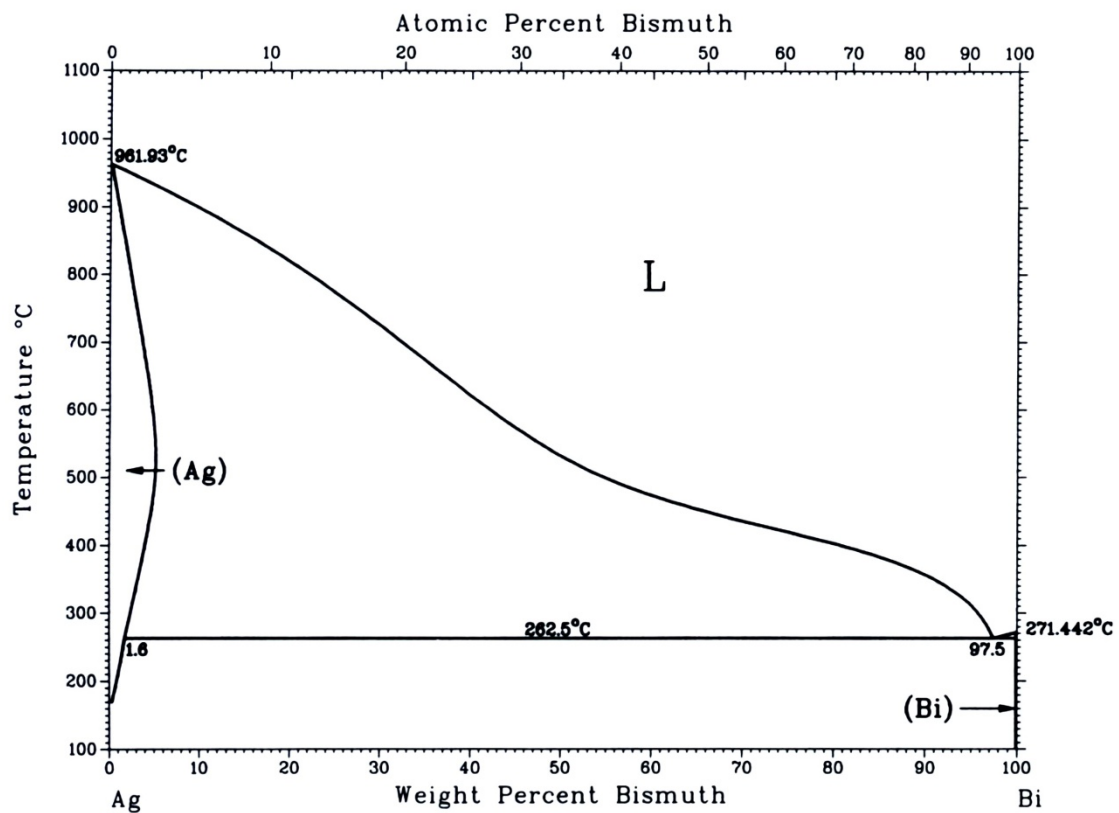


Ag/Cu couple (AC)
970°C; 30 min
E: mag. 500×
PC



Bi – Ag

Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
 by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•26)

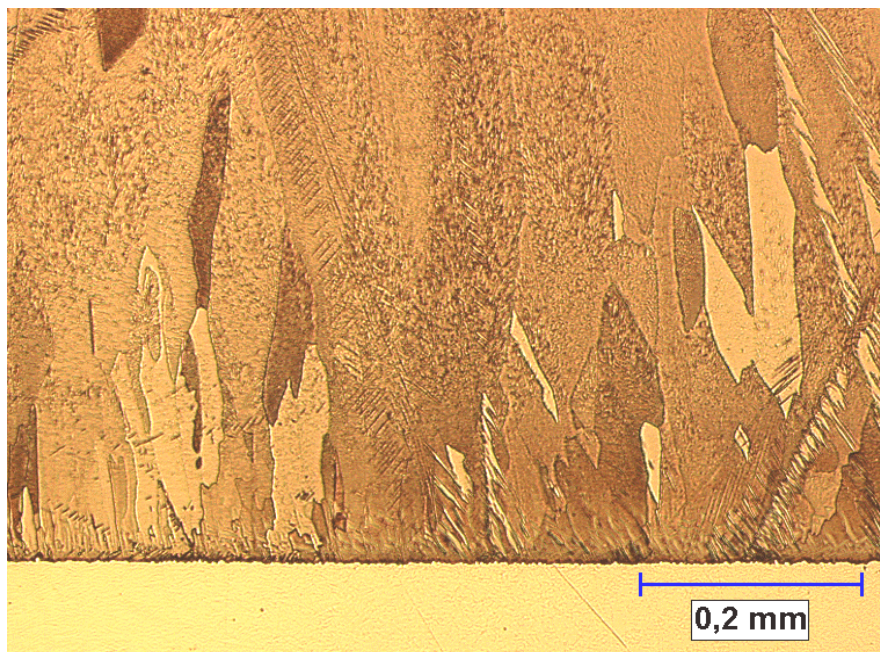
R.P. Elliott and F.A. Shunk, 1980

Phase	Composition, wt% Bi	Pearson symbol	Space group
(Ag)	0 to 4.945	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
(Bi)	~100	<i>hR2</i>	<i>R$\bar{3}m$</i>

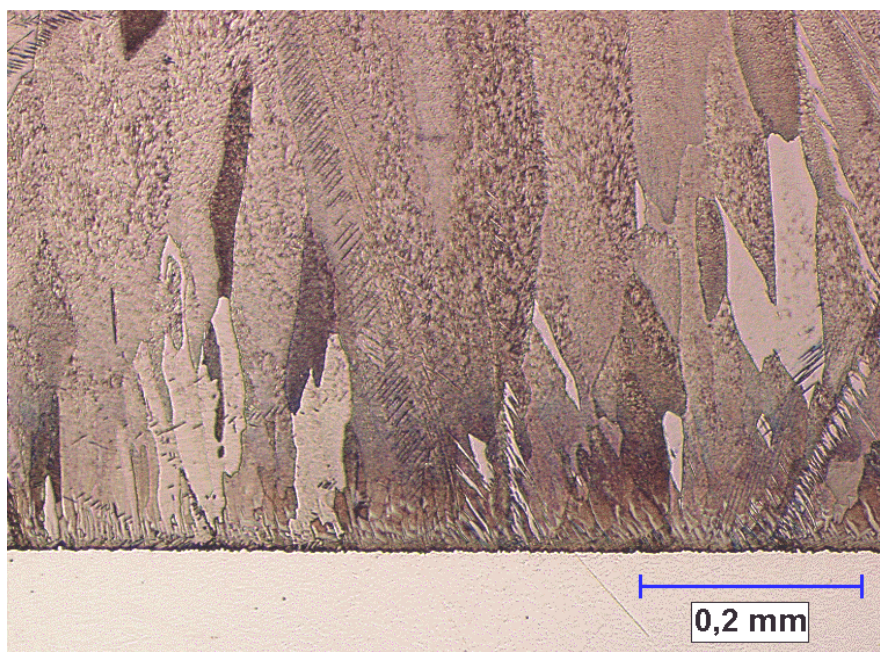
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•26)

Properties of solder/substrate couples

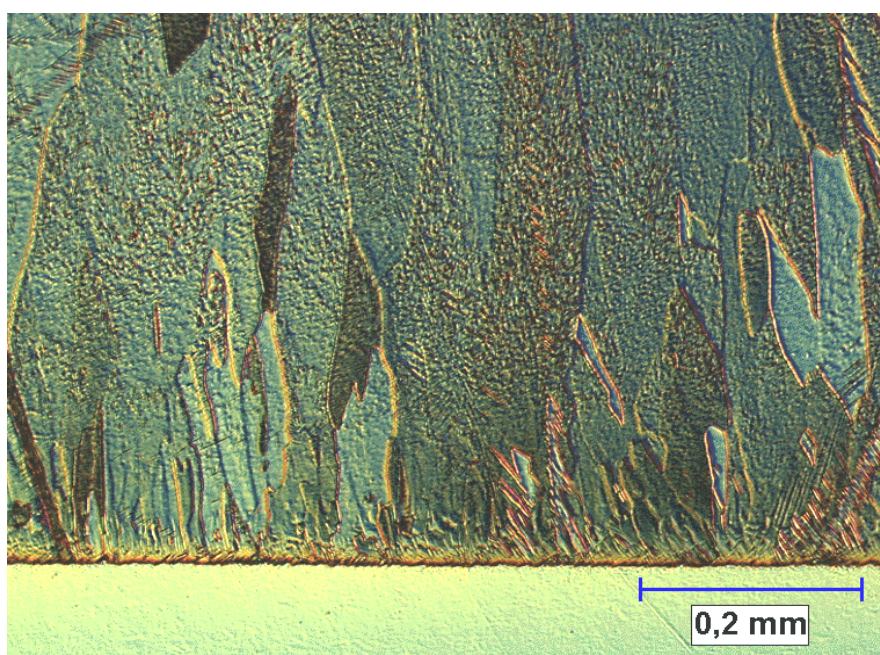
Couple	Conditions	θ , deg
Bi / Ag	280°C, 5 min, flux	34°
Bi / Ag	280°C, 30 min, flux	47°



Bi/Ag couple
280°C; 5 min
E: mag. 100×
CL

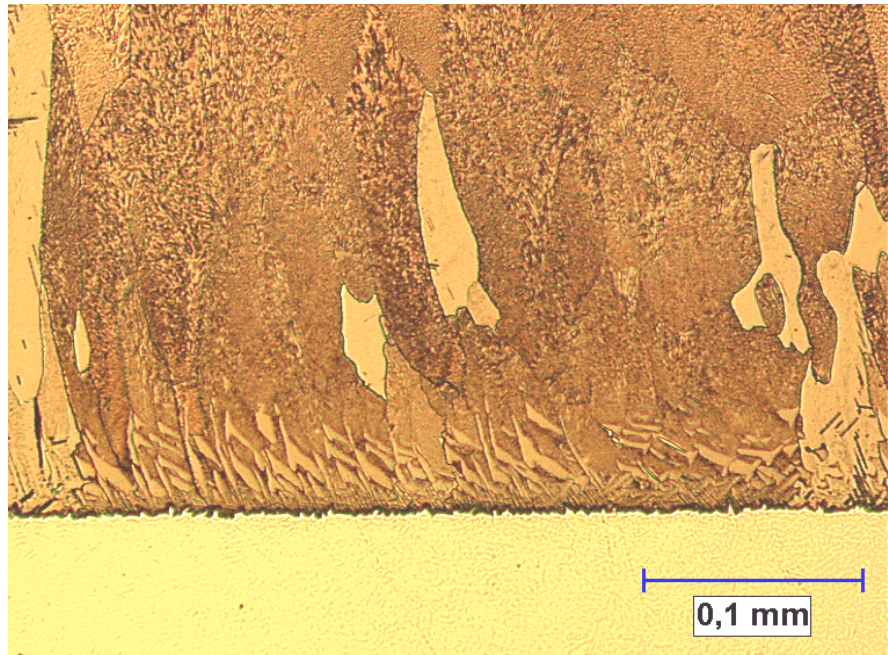


Bi/Ag couple
280°C; 5 min
E: mag. 100×
PL

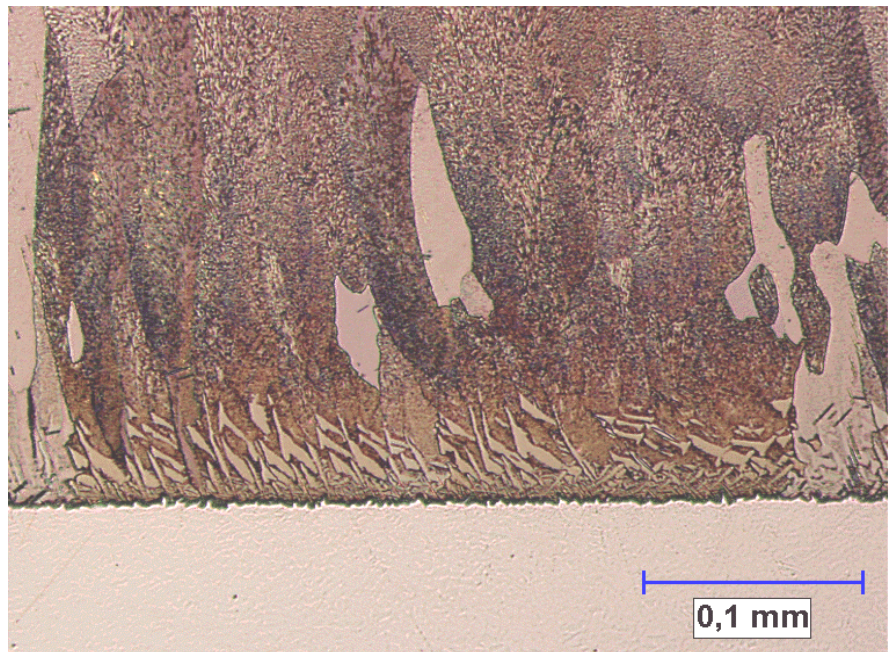


Bi/Ag couple
280°C; 5 min
E: mag. 100×
PC

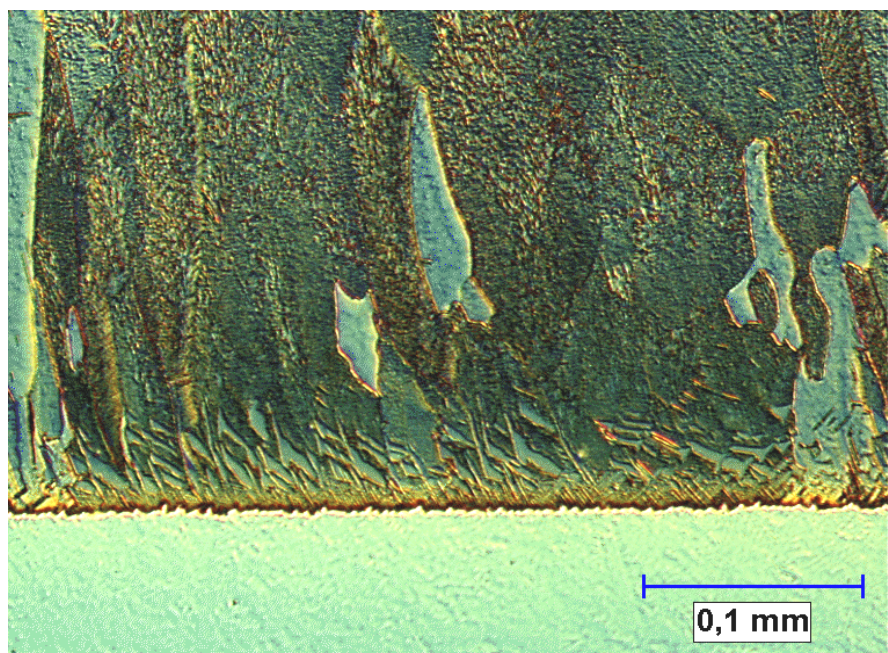
Bi/Ag couple
280°C; 5 min
E: mag. 200×
CL

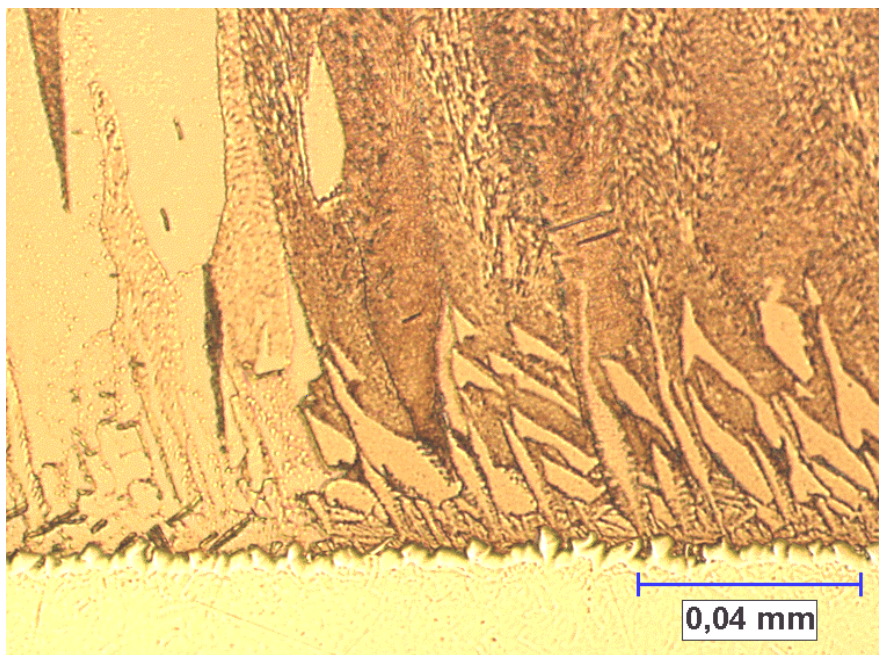


Bi/Ag couple
280°C; 5 min
E: mag. 200×
PL

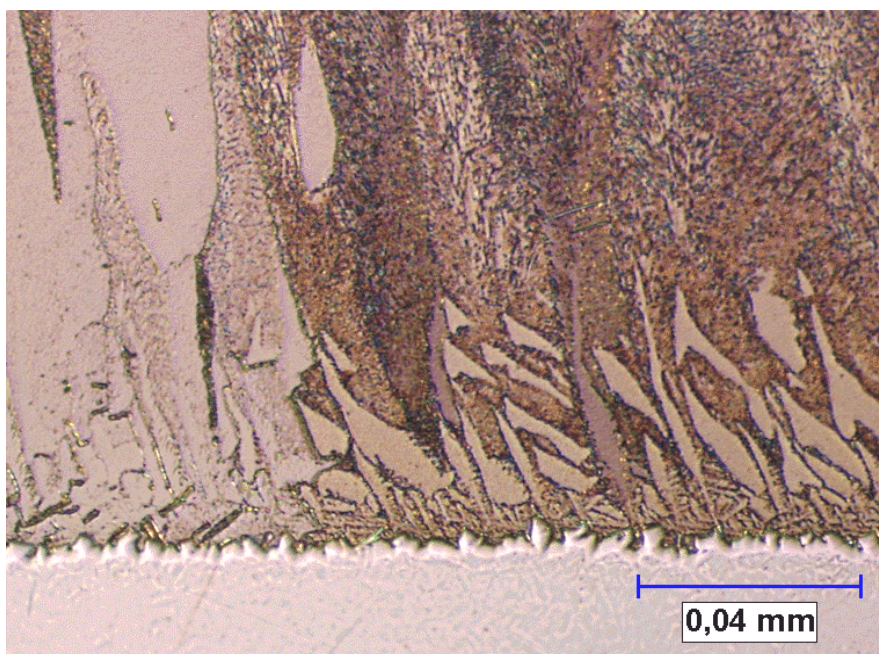


Bi/Ag couple
280°C; 5 min
E: mag. 200×
PC

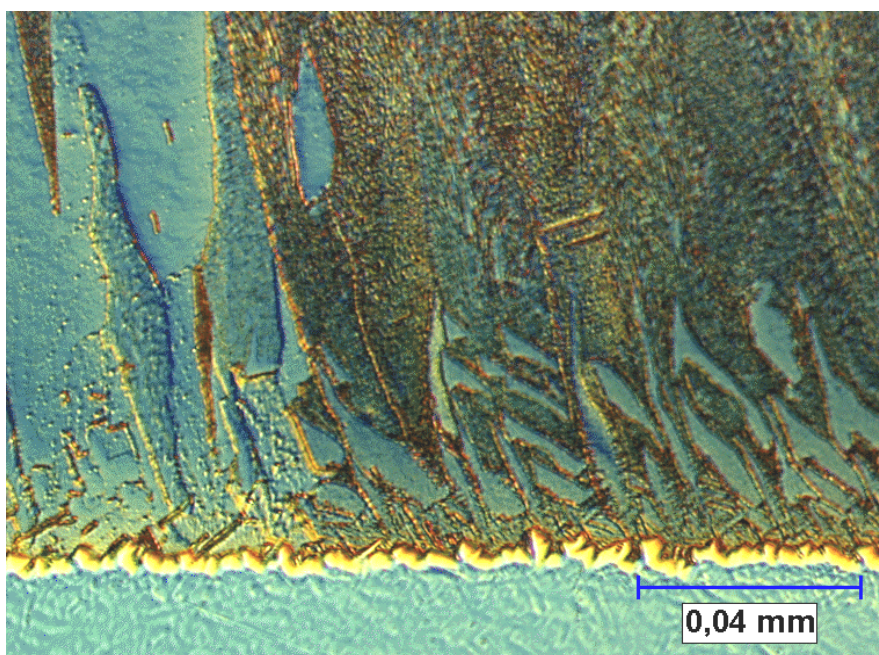




Bi/Ag couple
280°C; 5 min
E: mag. 500×
CL

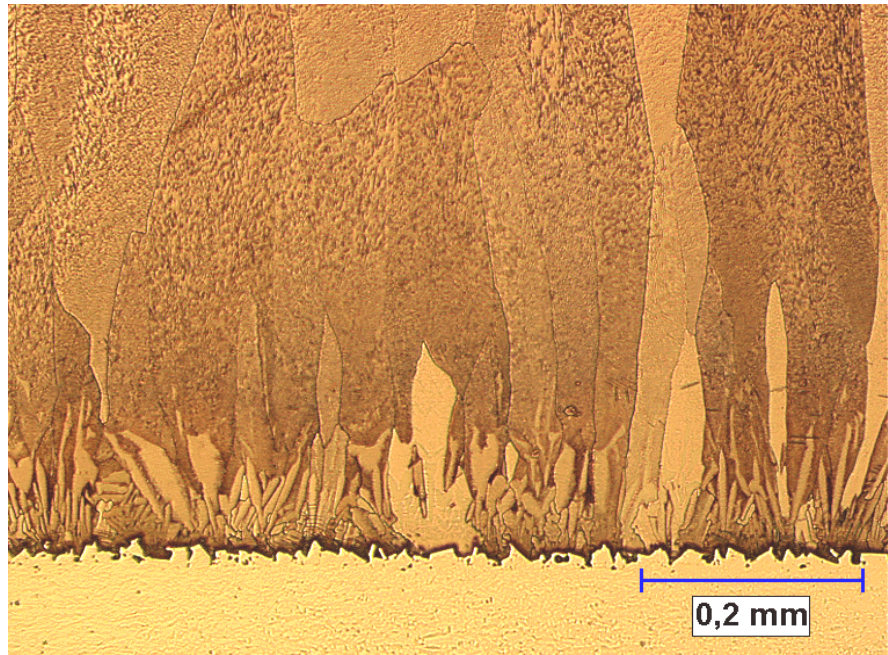


Bi/Ag couple
280°C; 5 min
E: mag. 500×
PL

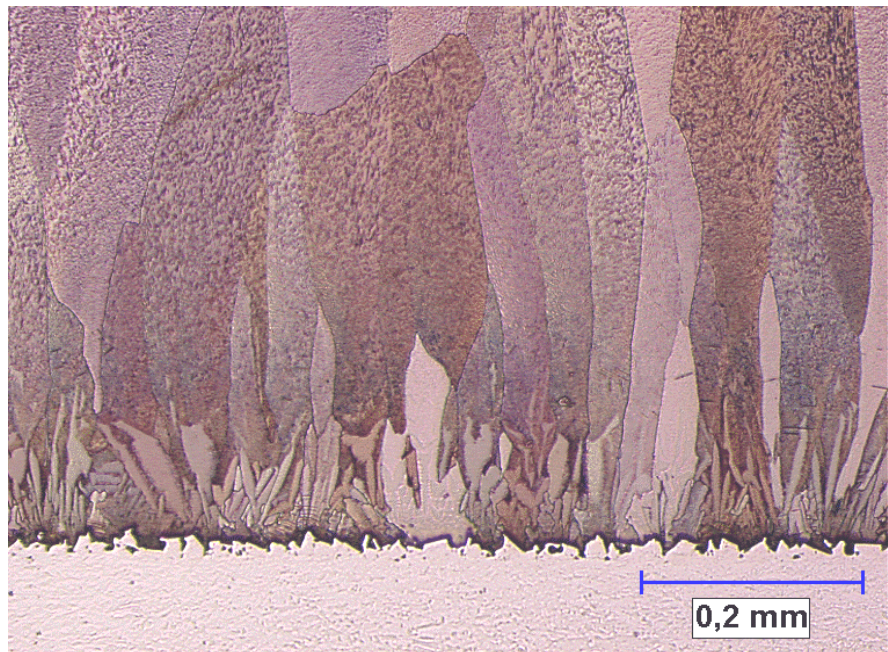


Bi/Ag couple
280°C; 5 min
E: mag. 500×
PC

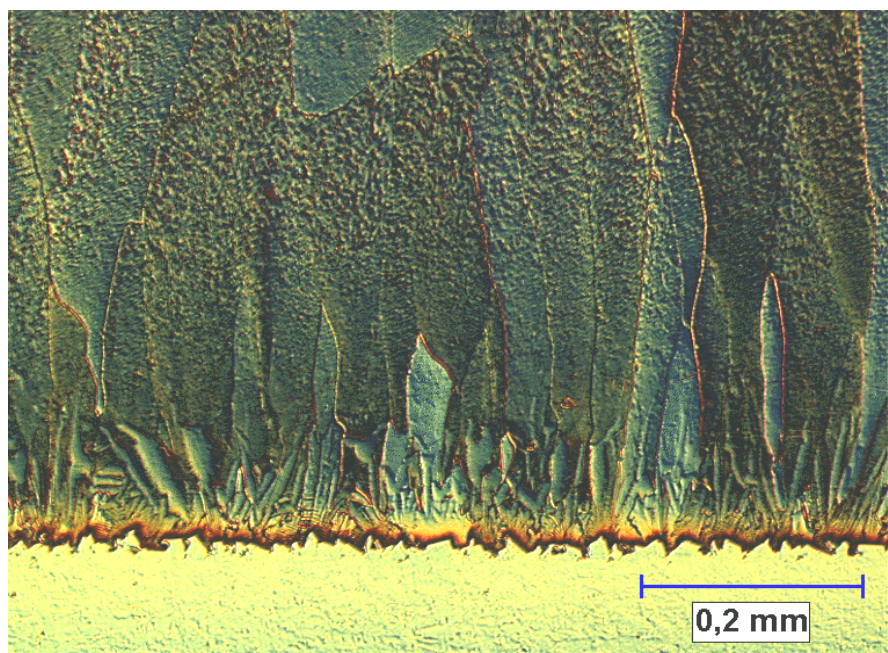
Bi/Ag couple
280°C; 30 min
E: mag. 100×
CL

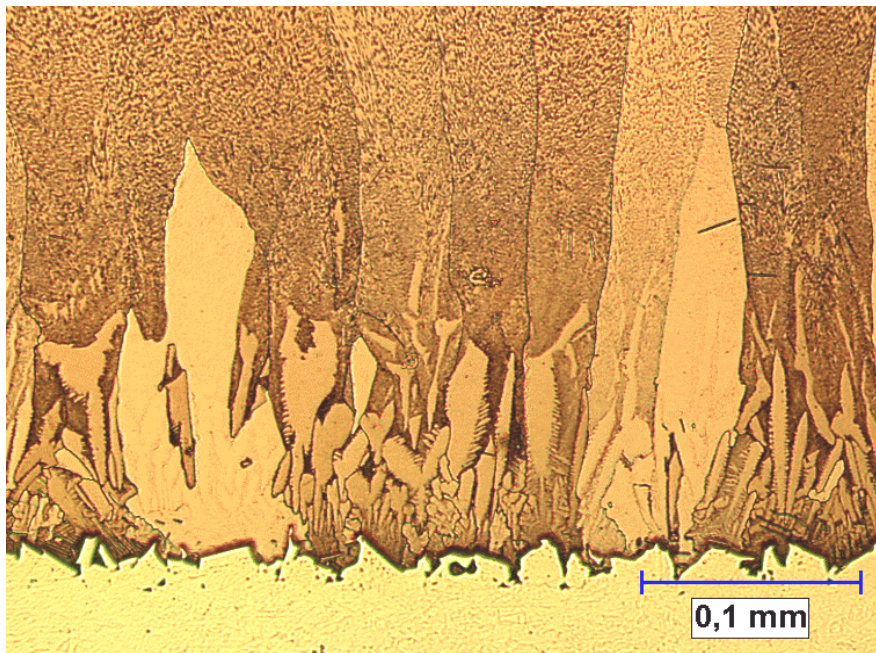


Bi/Ag couple
280°C; 30 min
E: mag. 100×
PL

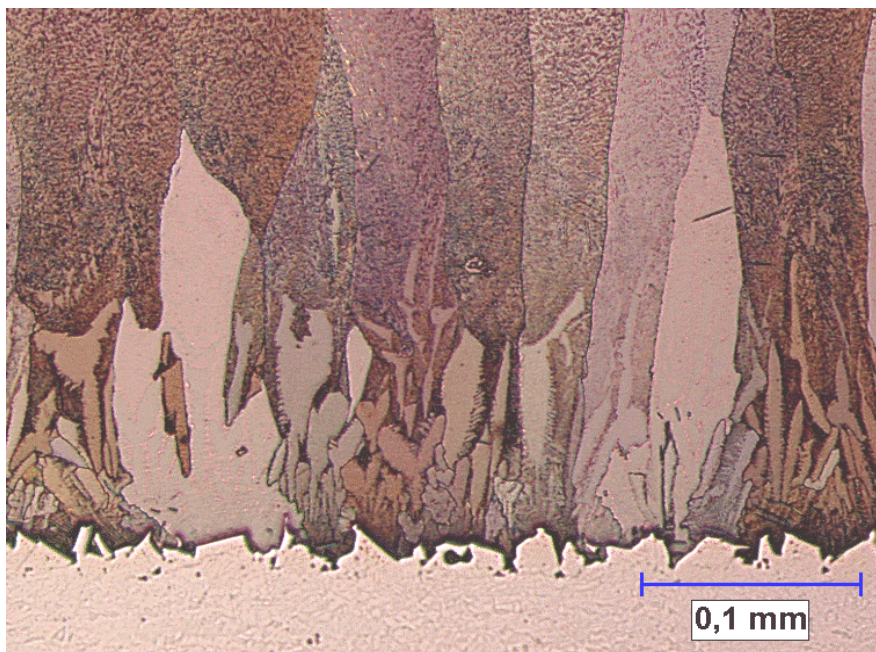


Bi/Ag couple
280°C; 30 min
E: mag. 100×
PC

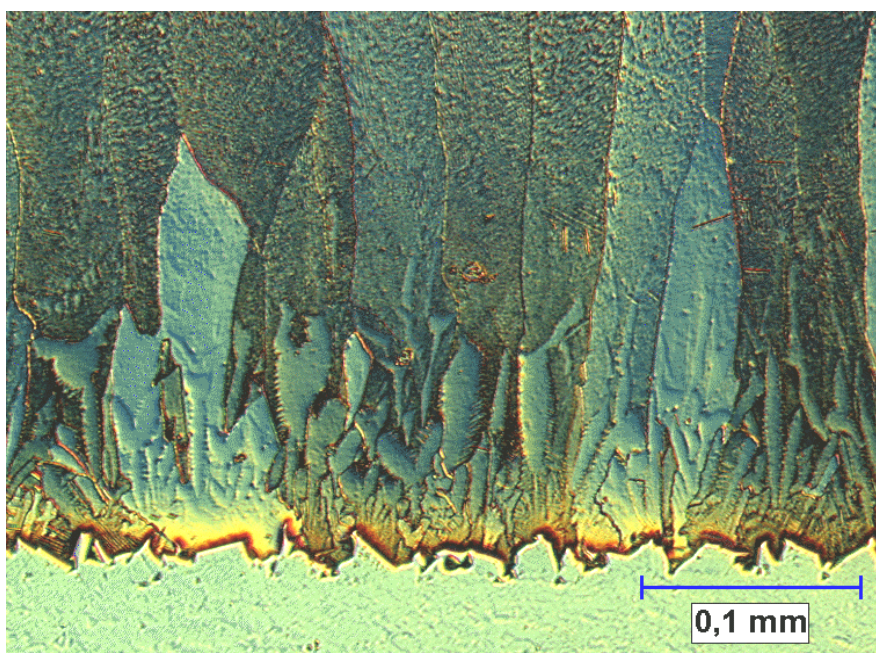




Bi/Ag couple
280°C; 30 min
E: mag. 200×
CL

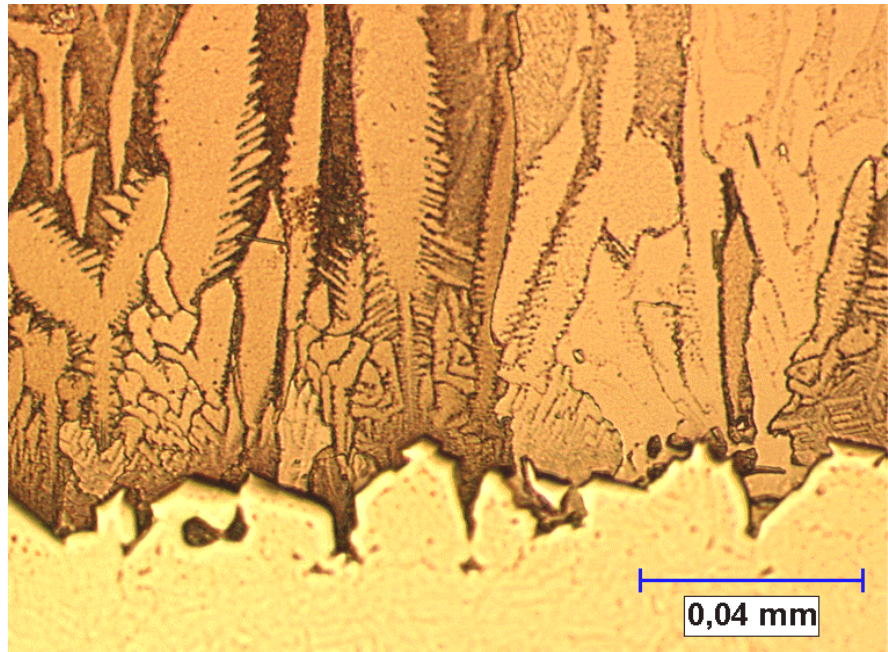


Bi/Ag couple
280°C; 30 min
E: mag. 200×
PL

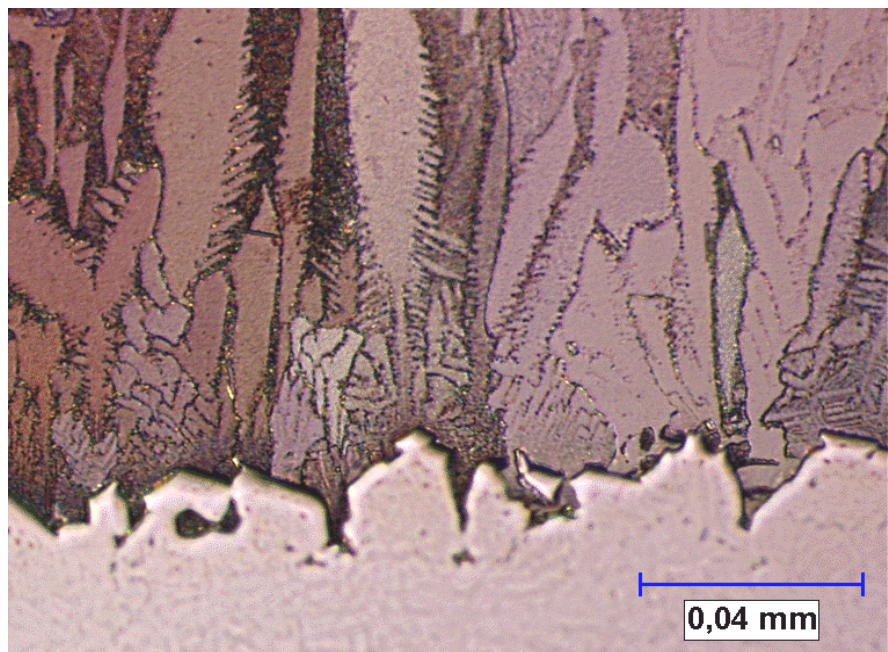


Bi/Ag couple
280°C; 30 min
E: mag. 200×
PC

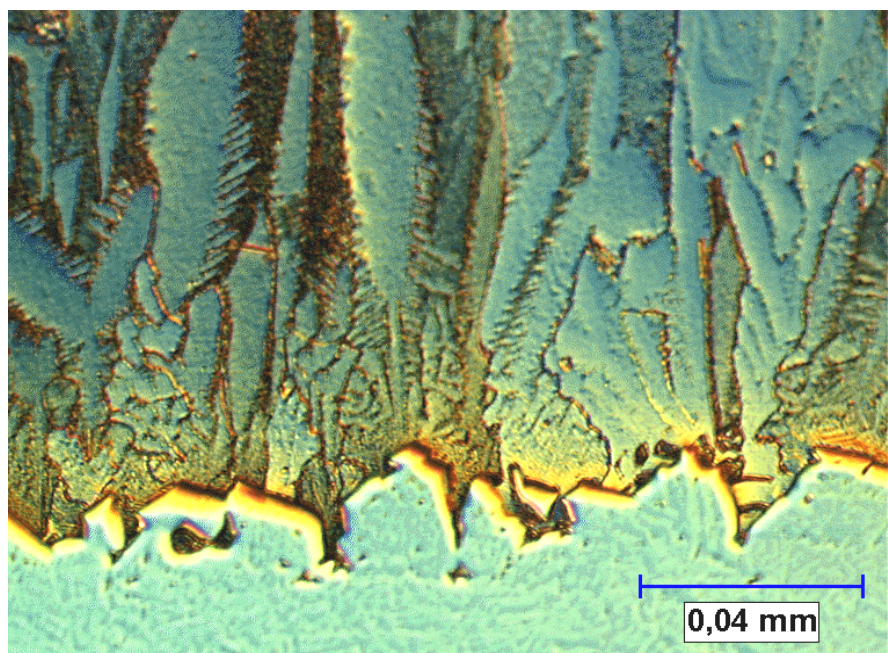
Bi/Ag couple
280°C; 30 min
E: mag. 500×
CL



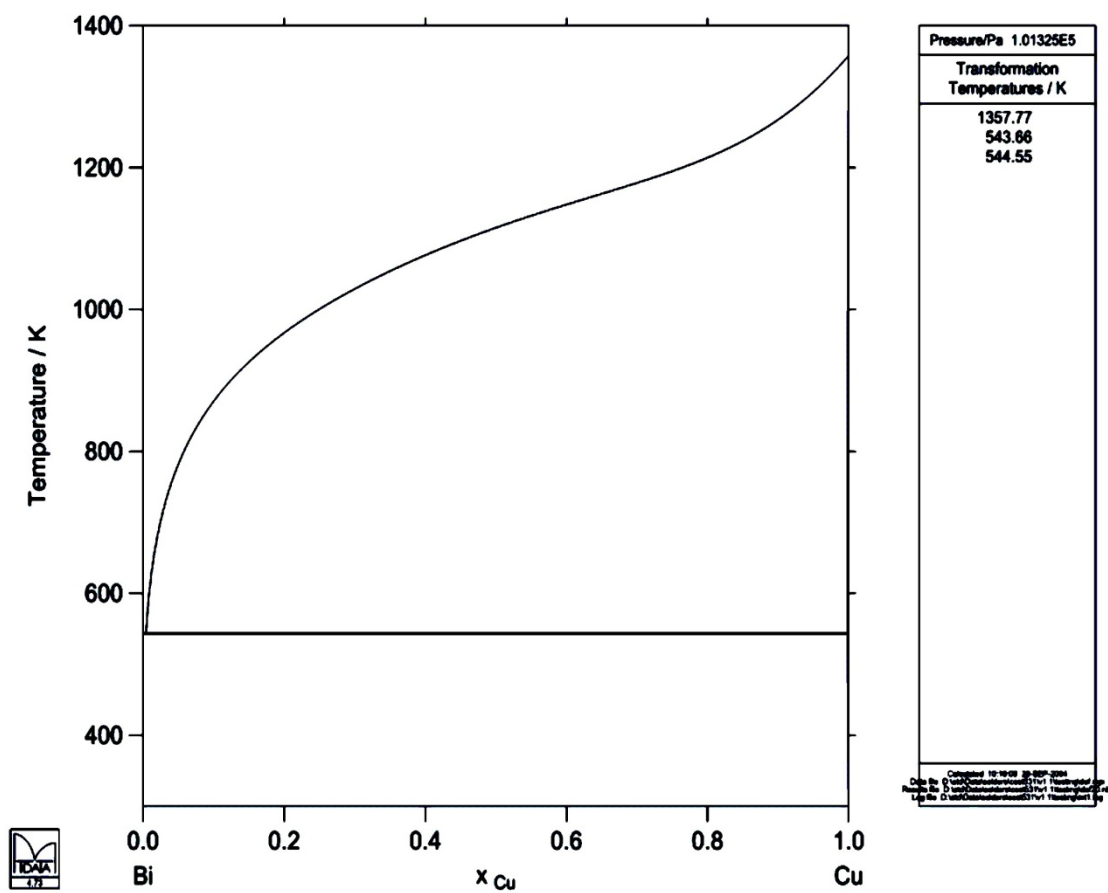
Bi/Ag couple
280°C; 30 min
E: mag. 500×
PL



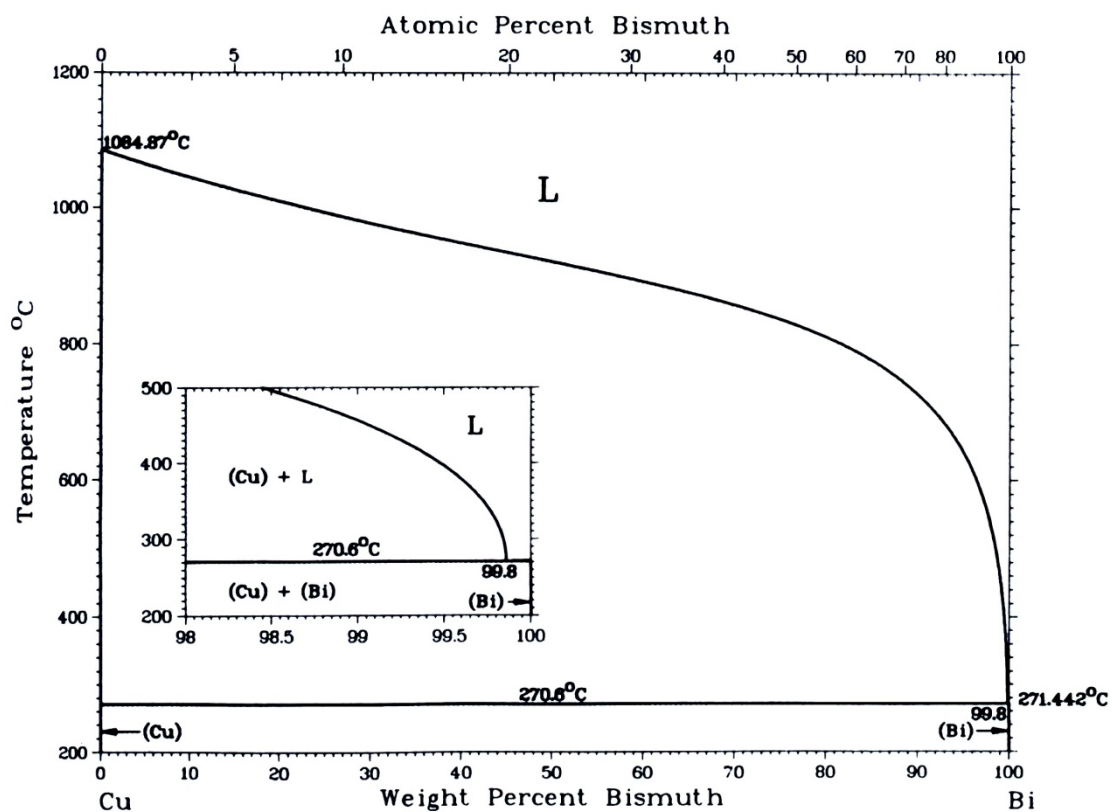
Bi/Ag couple
280°C; 30 min
E: mag. 500×
PC



Bi – Cu



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•99)

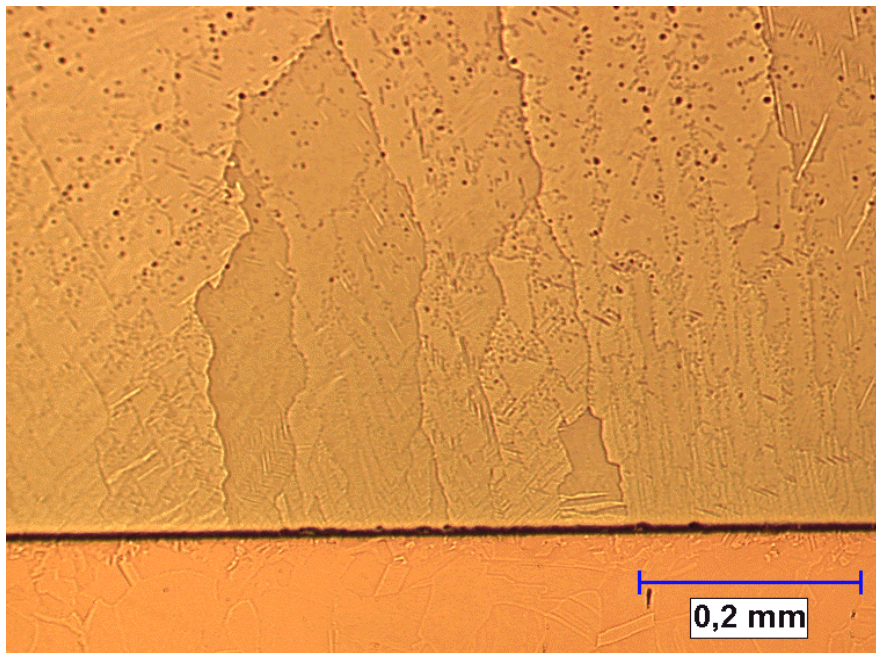
D.J. Chakrabarti and D.E. Laughlin, 1984

Phase	Composition, wt% Bi	Pearson symbol	Space group
(Cu)	0 to 0.010	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
(Bi)	100	<i>hR2</i>	<i>R$\bar{3}m$</i>
Metastable phase			
Cu₅Bi₂	57	...	...

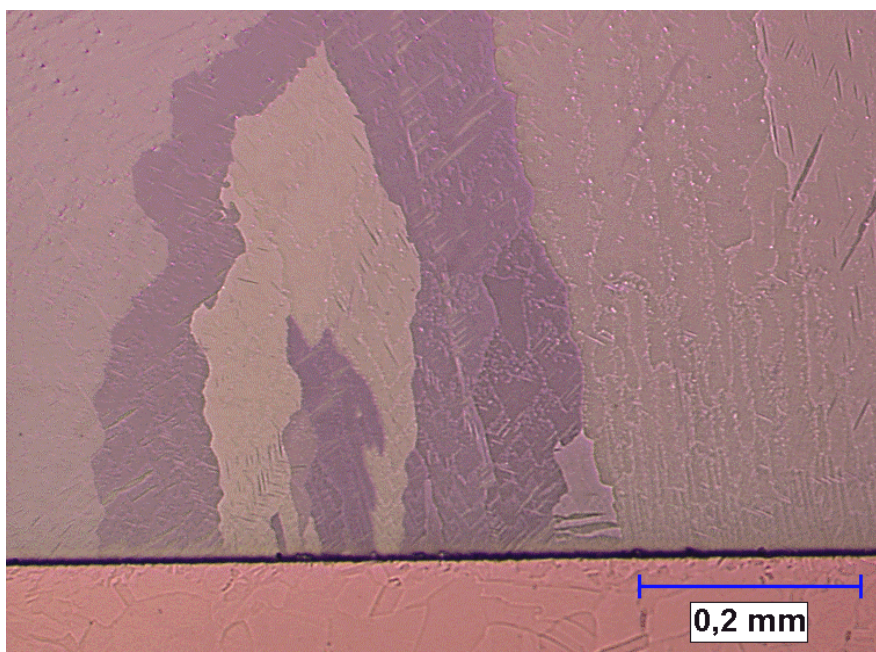
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•99)

Properties of solder/substrate couples

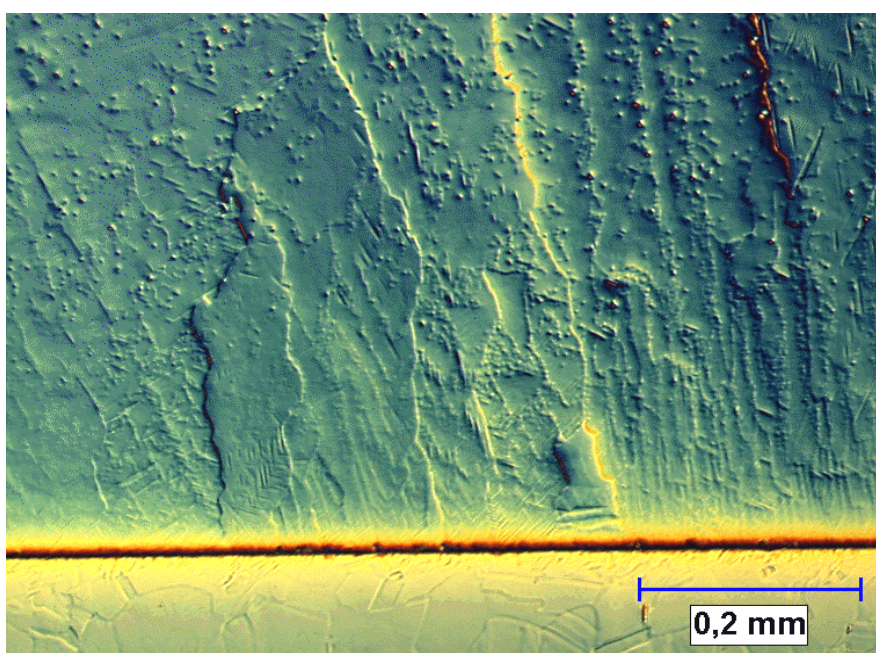
Couple	Conditions	θ, deg	τ, MPa
Bi / Cu	280°C, 5 min, flux	82°	21
Bi / Cu	280°C, 30 min, flux	81°	–



Bi/Cu couple
280°C; 5 min
E: mag. 100×
CL

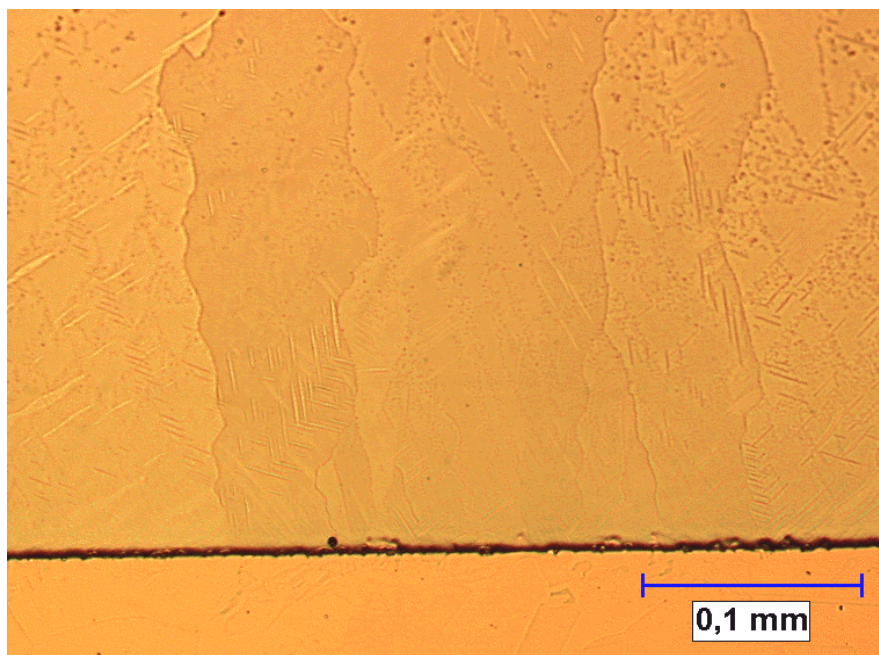


Bi/Cu couple
280°C; 5 min
E: mag. 100×
PL

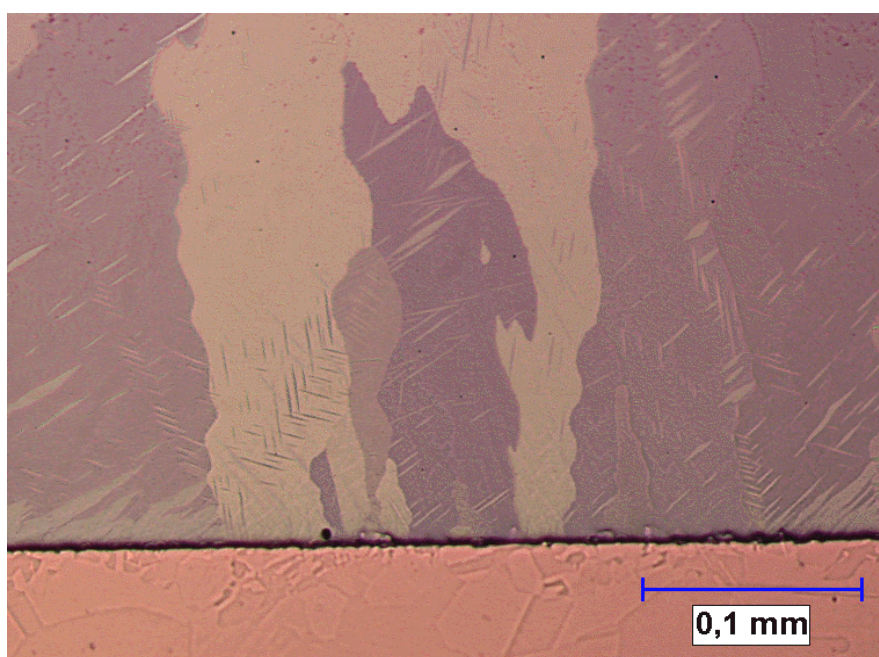


Bi/Cu couple
280°C; 5 min
E: mag. 100×
PC

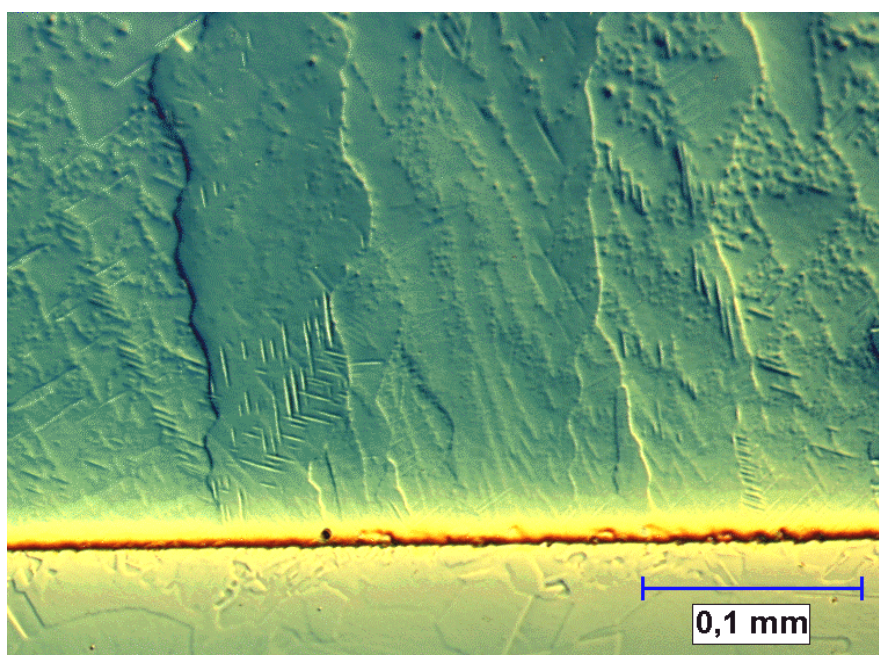
Bi/Cu couple
280°C; 5 min
E: mag. 200×
CL

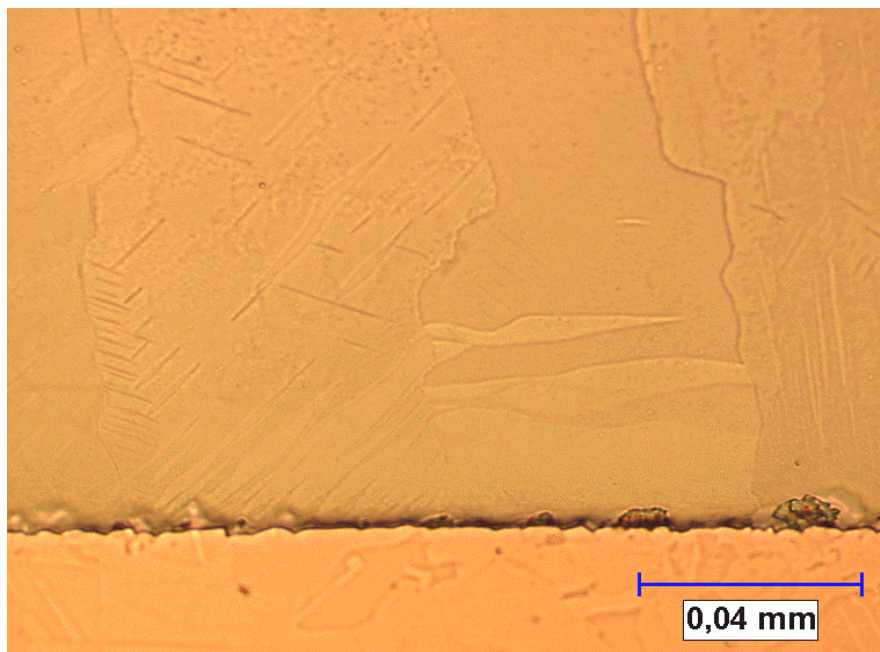


Bi/Cu couple
280°C; 5 min
E: mag. 200×
PL

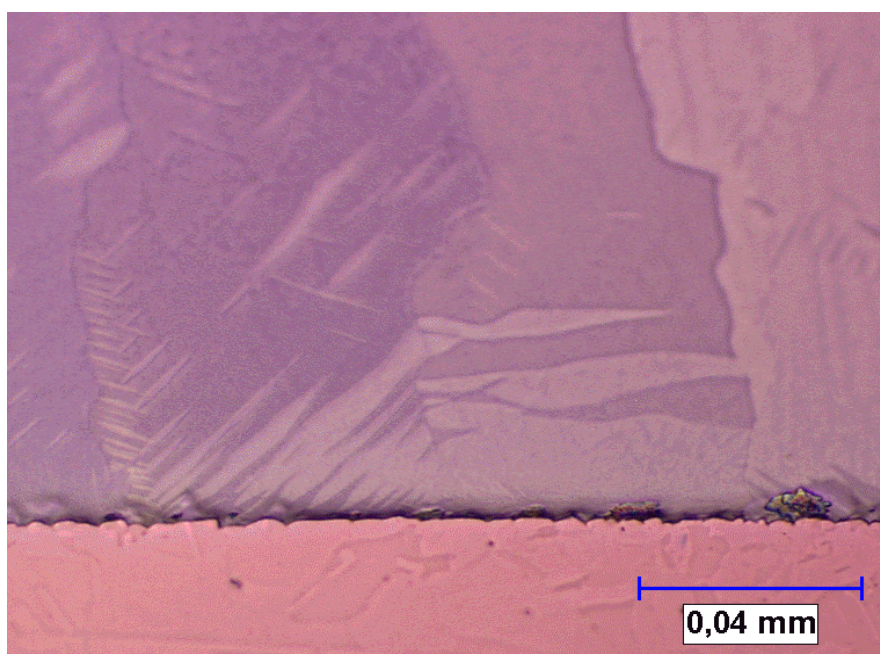


Bi/Cu couple
280°C; 5 min
E: mag. 200×
PC

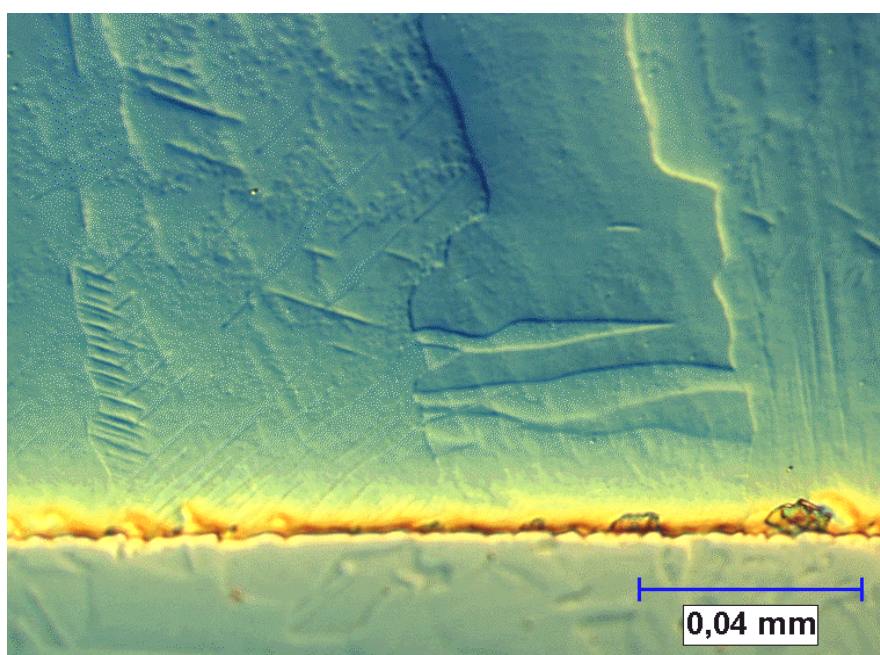




Bi/Cu couple
280°C; 5 min
E: mag. 500×
CL

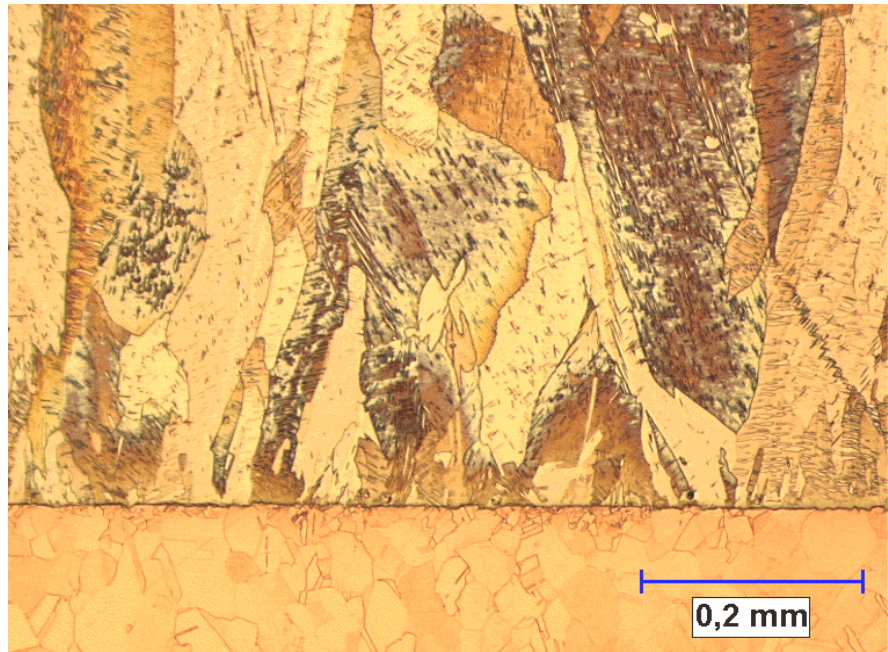


Bi/Cu couple
280°C; 5 min
E: mag. 500×
PL

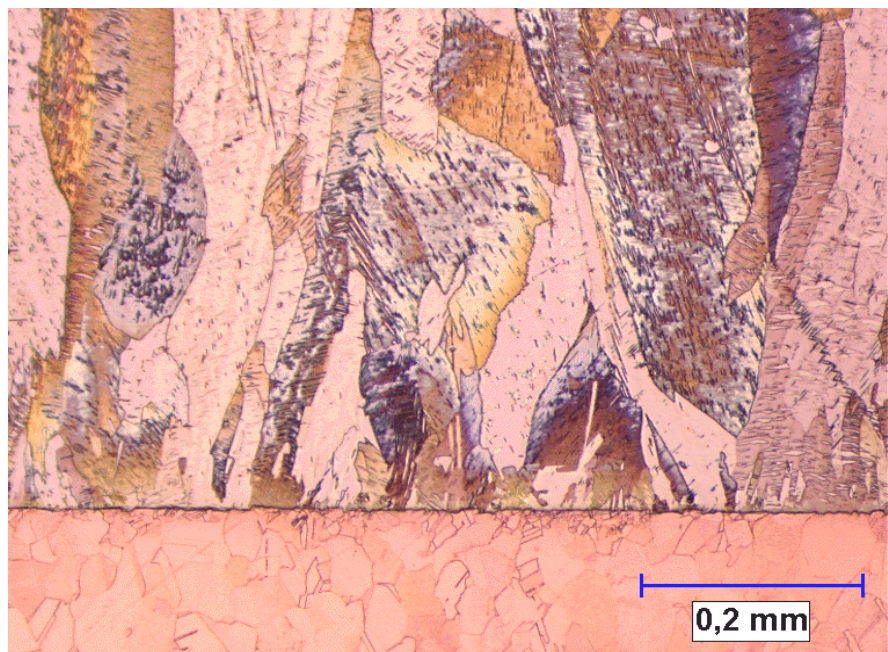


Bi/Cu couple
280°C; 5 min
E: mag. 500×
PC

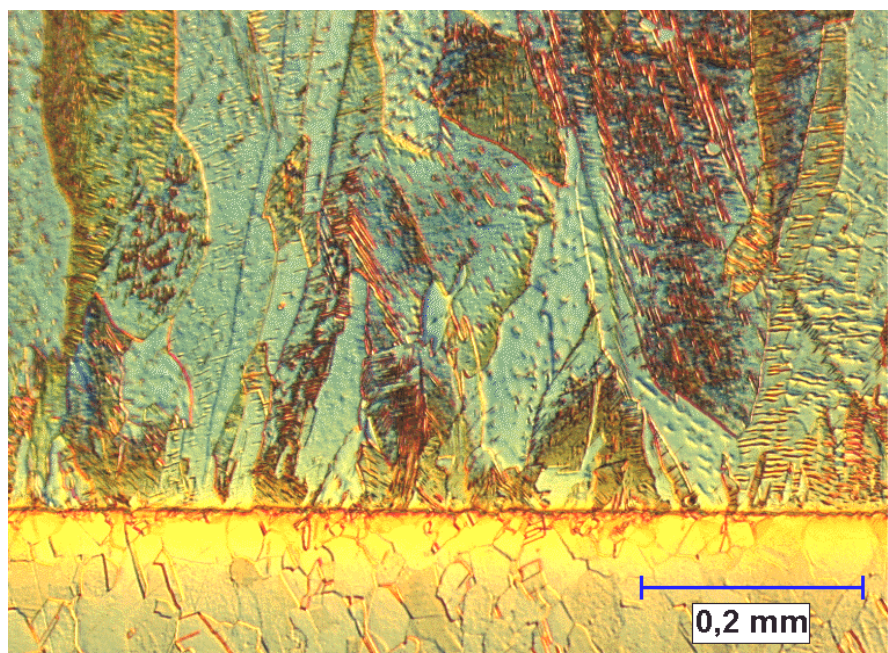
Bi/Cu couple
280°C; 30 min
E: mag. 100×
CL

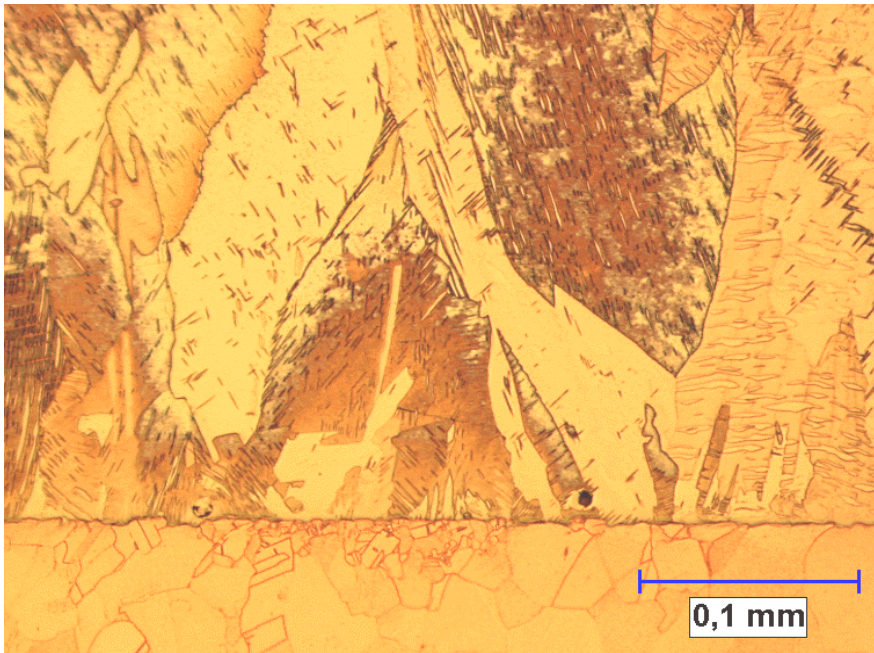


Bi/Cu couple
280°C; 30 min
E: mag. 100×
PL

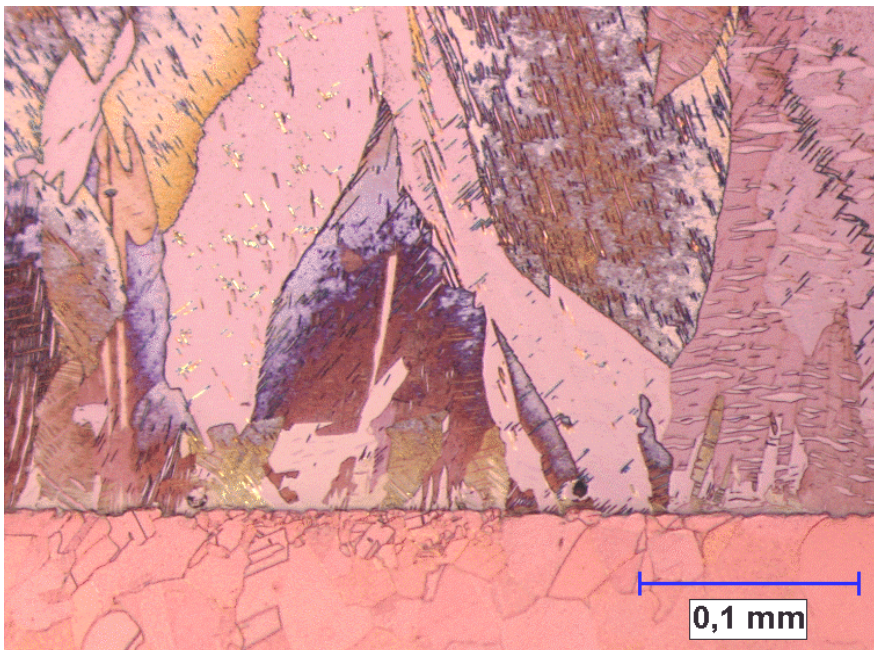


Bi/Cu couple
280°C; 30 min
E: mag. 100×
PC

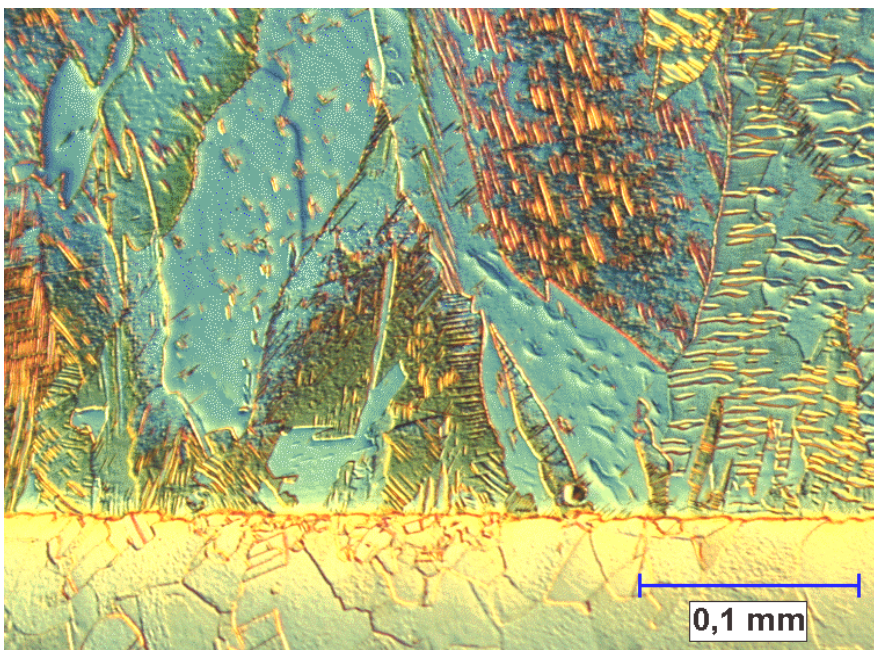




Bi/Cu couple
280°C; 30 min
E: mag. 200×
CL

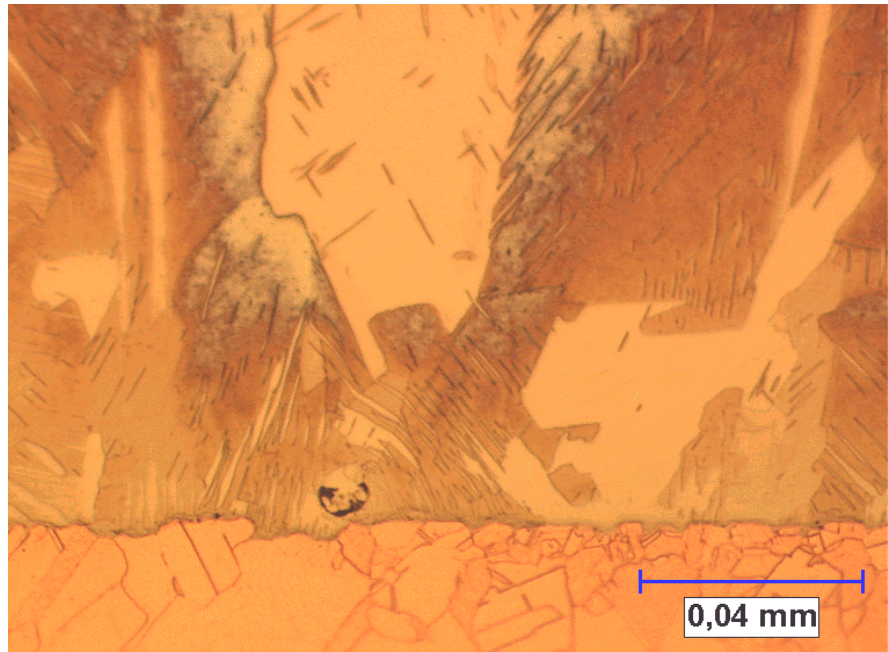


Bi/Cu couple
280°C; 30 min
E: mag. 200×
PL

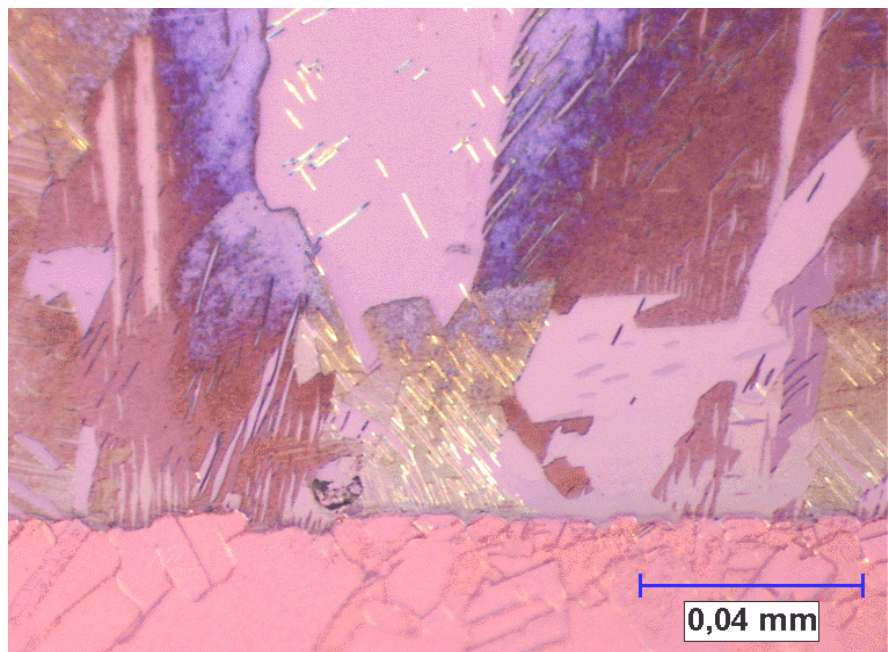


Bi/Cu couple
280°C; 30 min
E: mag. 200×
PC

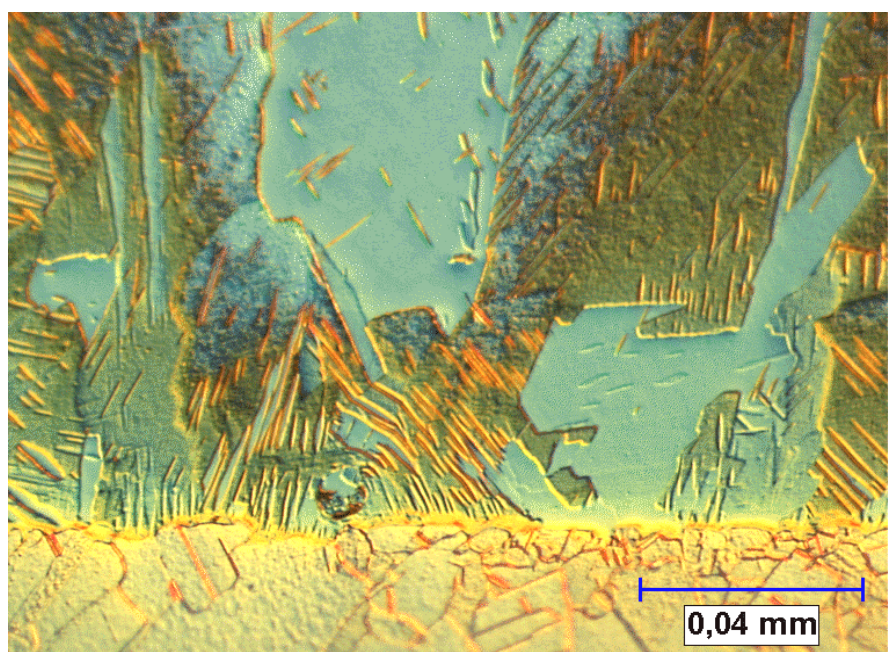
Bi/Cu couple
280°C; 30 min
E: mag. 500×
CL

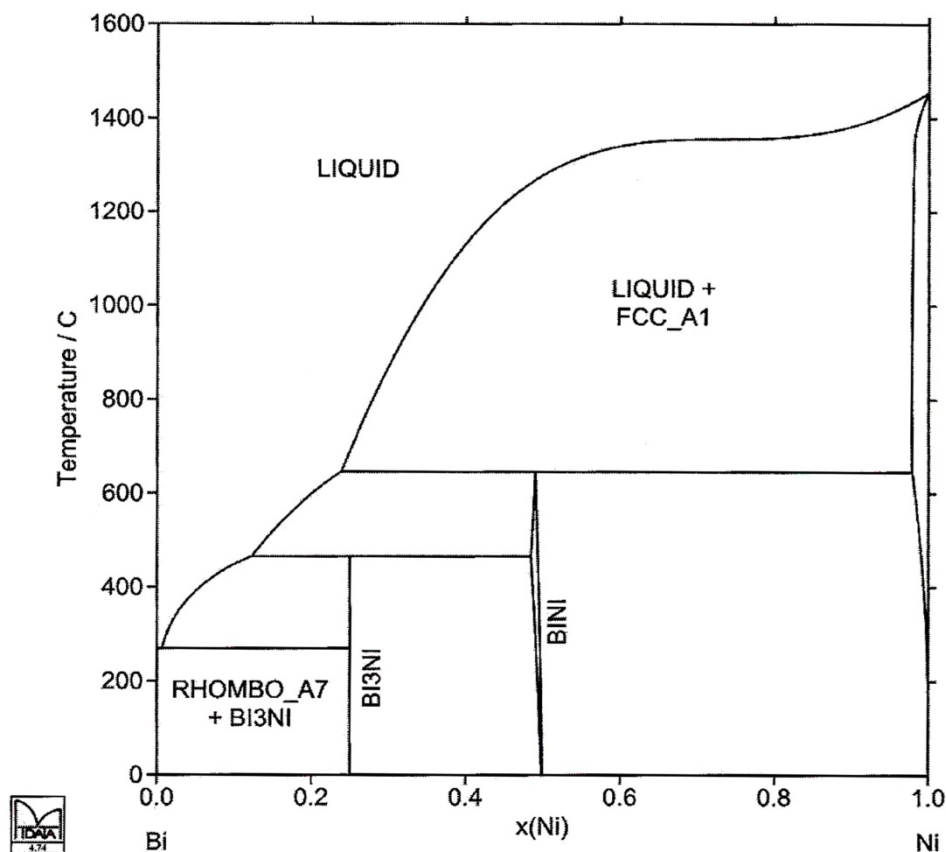


Bi/Cu couple
280°C; 30 min
E: mag. 500×
PL

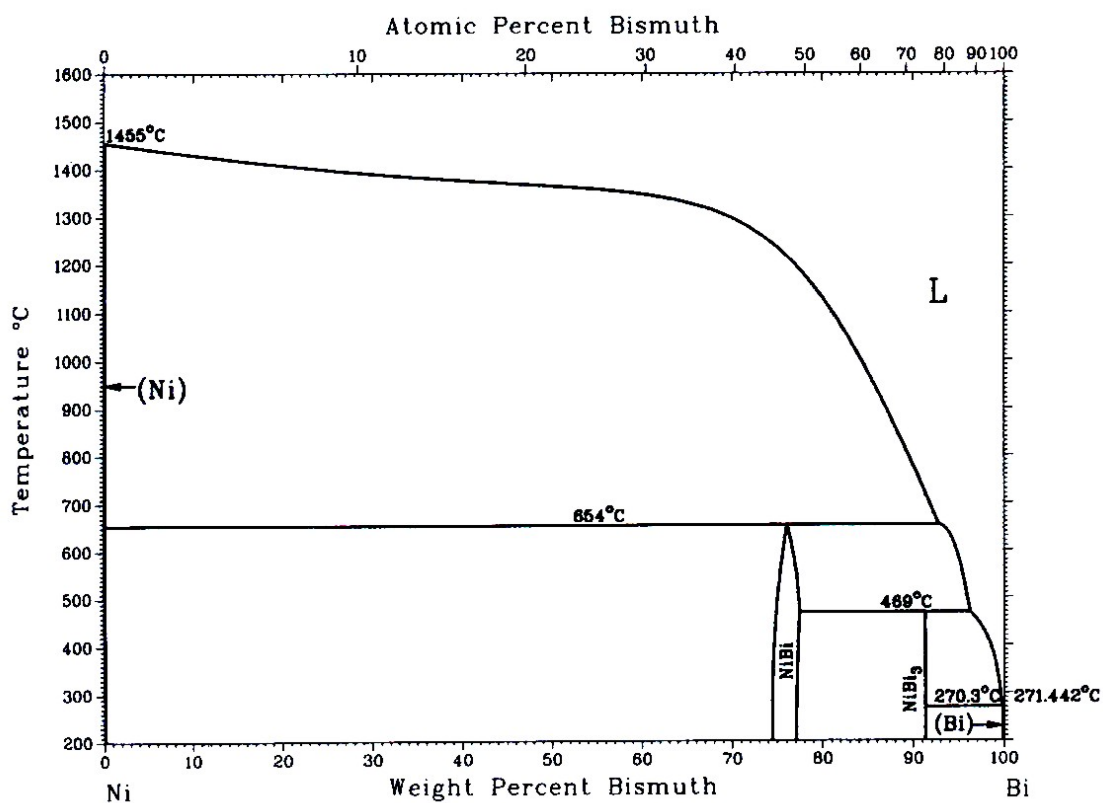


Bi/Cu couple
280°C; 30 min
E: mag. 500×
PC



Bi – Ni

Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•103)

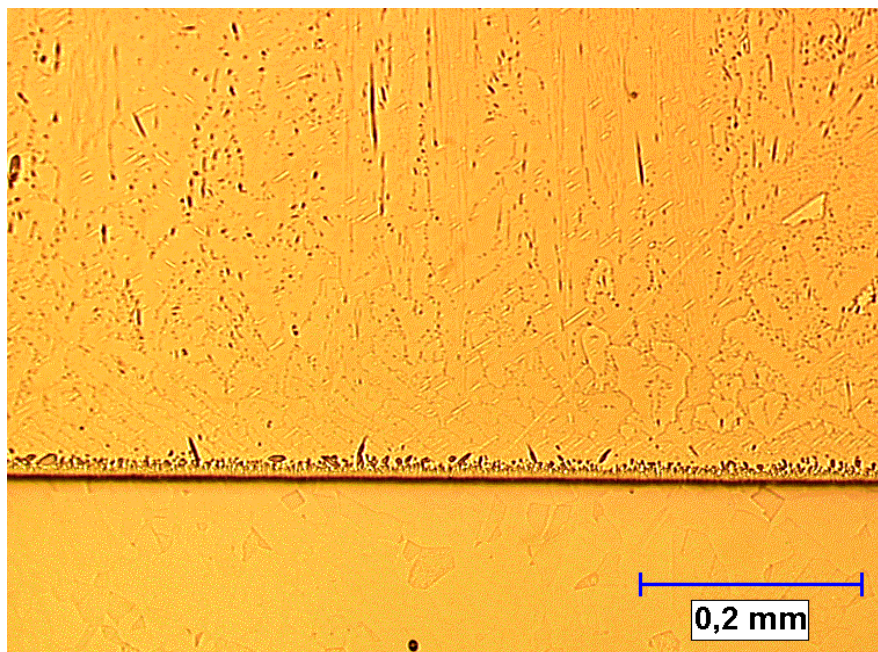
P. Nash, 1991

Phase	Composition, wt% Bi	Pearson symbol	Space group
(Ni)	0	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
NiBi	74 to 77	<i>hP4</i>	<i>P6₃/mmc</i>
NiBi ₃	91	...	...
(Bi)	100	<i>hR2</i>	<i>R$\bar{3}m$</i>

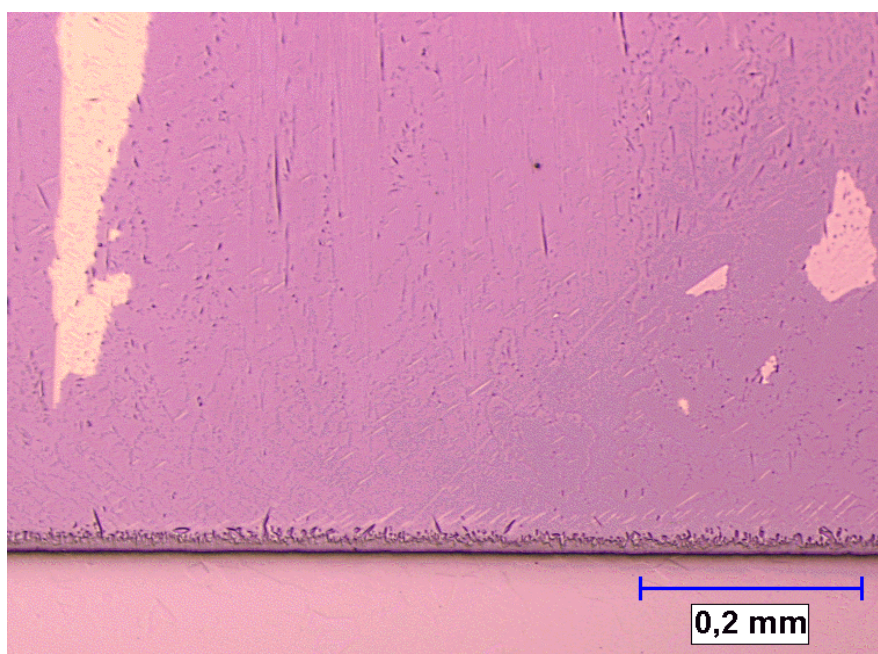
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•103)

Properties of solder/substrate couples

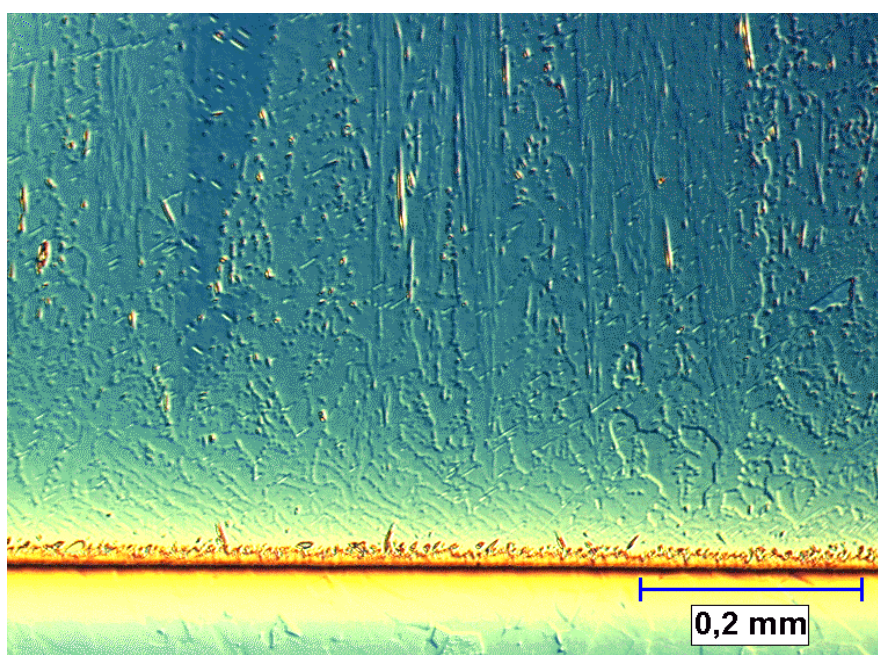
Couple	Conditions	θ, deg	τ, MPa
Bi / Ni	280°C, 5 min, flux	63°	27
Bi / Ni	280°C, 30 min, flux	47°	26



Bi/Ni couple
230°C; 5 min
NE: mag. 100×
CL

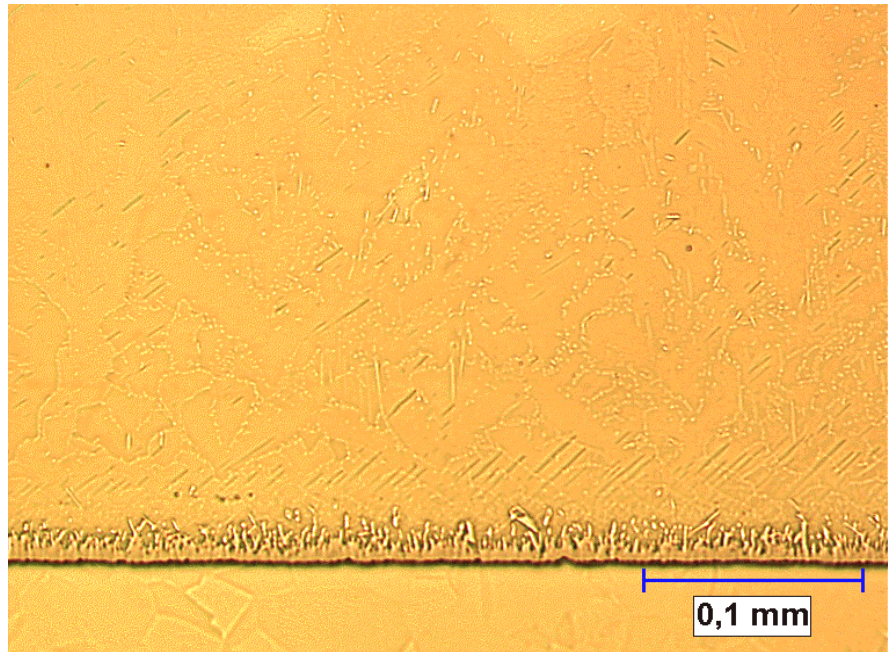


Bi/Ni couple
230°C; 5 min
NE: mag. 100×
PL

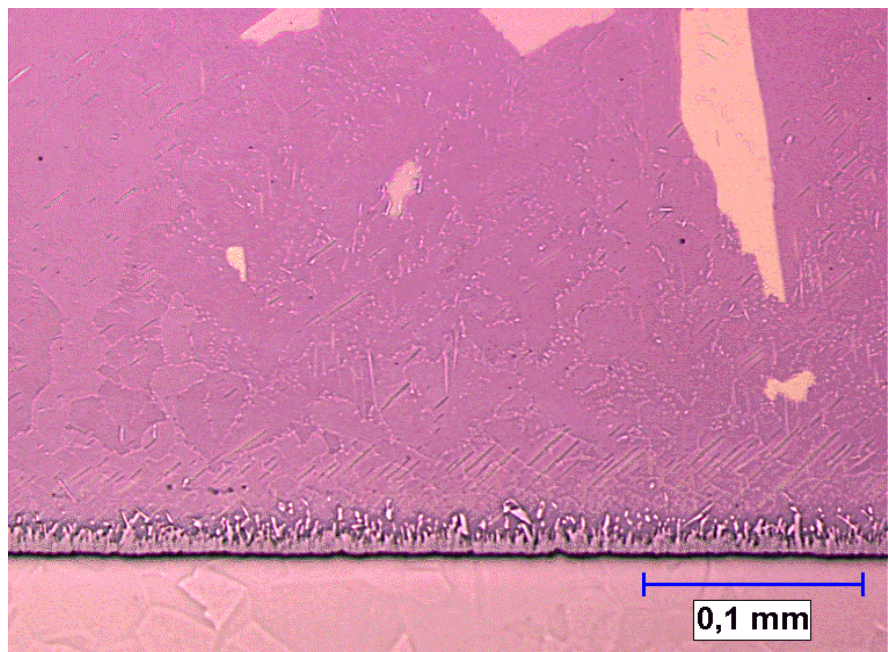


Bi/Ni couple
230°C; 5 min
NE: mag. 100×
PC

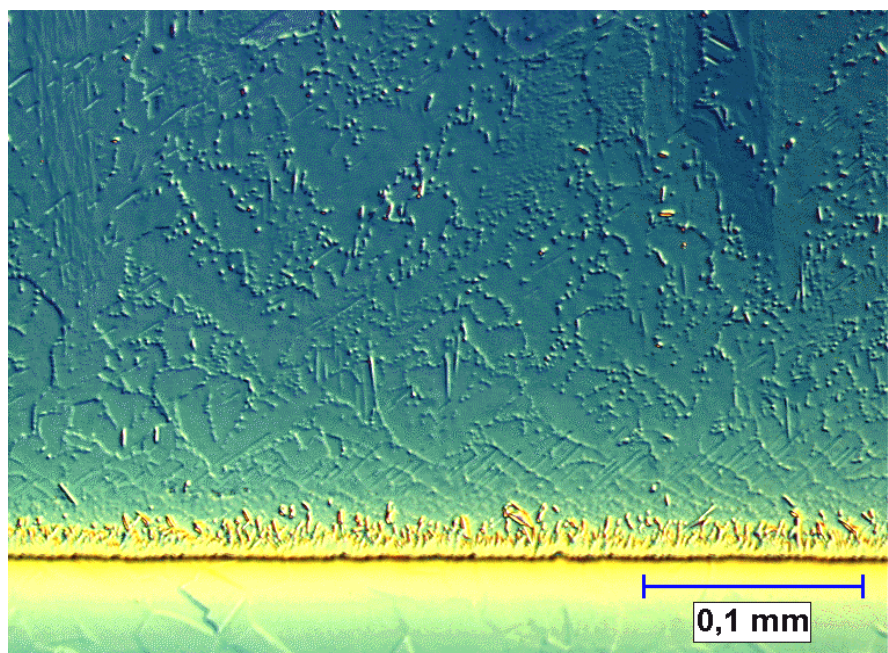
Bi/Ni couple
230°C; 5 min
NE: mag. 200×
CL

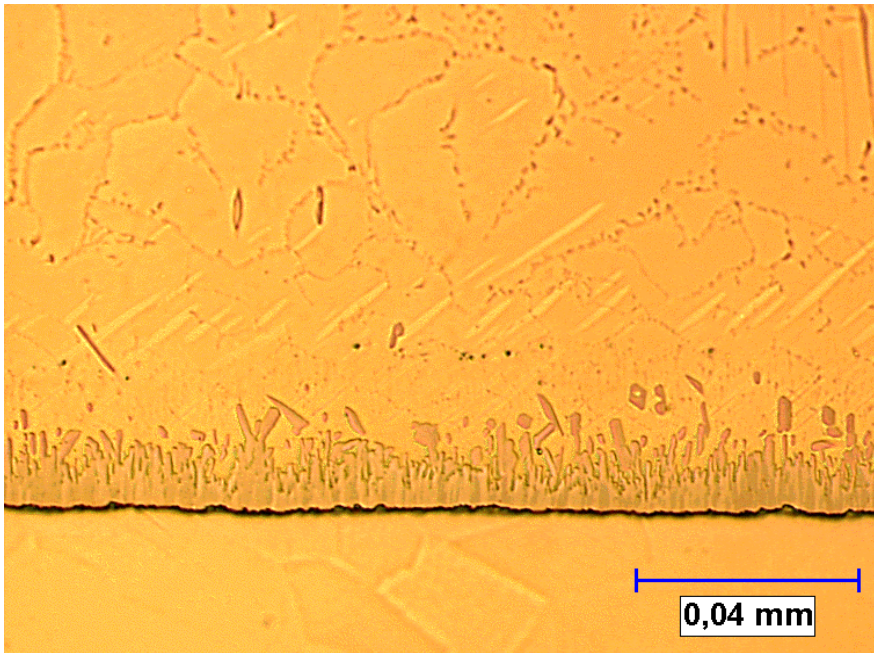


Bi/Ni couple
230°C; 5 min
NE: mag. 200×
PL

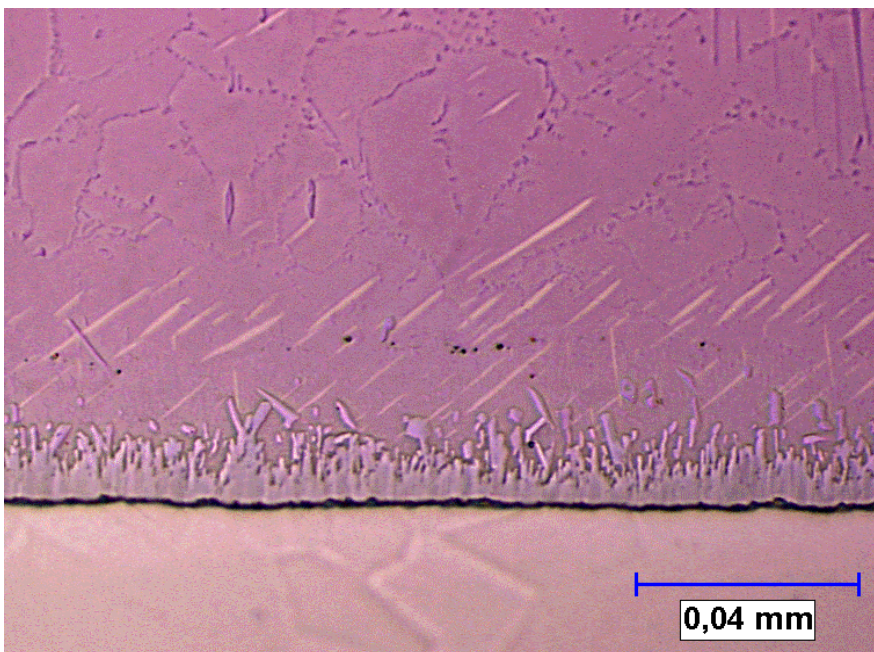


Bi/Ni couple
230°C; 5 min
NE: mag. 200×
PC

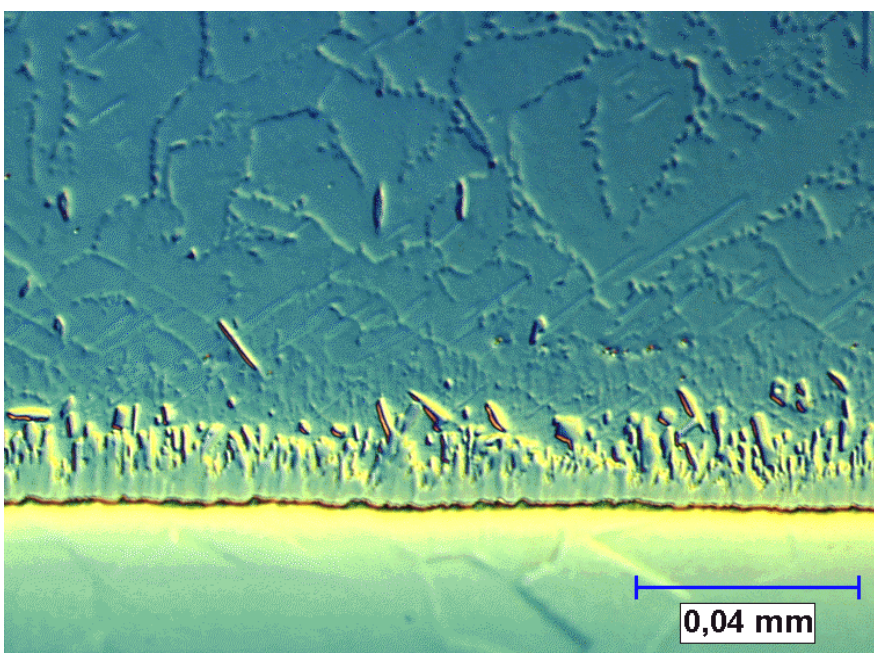




Bi/Ni couple
230°C; 5 min
NE: mag. 500×
CL

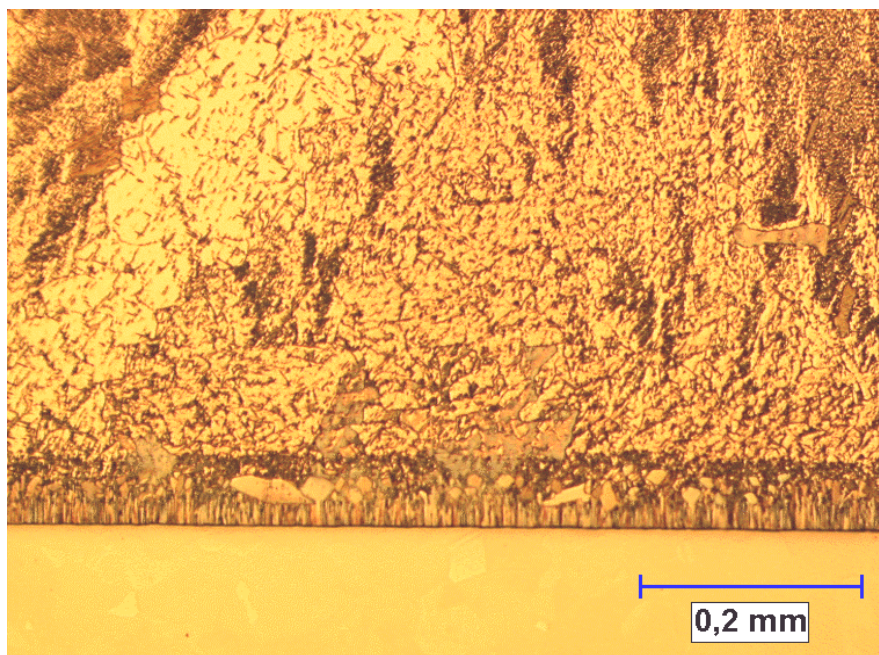


Bi/Ni couple
230°C; 5 min
NE: mag. 500×
PL

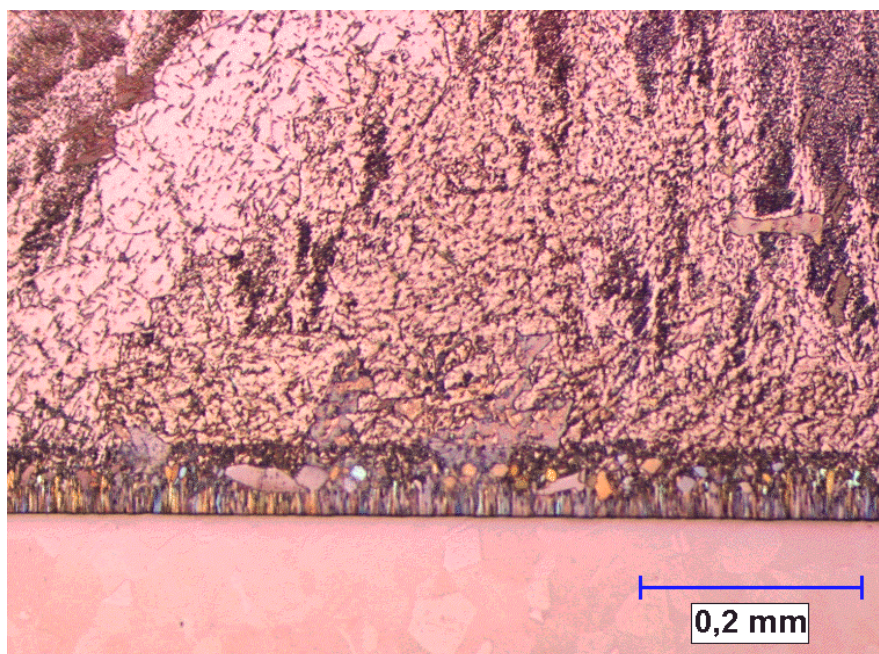


Bi/Ni couple
230°C; 5 min
NE: mag. 500×
PC

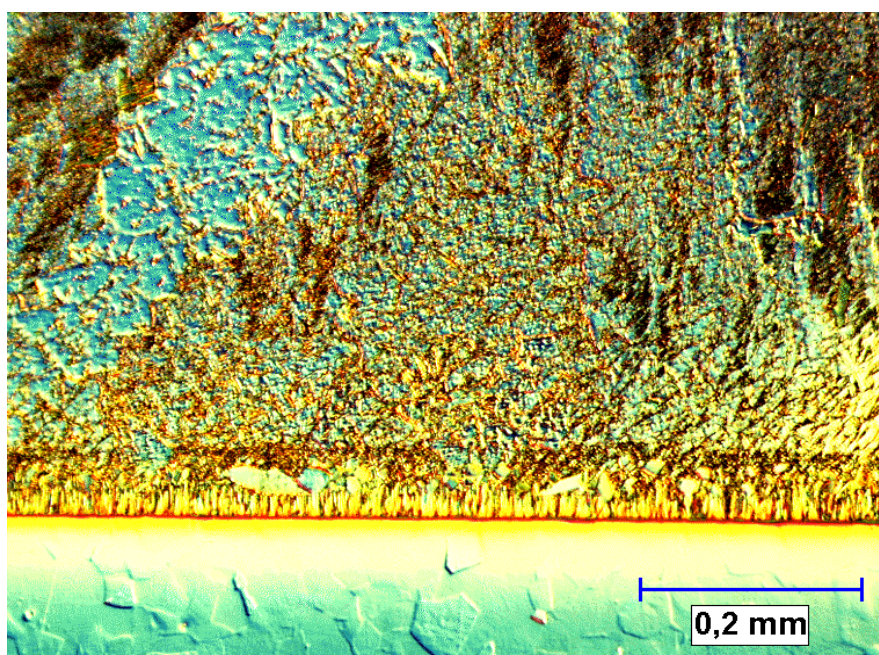
Bi/Ni couple
230°C; 30 min
E: mag. 100×
CL

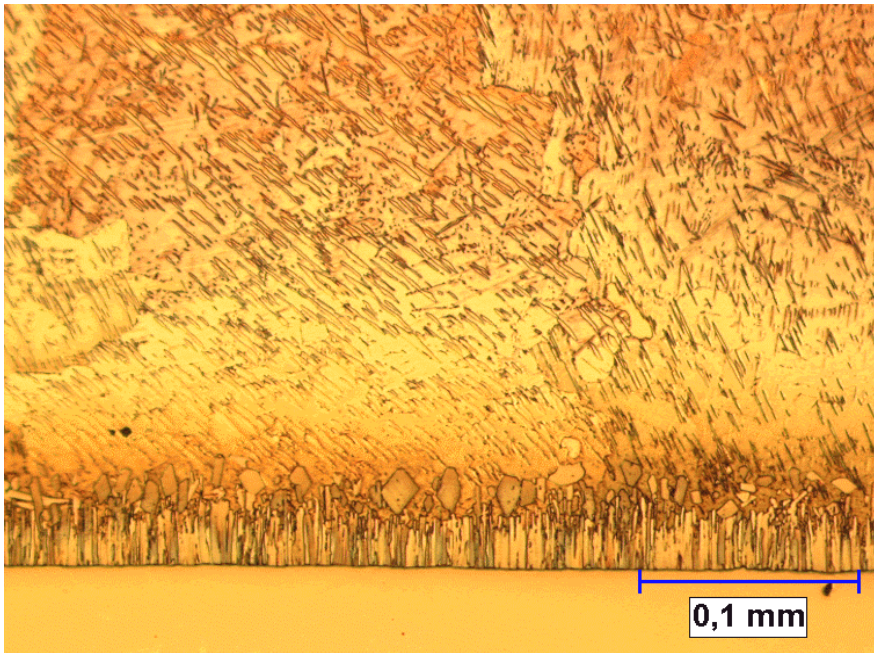


Bi/Ni couple
230°C; 30 min
E: mag. 100×
PL

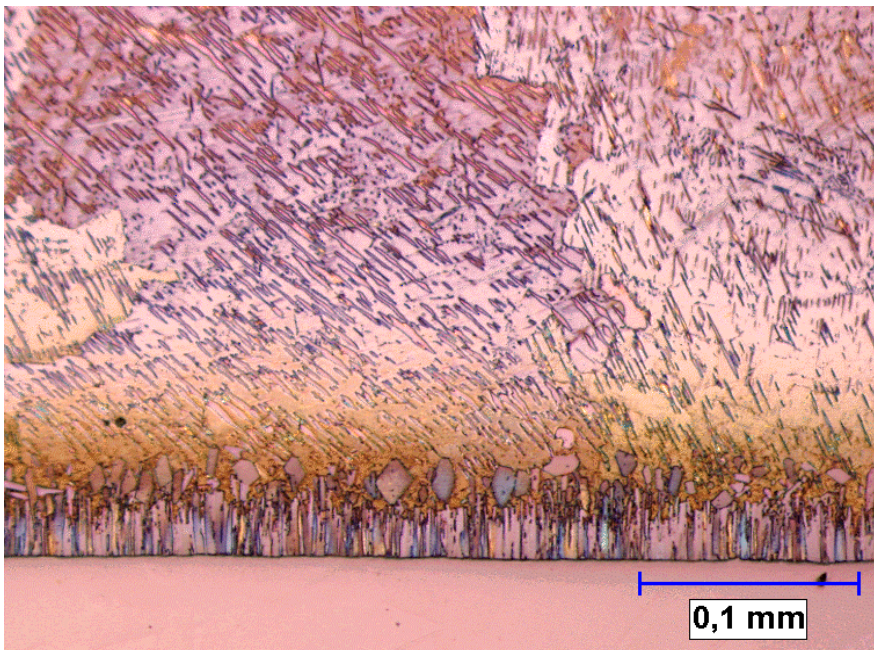


Bi/Ni couple
230°C; 30 min
E: mag. 100×
PC

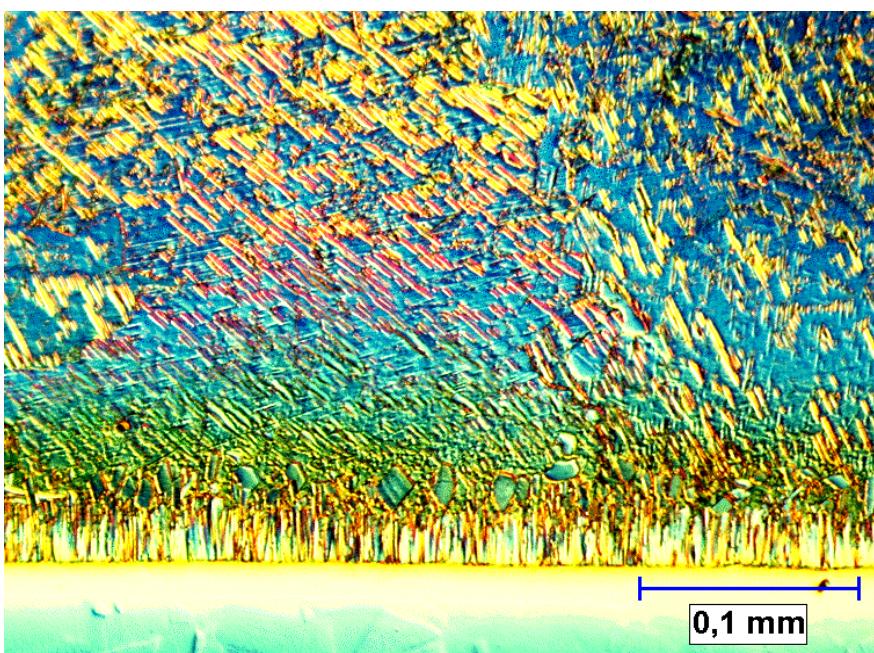




Bi/Ni couple
230°C; 30 min
E: mag. 200×
CL

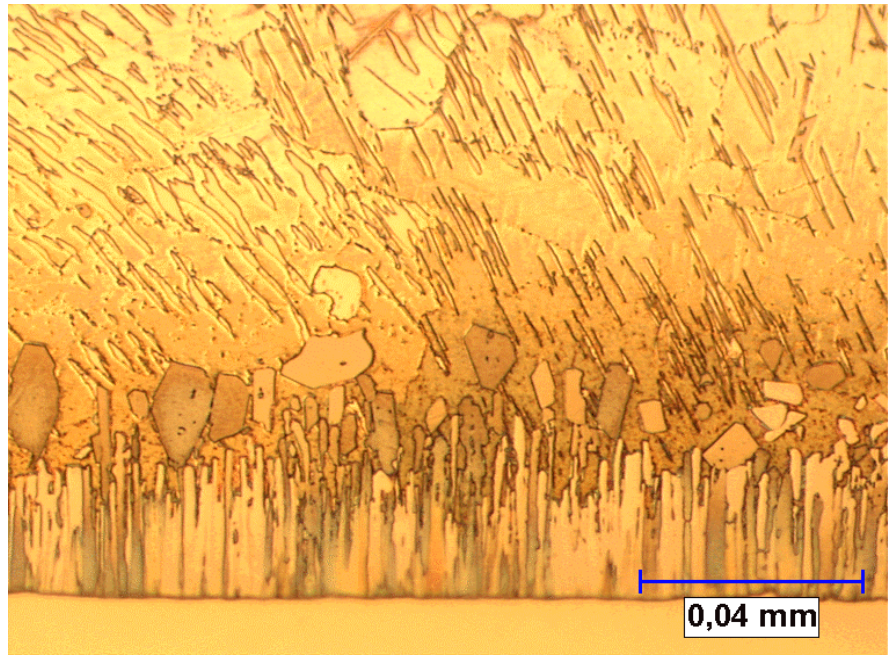


Bi/Ni couple
230°C; 30 min
E: mag. 200×
PL

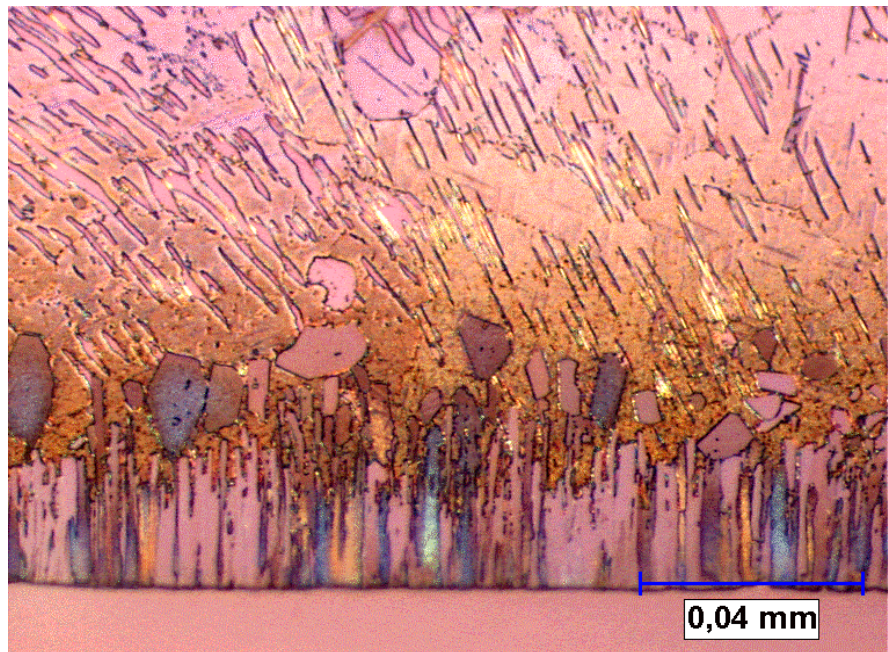


Bi/Ni couple
230°C; 30 min
E: mag. 200×
PC

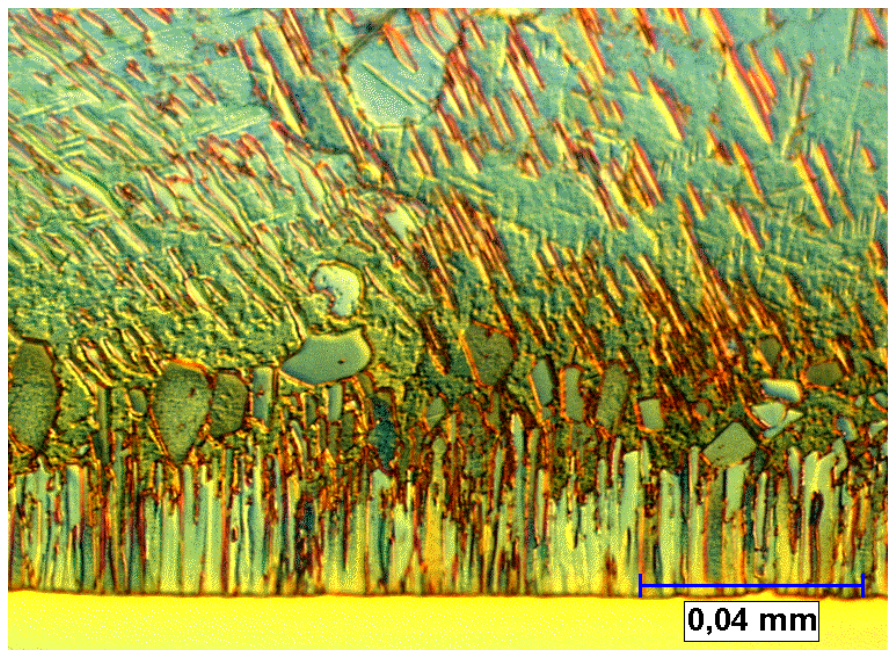
Bi/Ni couple
230°C; 30 min
E: mag. 500×
CL



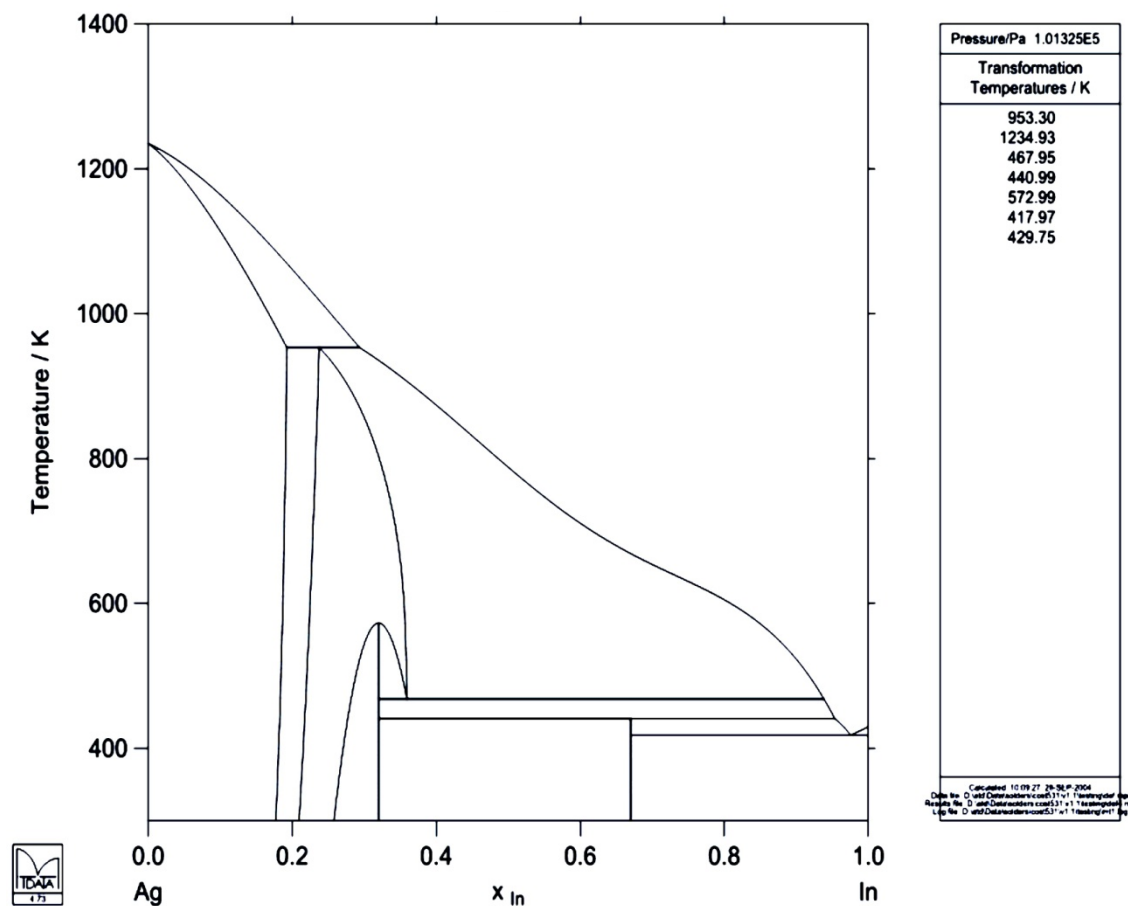
Bi/Ni couple
230°C; 30 min
E: mag. 500×
PL



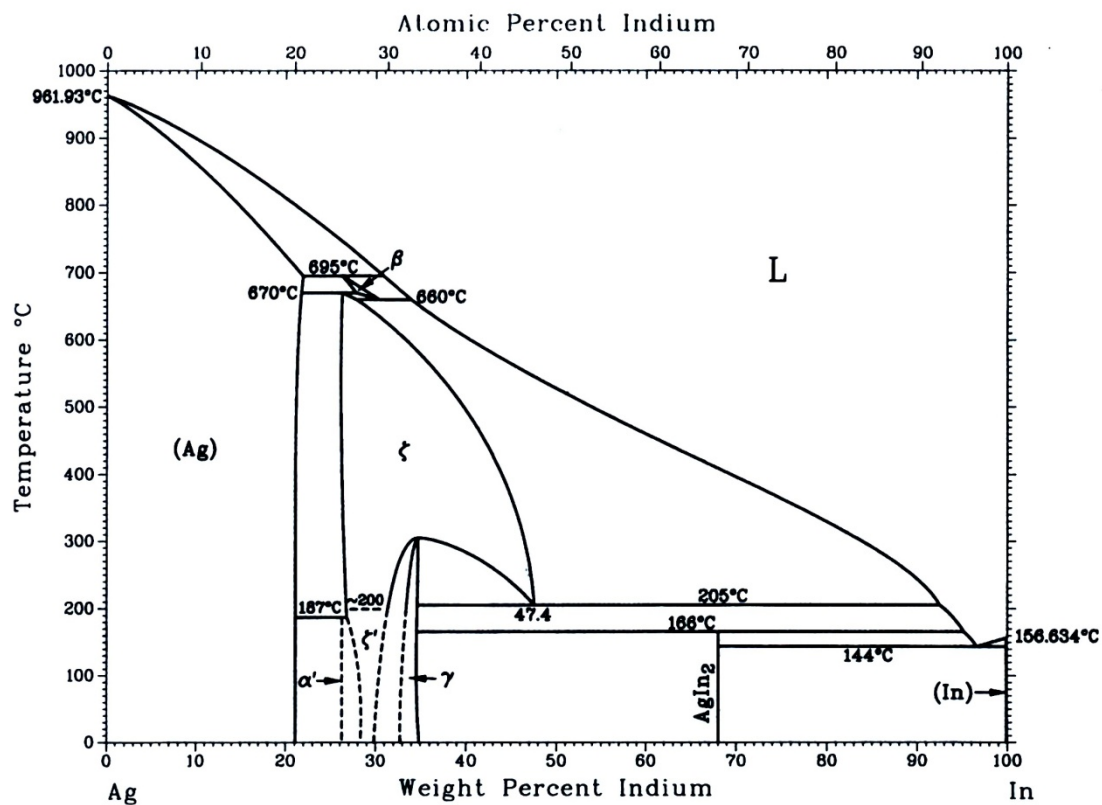
Bi/Ni couple
230°C; 30 min
E: mag. 500×
PC



In – Ag



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•31)

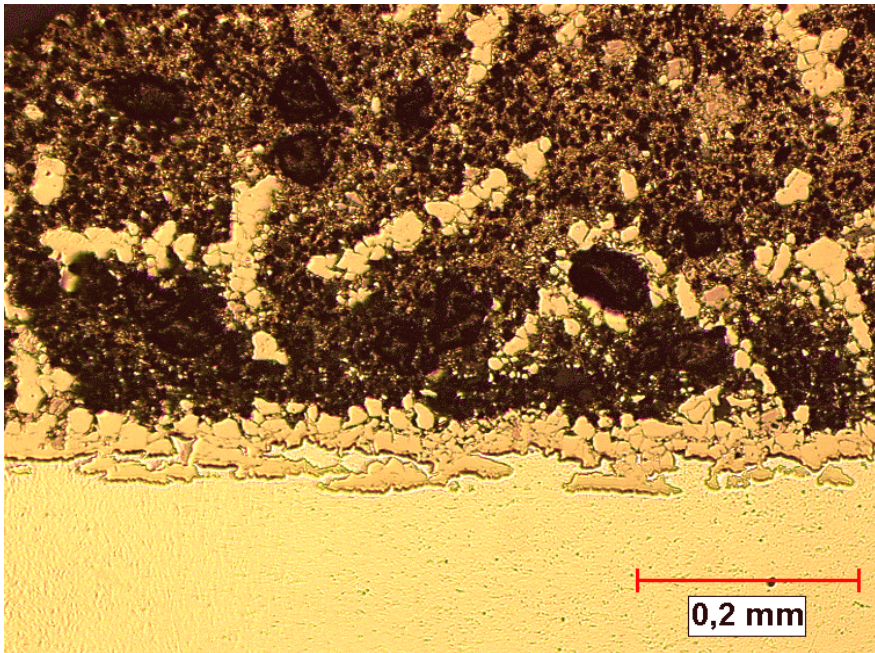
M.R. Baren, 1992

Phase	Composition, wt% In	Pearson symbol	Space group
α (Ag)	0 to 22.1	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
β	26.2 to 31.3	<i>cI2</i>	<i>Im$\bar{3}m$</i>
α' (Ag ₃ In)	26	<i>cP4?</i>	<i>Pm$\bar{3}m?$</i>
ζ	26.2 to 47.6	<i>hP*</i>	...
ζ'	?	<i>hP8</i>	<i>P6₃/mmc</i>
γ (Ag ₂ In)	32.5 to 35.0	<i>cP52</i>	<i>P$\bar{4}3m$</i>
ϕ (AgIn ₂)	68.1	<i>tI12</i>	<i>I4/mcm</i>
(In)	100	<i>tI2</i>	<i>I4/mmm</i>
Metastable phases			
...	19.4	<i>hP2</i>	<i>P6₃/mmc</i>
...	71 to 81	<i>cF4</i>	<i>Fm$\bar{3}m$</i>

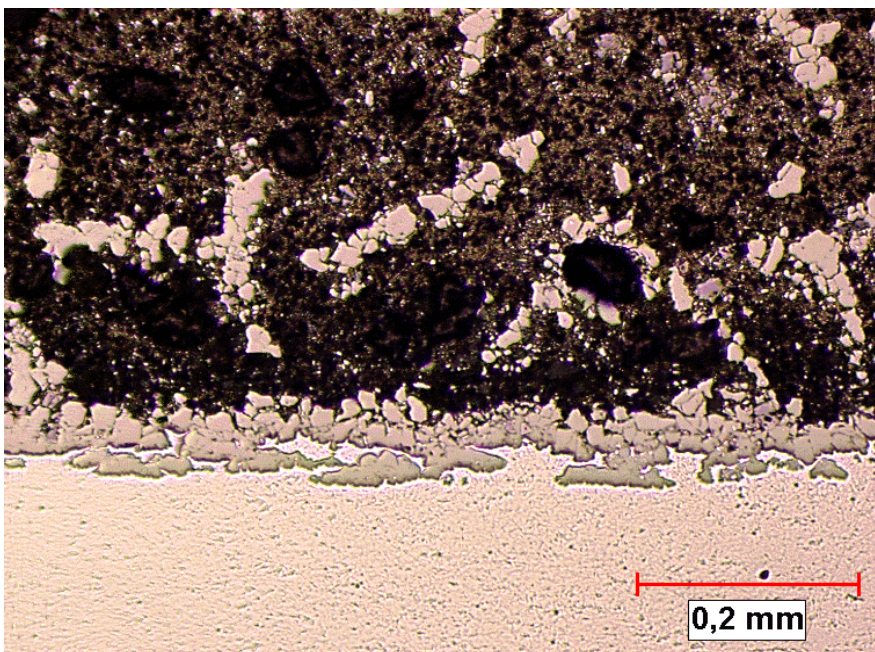
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•31)

Properties of solder/substrate couples

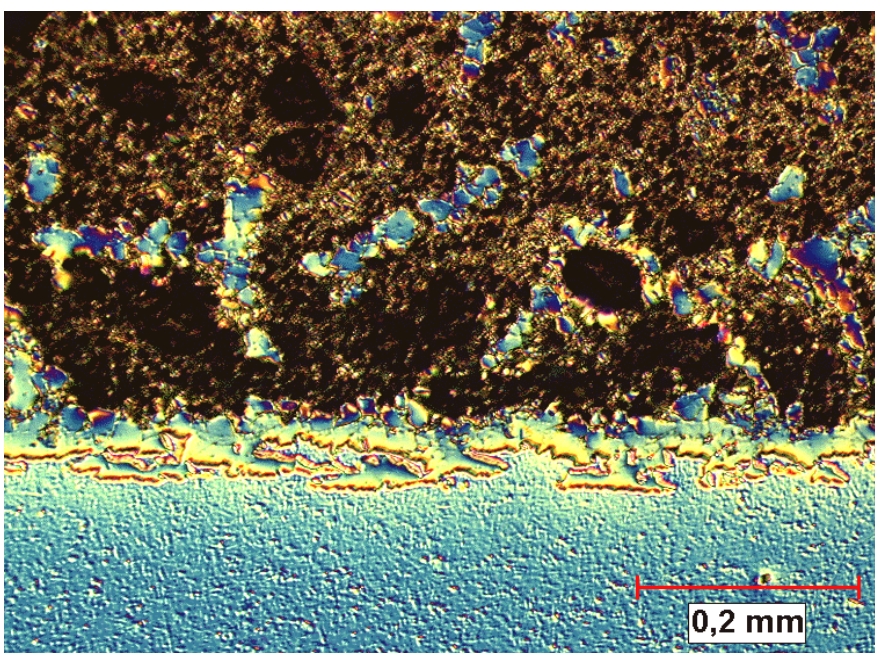
Couple	Conditions	θ , deg	τ , MPa
In / Ag	230°C, 5 min, flux	31°	9
In / Ag	230°C, 30 min, flux	20°	8



In/Ag couple
230°C; 5 min
E: mag. 100×
CL

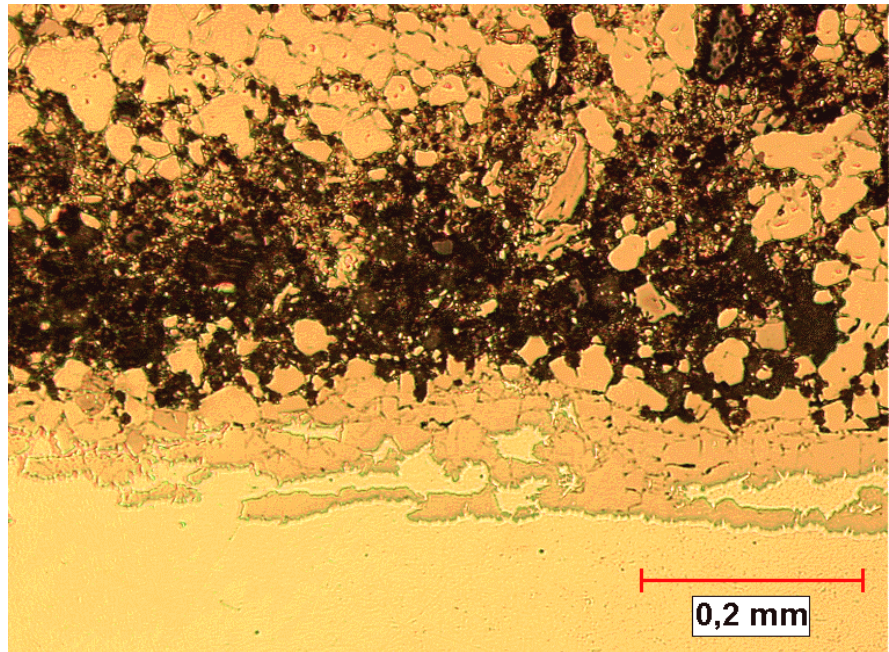


In/Ag couple
230°C; 5 min
E: mag. 100×
PL

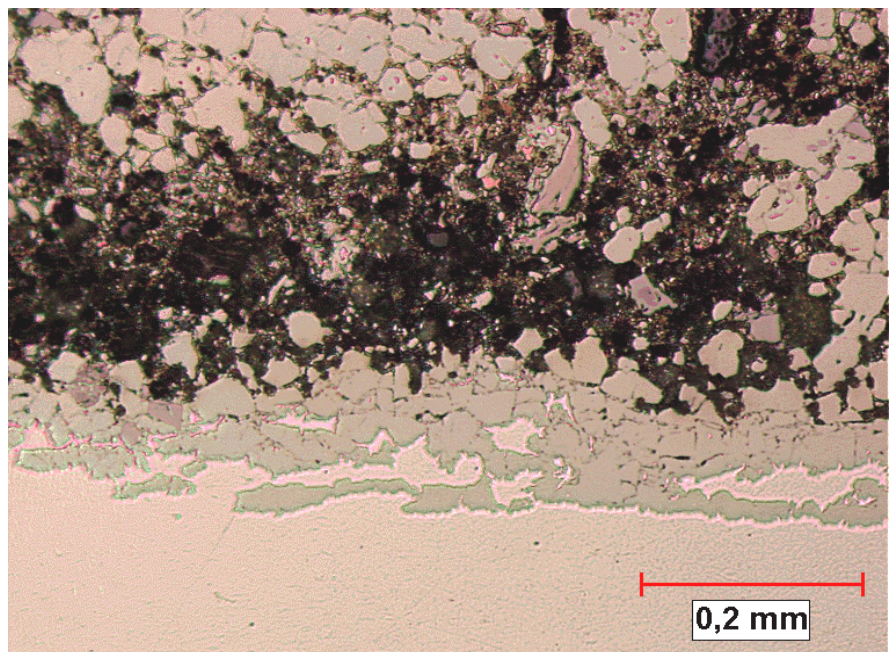


In/Ag couple
230°C; 5 min
E: mag. 100×
PC

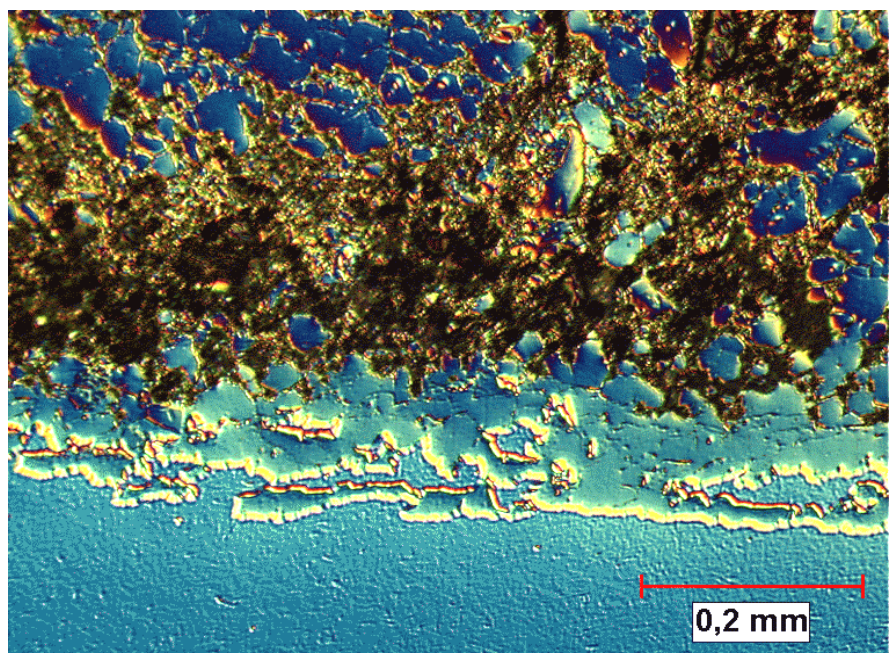
In/Ag couple
230°C; 5 min
E: mag. 200×
CL

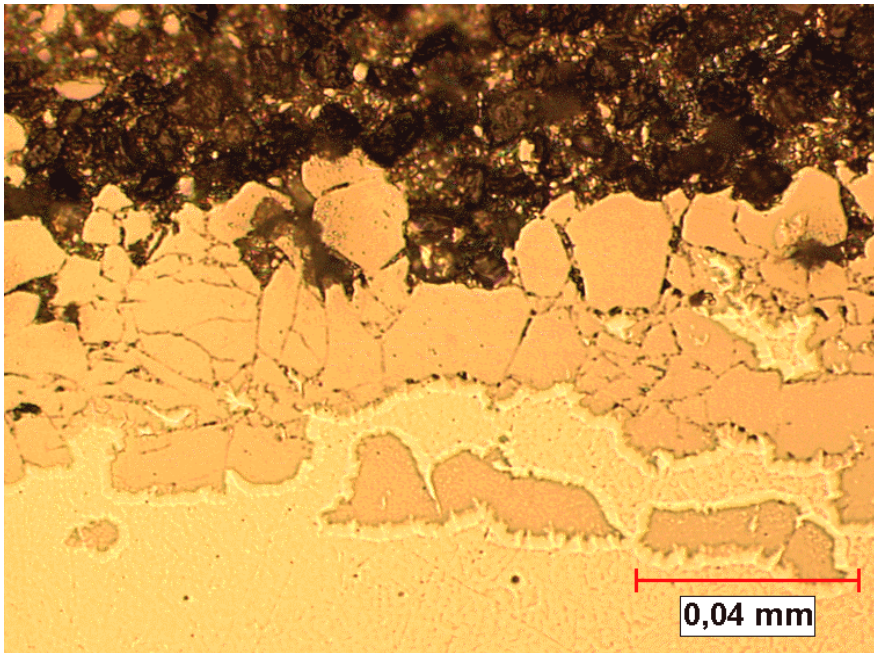


In/Ag couple
230°C; 5 min
E: mag. 200×
PL

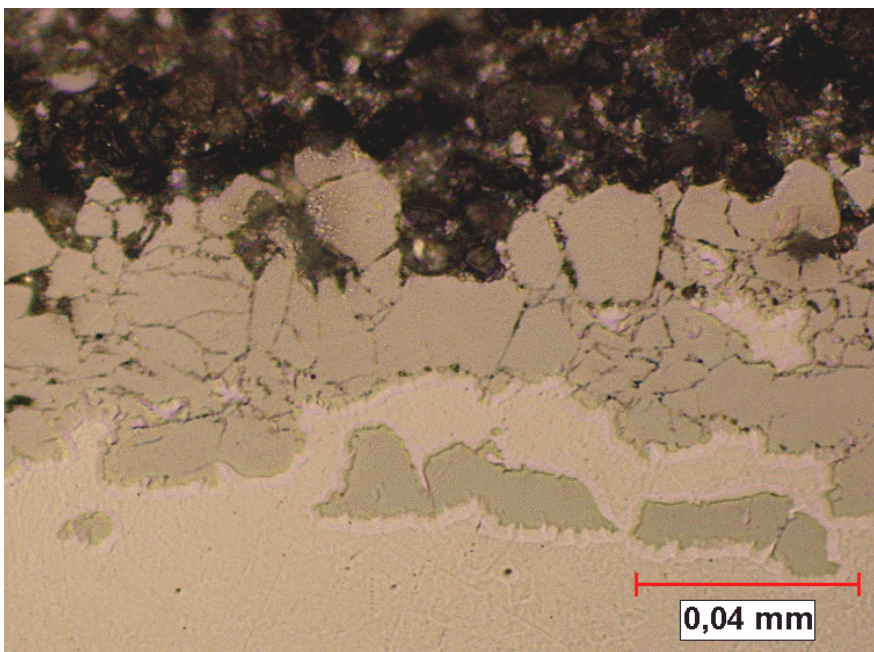


In/Ag couple
230°C; 5 min
E: mag. 200×
PC

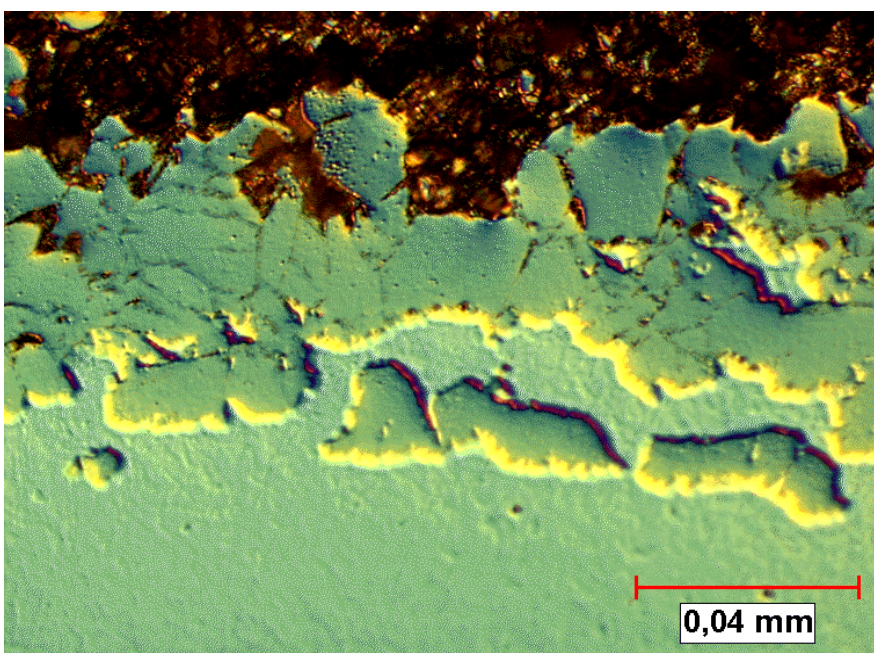




In/Ag couple
230°C; 5 min
E: mag. 500×
CL

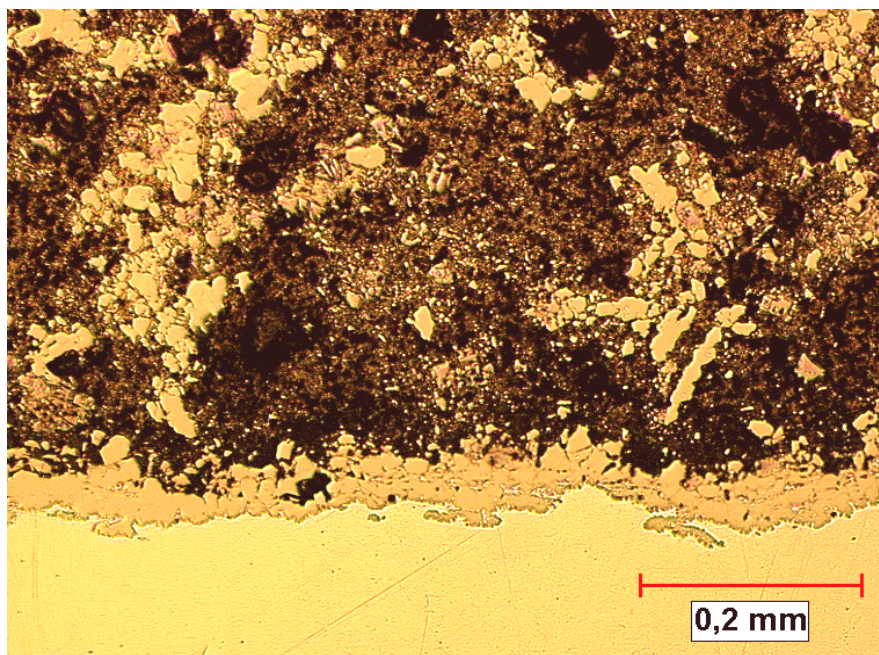


In/Ag couple
230°C; 5 min
E: mag. 500×
PL

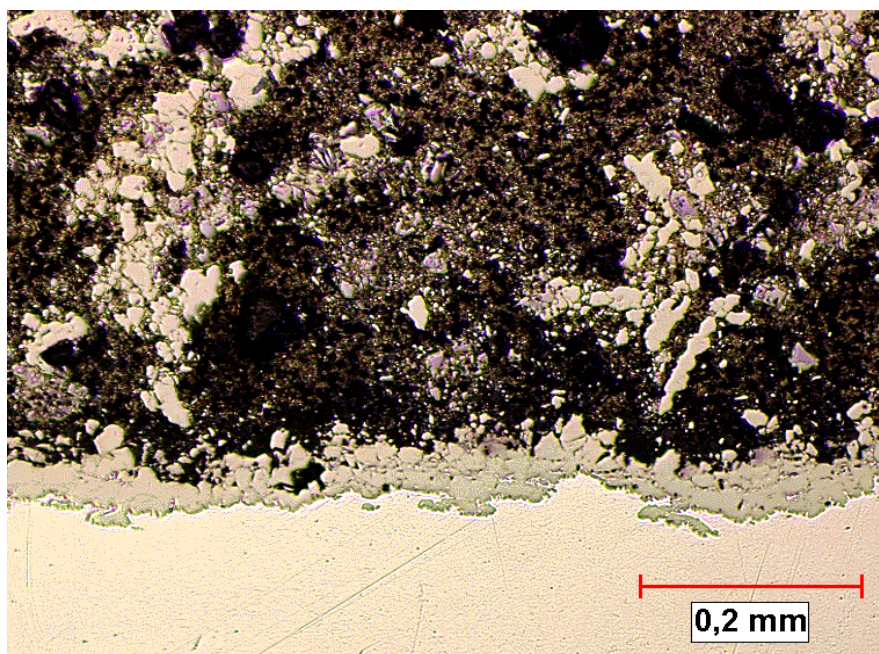


In/Ag couple
230°C; 5 min
E: mag. 500×
PC

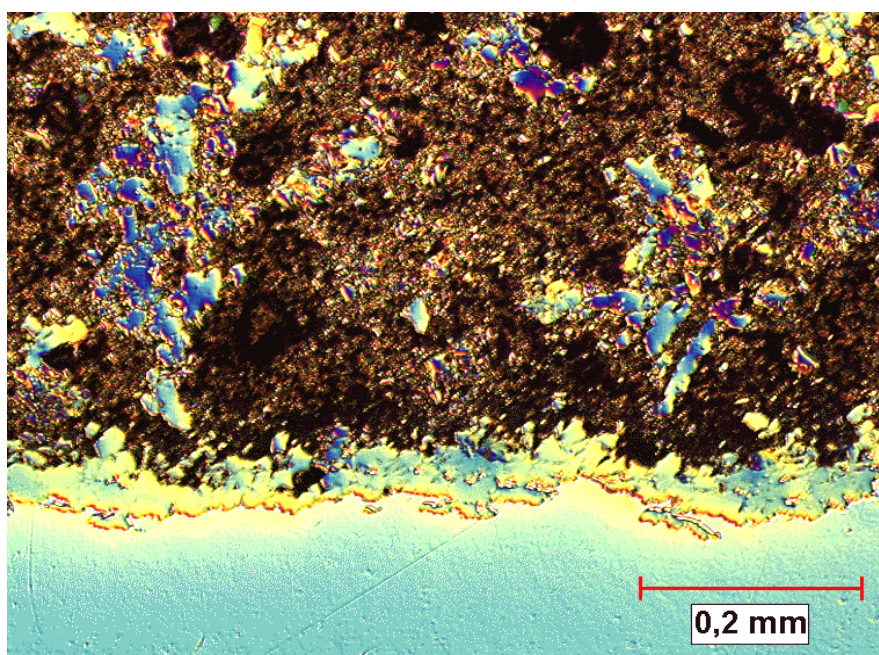
In/Ag couple
230°C; 30 min
E: mag. 100×
CL

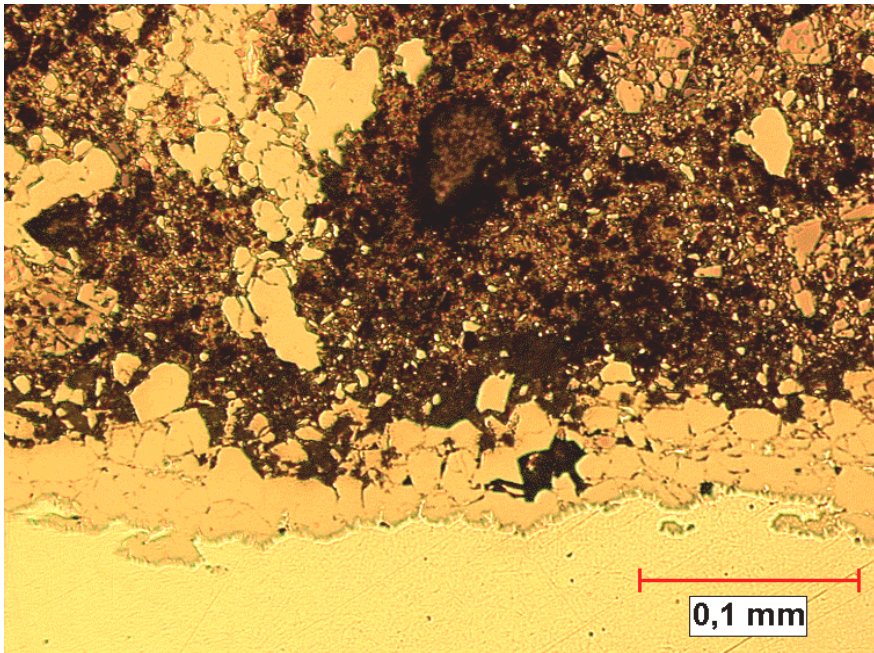


In/Ag couple
230°C; 30 min
E: mag. 100×
PL

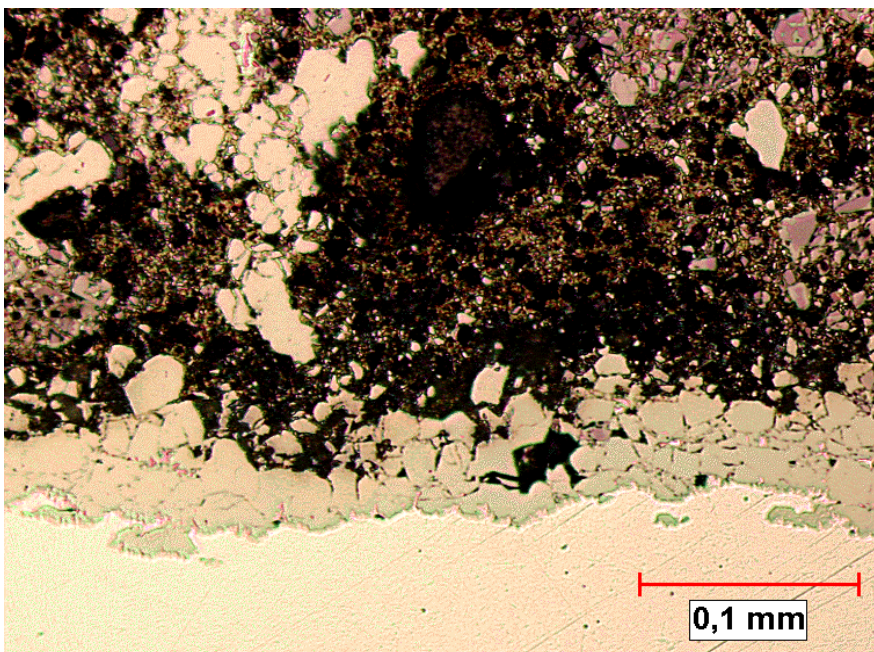


In/Ag couple
230°C; 30 min
E: mag. 100×
PC

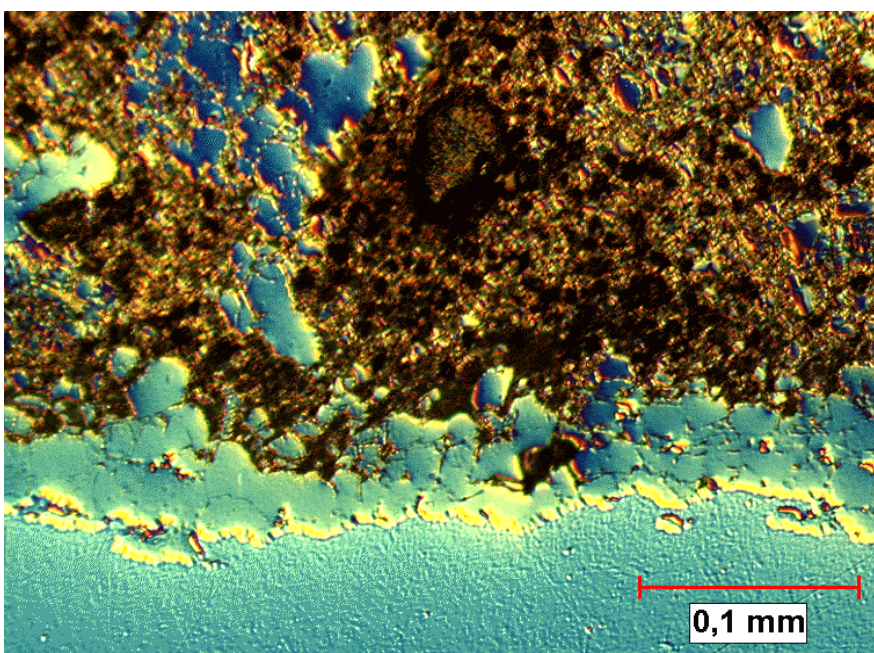




In/Ag couple
230°C; 30 min
E: mag. 200×
CL

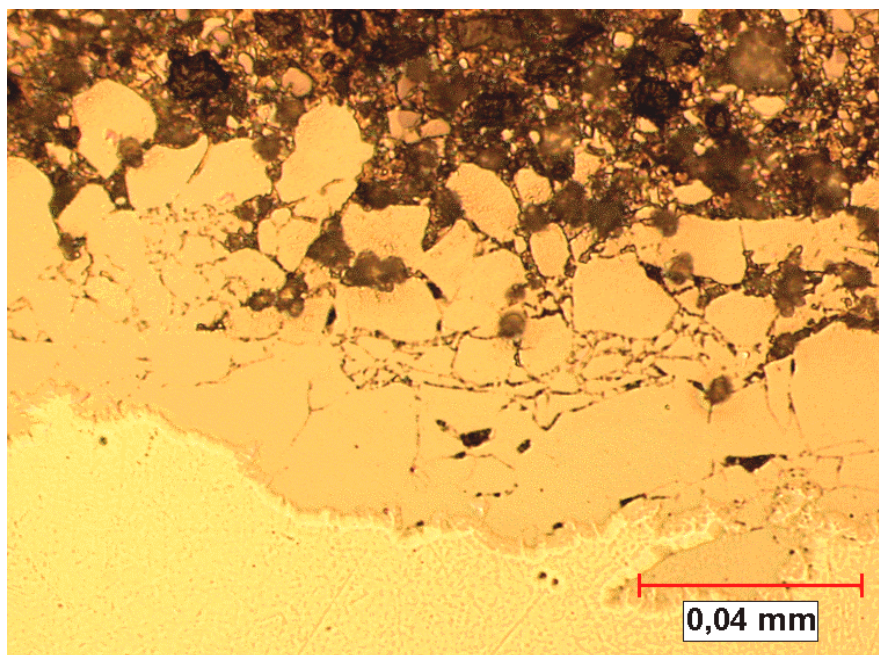


In/Ag couple
230°C; 30 min
E: mag. 200×
PL

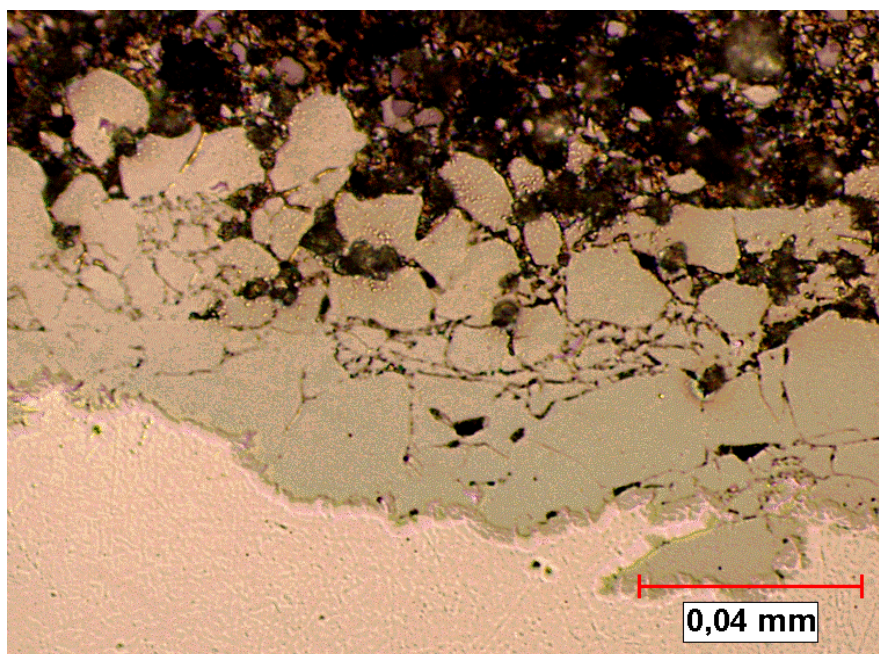


In/Ag couple
230°C; 30 min
E: mag. 200×
PC

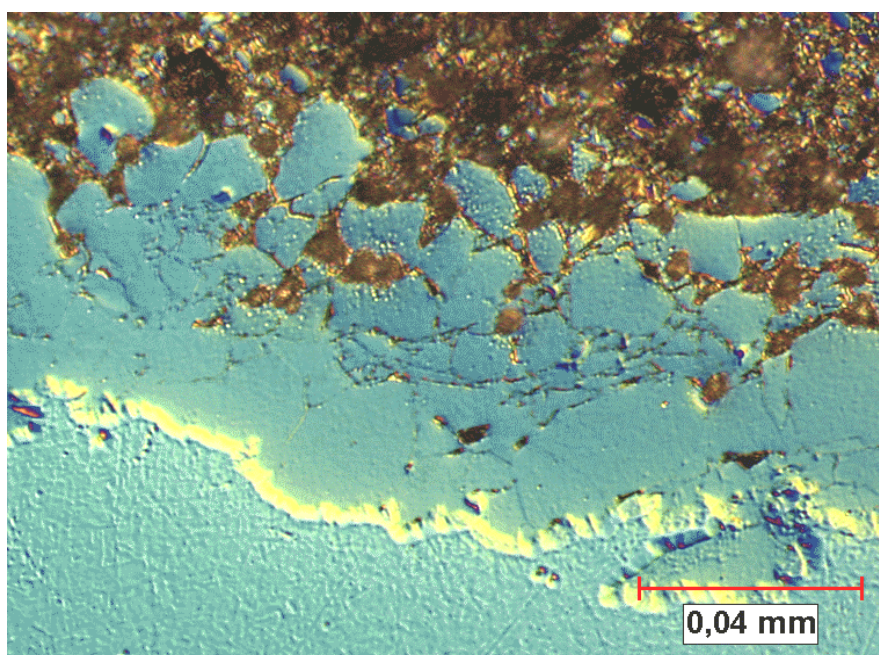
In/Ag couple
230°C; 30 min
E: mag. 500×
CL



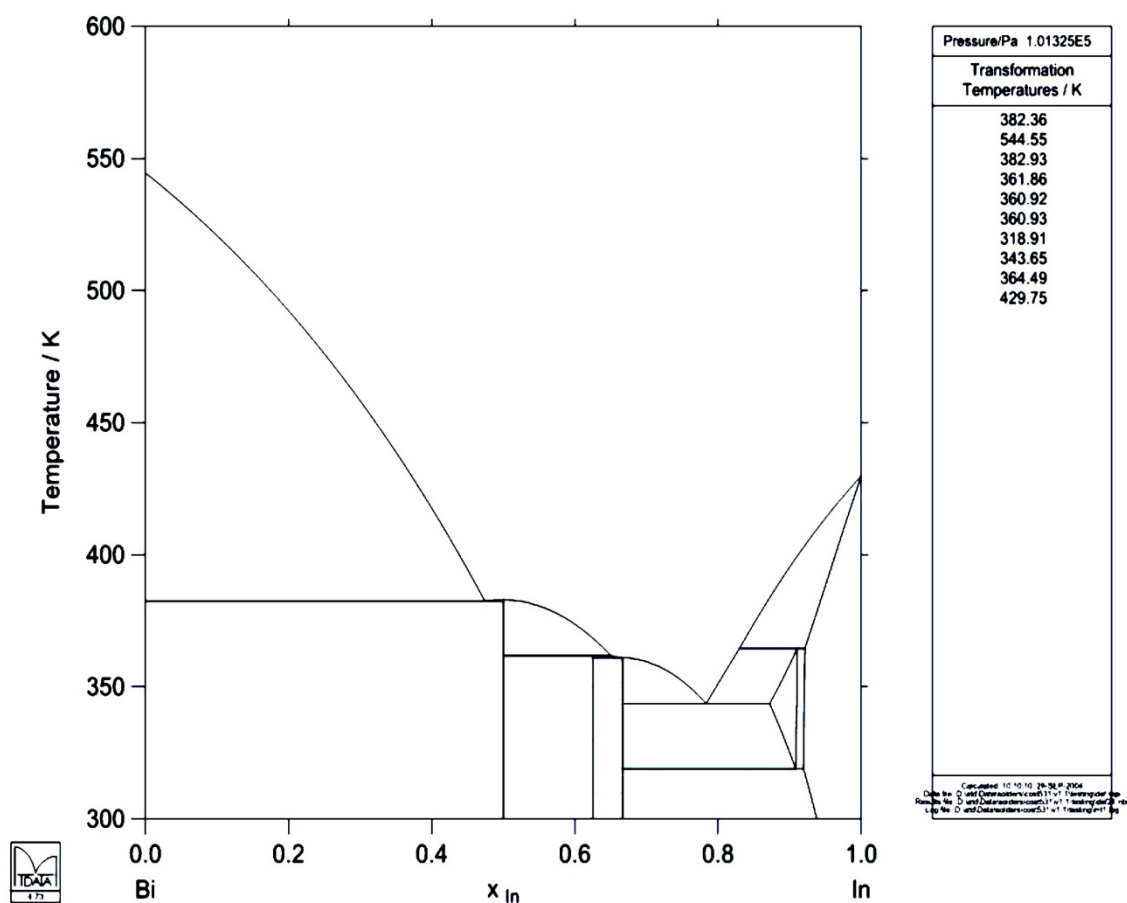
In/Ag couple
230°C; 30 min
E: mag. 500×
PL



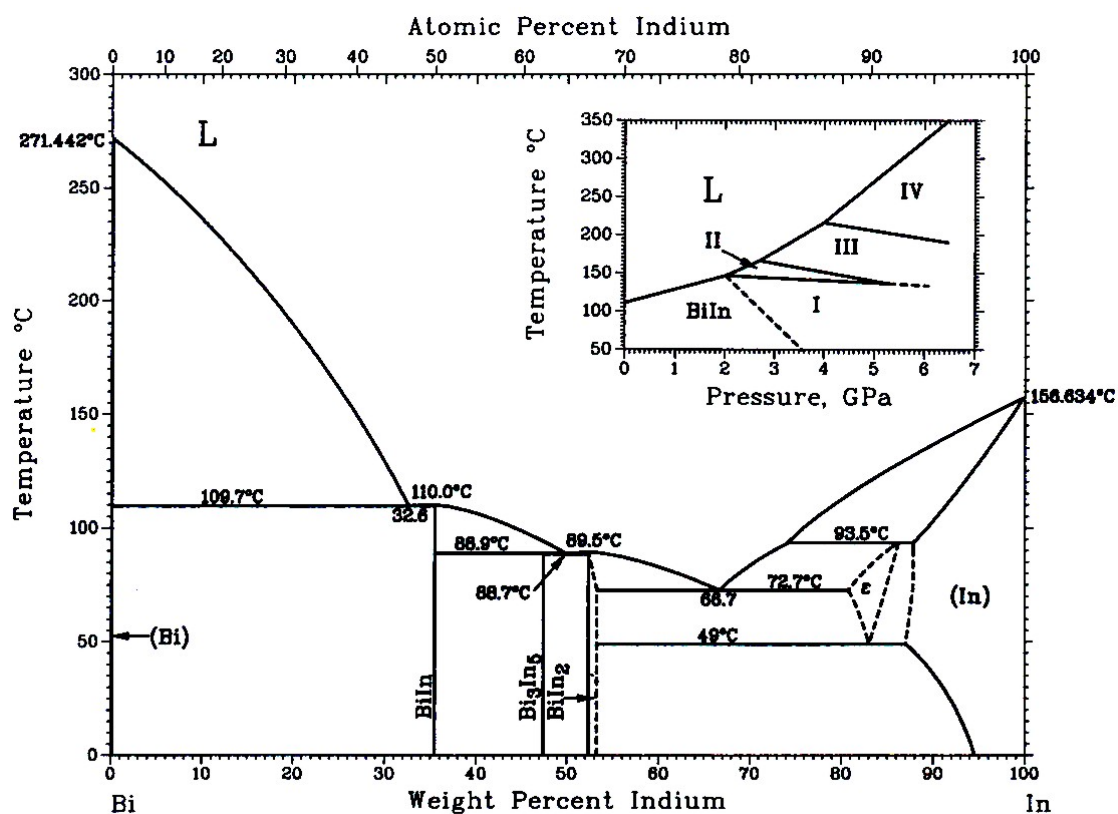
In/Ag couple
230°C; 30 min
E: mag. 500×
PC



In – Bi



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•100)

H. Okamoto, 1992

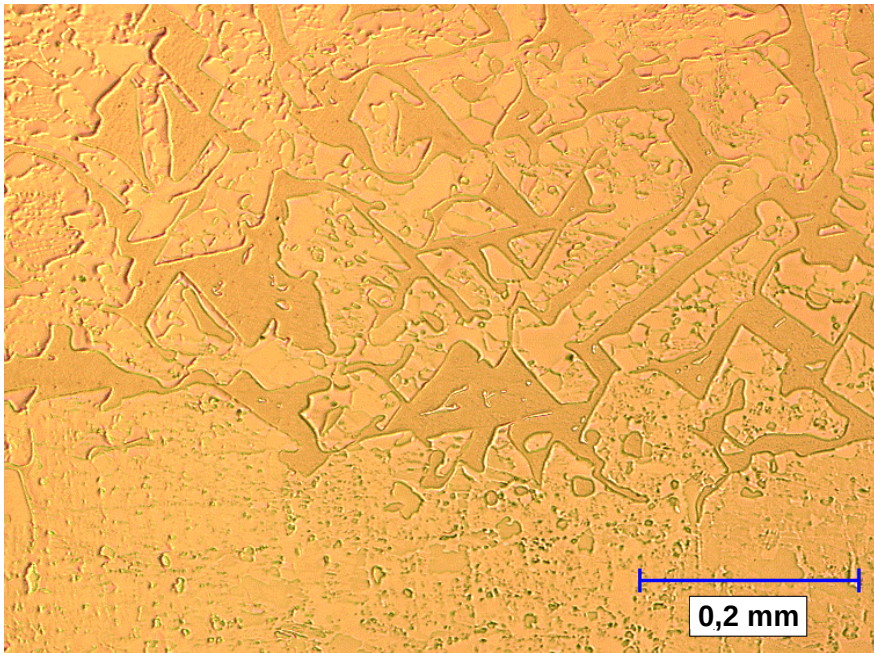
Phase	Composition, wt% In	Pearson symbol	Space group
Stable phases			
(α Bi)	0 to 0.005	<i>hR2</i>	<i>R$\bar{3}m$</i>
BiIn	35.4	<i>tP4</i>	<i>P4/nmm</i>
Bi ₃ In ₅	47.5 to 47.97	<i>tI32</i>	<i>I4/mcm</i>
BiIn ₂	52.5 to 53.5	<i>hP6</i>	<i>P6₃/mmc</i>
ϵ	80 to 86	<i>tI2</i>	...
(In)	~86 to 100	<i>tI2</i>	<i>I4/mmm</i>
High-pressure/metastable phases			
(γ Bi)	0	<i>mP4</i>	<i>P2₁/m</i>
(β Bi)	0	<i>mC4</i>	<i>C2/m</i>
Bi ₄ In	12	<i>tI4</i>	<i>I4₁/amd</i>
Bi ₃ In	~15	<i>oI*</i>	<i>Immb</i>
γ	12 to 42	<i>hP1</i>	<i>P6/mmm</i>
γ_1	21 to 35.4	<i>oI*</i>	...
γ_2	21 to 35.4	<i>oI*</i>	...
X	21 to 35.4	<i>oI*</i>	...
BiIn'	35.4	<i>tP4</i>	<i>P4/nmm</i>
α_2	45 to 51	<i>cI2</i>	<i>Im$\bar{3}m$</i>
Bi ₂ In ₃ (a)	45	<i>hP*</i>	...
BiIn ₃	62	<i>t**</i>	...
α_1	~59 to 76	<i>tI2</i>	<i>I4/mmm</i>
(a) Thin film. Probably Bi ₃ In ₅			

Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•100)

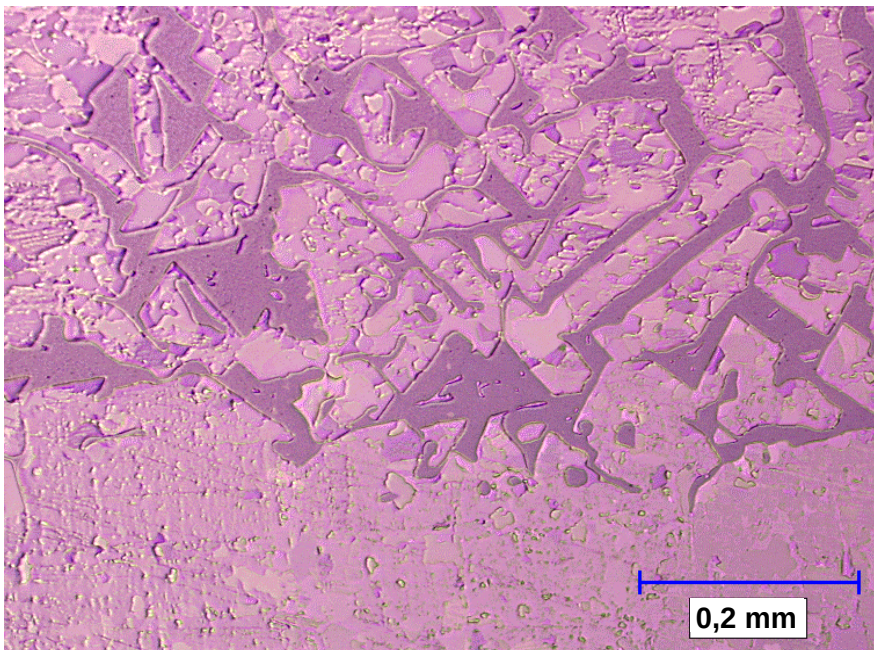
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
In / Bi	230°C, 5 min, flux	~0°	*
In / Bi	230°C, 30 min, flux	~0°	*

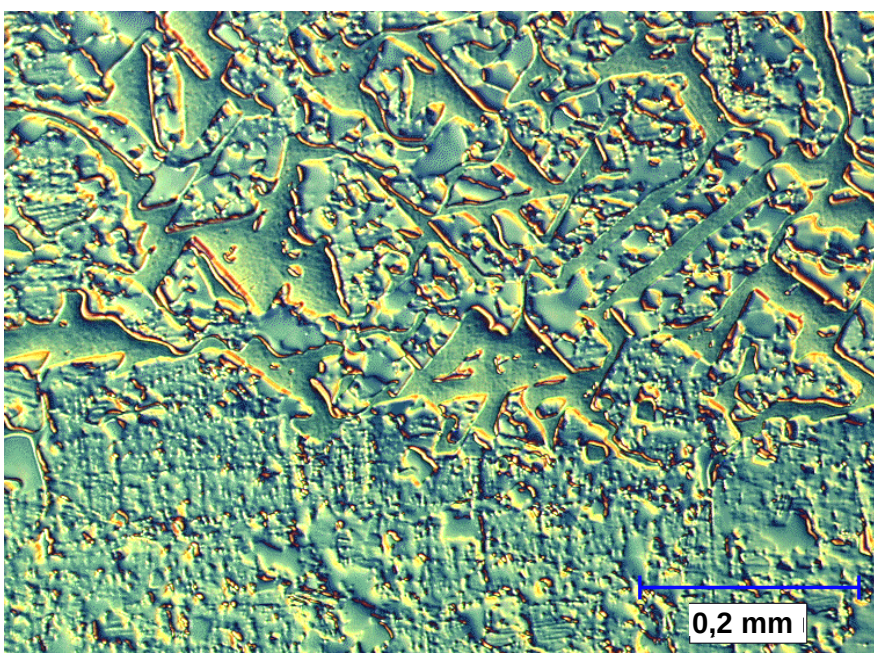
* impossible to measure due to a low contact angle



In/Bi couple
230°C; 5 min
E: mag. 100×
CL

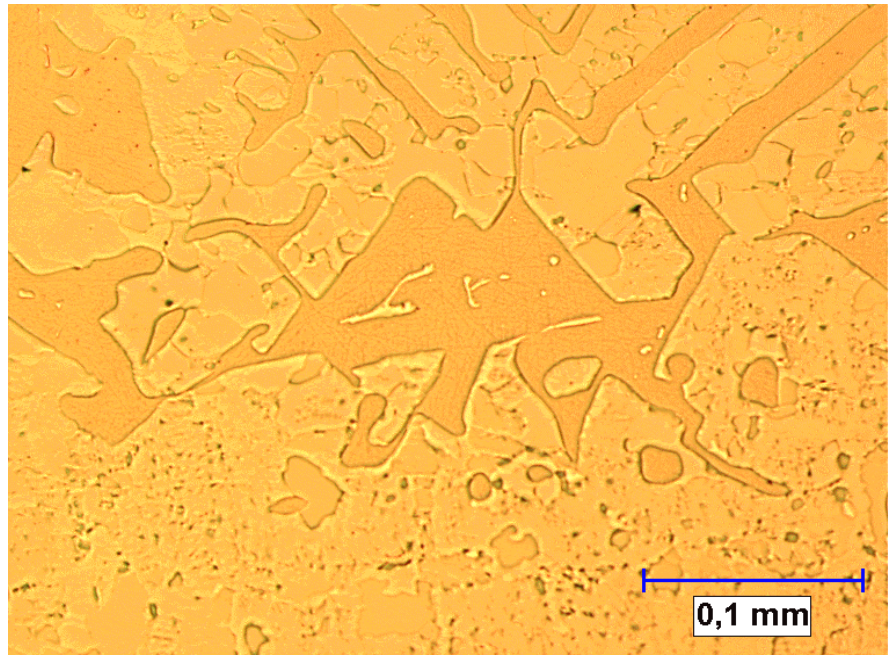


In/Bi couple
230°C; 5 min
E: mag. 100×
PL

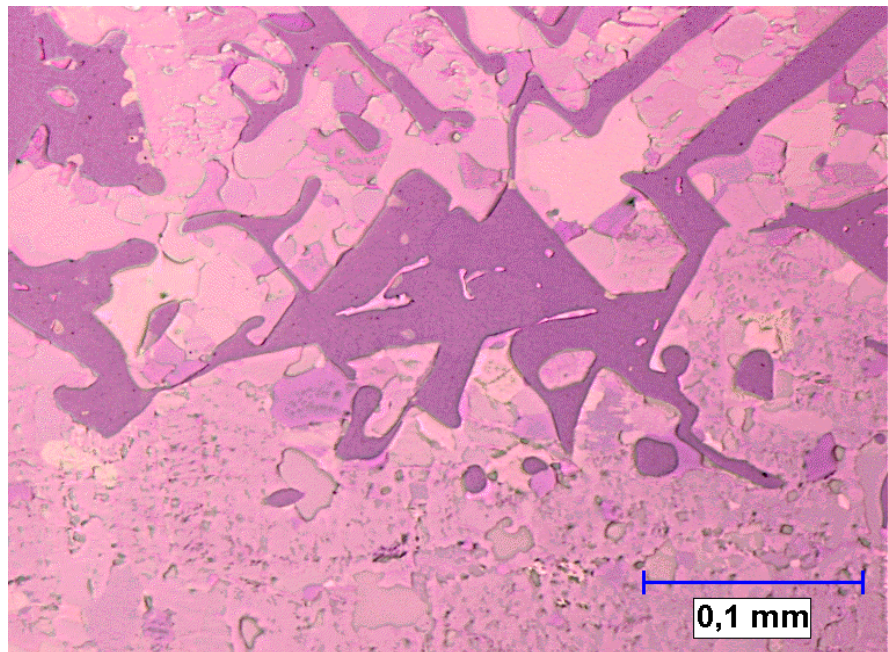


In/Bi couple
230°C; 5 min
E: mag. 100×
PC

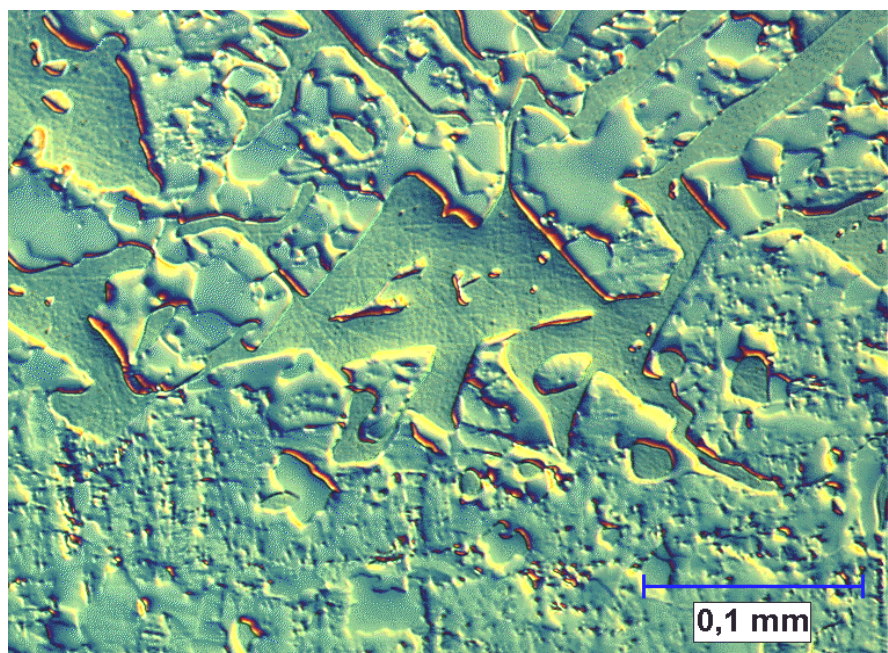
In/Bi couple
230°C; 5 min
E: mag. 200×
CL

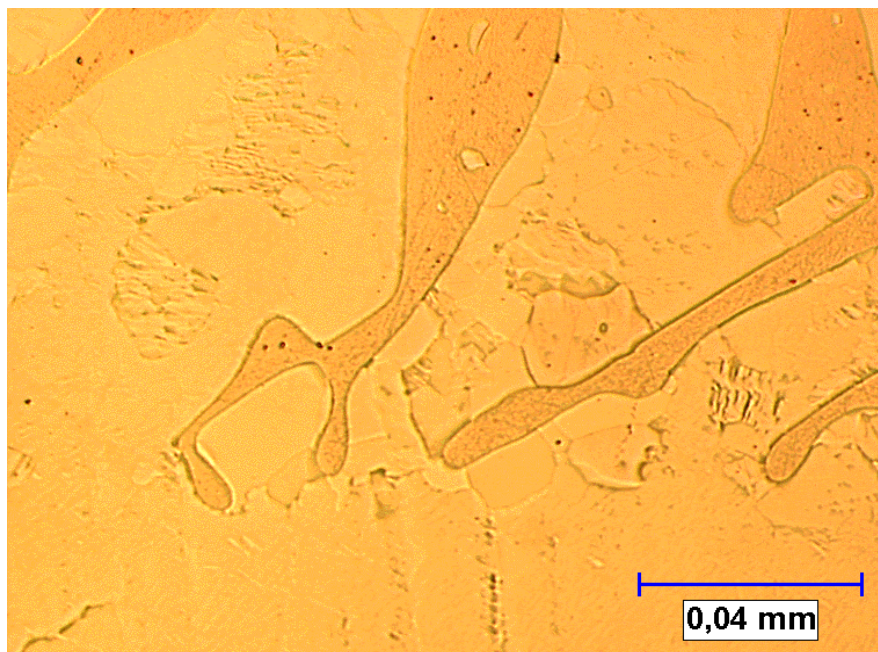


In/Bi couple
230°C; 5 min
E: mag. 200×
PL

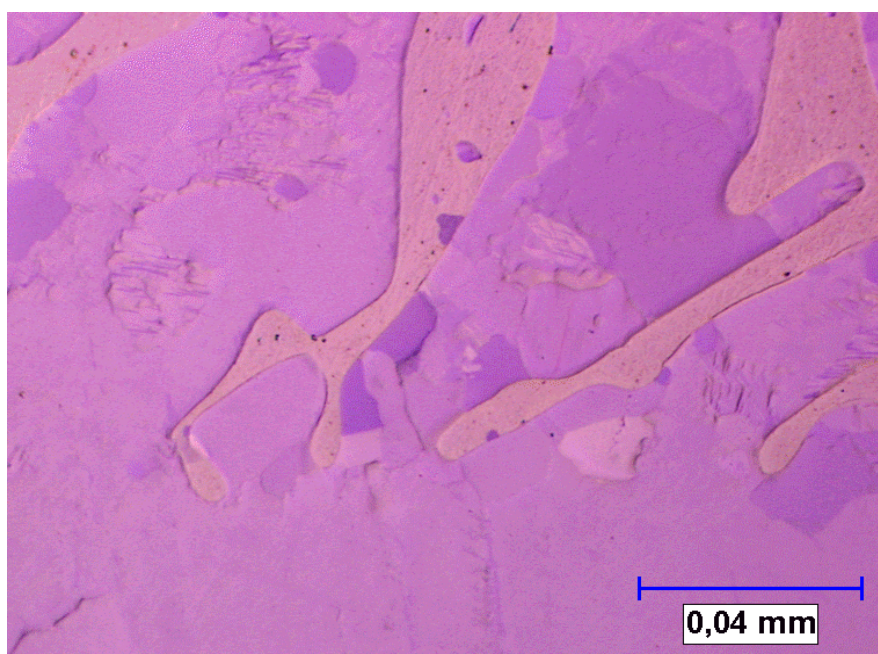


In/Bi couple
230°C; 5 min
E: mag. 200×
PC

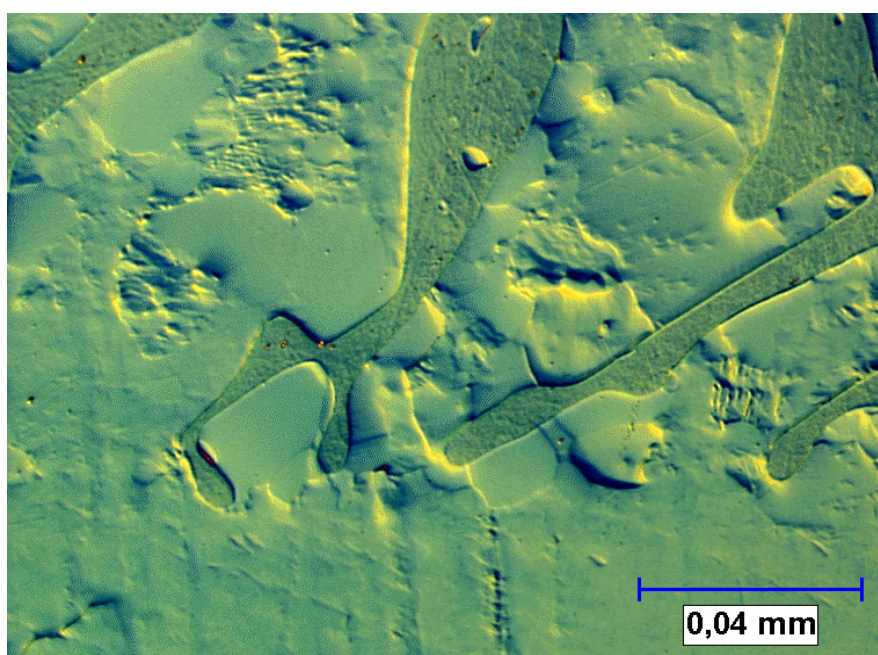




In/Bi couple
230°C; 5 min
E: mag. 500×
CL

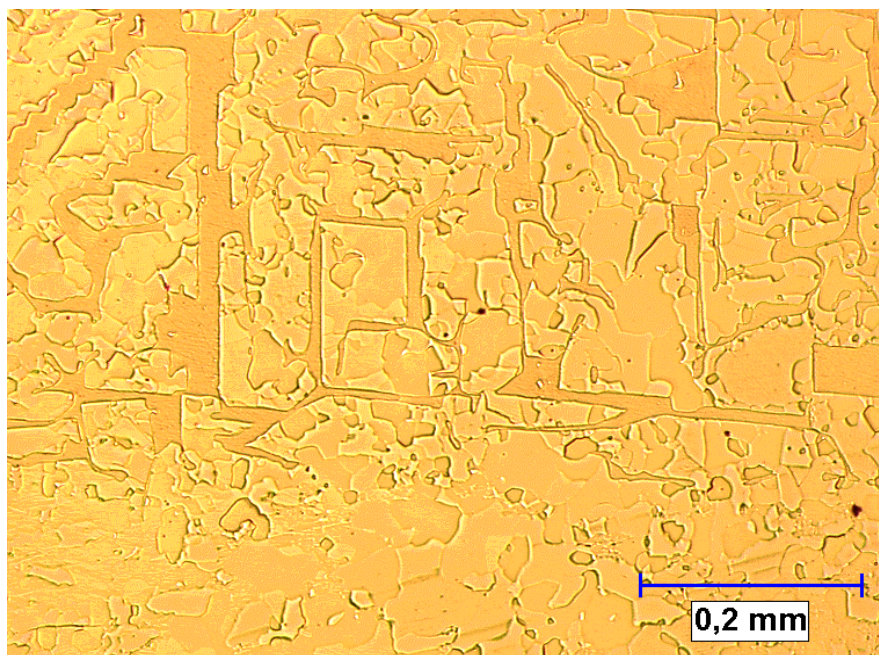


In/Bi couple
230°C; 5 min
E: mag. 500×
PL

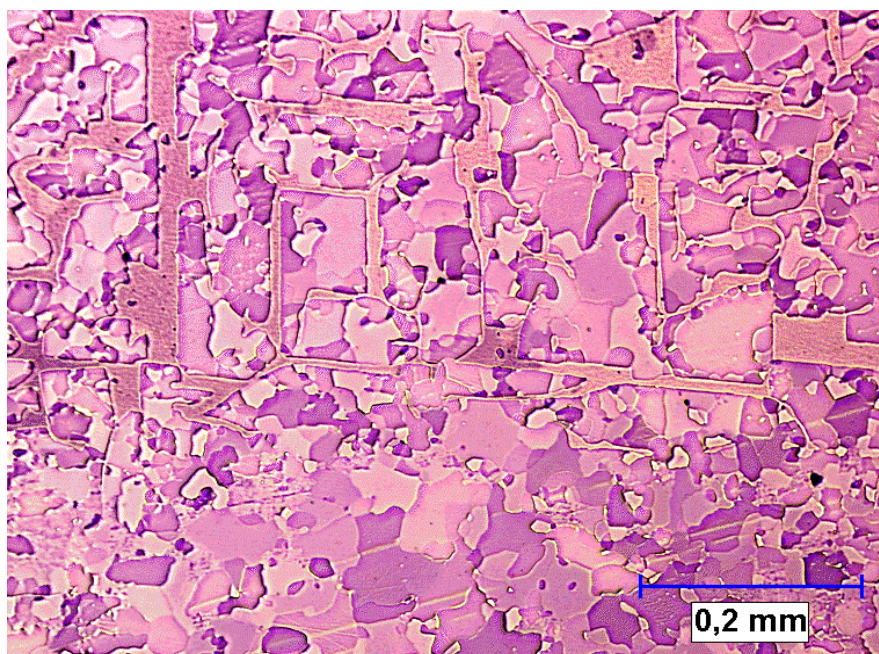


In/Bi couple
230°C; 5 min
E: mag. 500×
PC

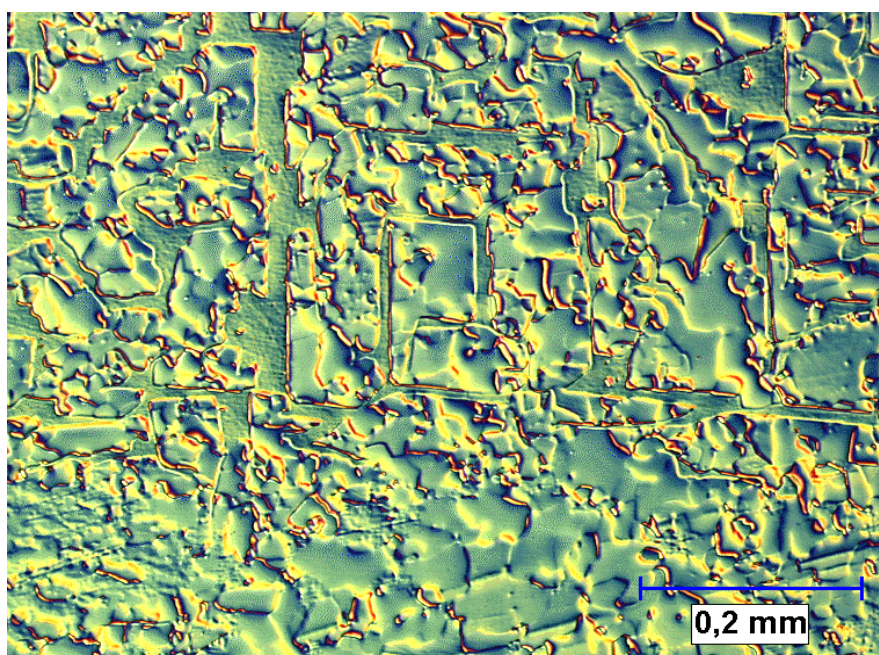
In/Bi couple
230°C; 30 min
E: mag. 100×
CL

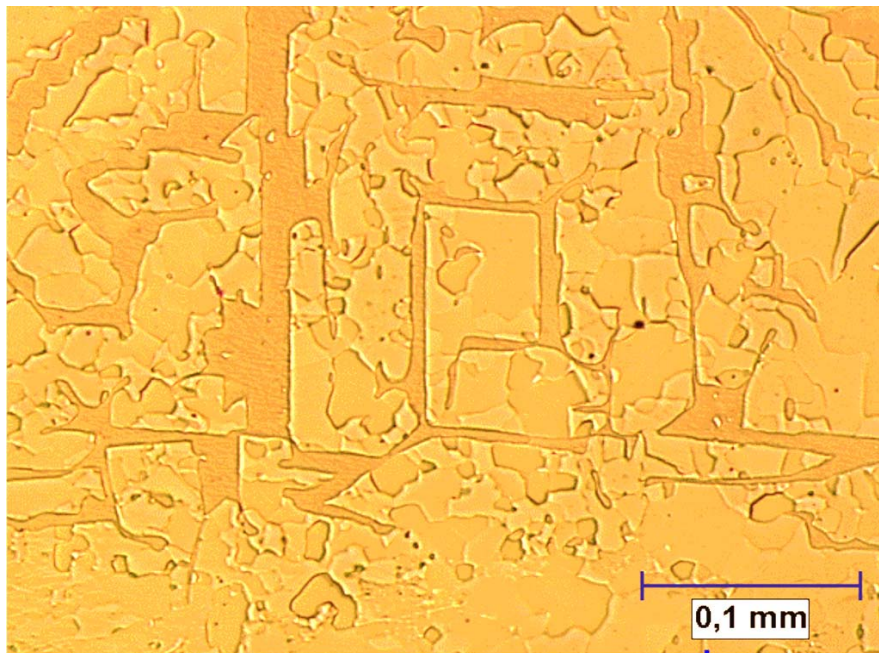


In/Bi couple
230°C; 30 min
E: mag. 100×
PL

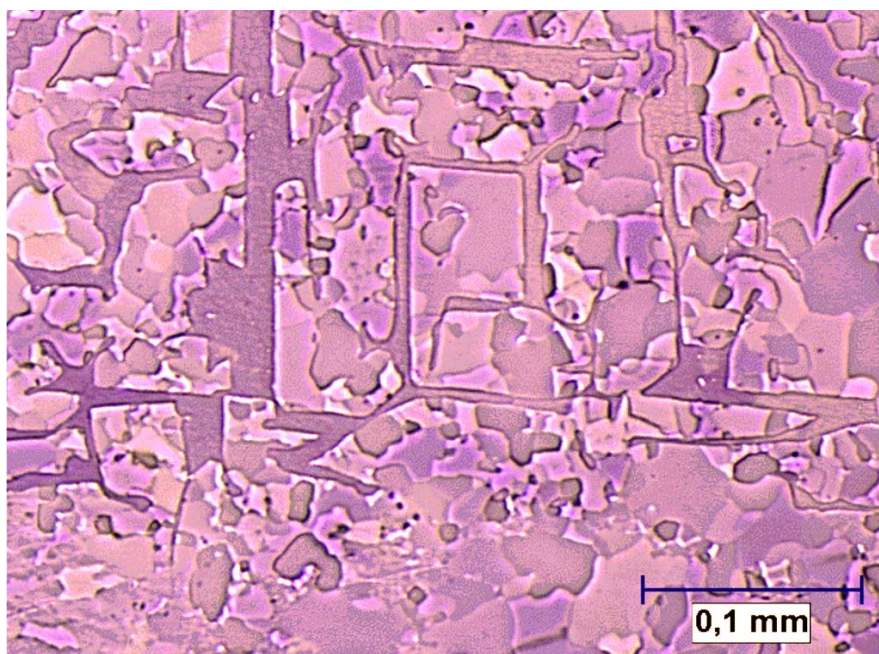


In/Bi couple
230°C; 30 min
E: mag. 100×
PC

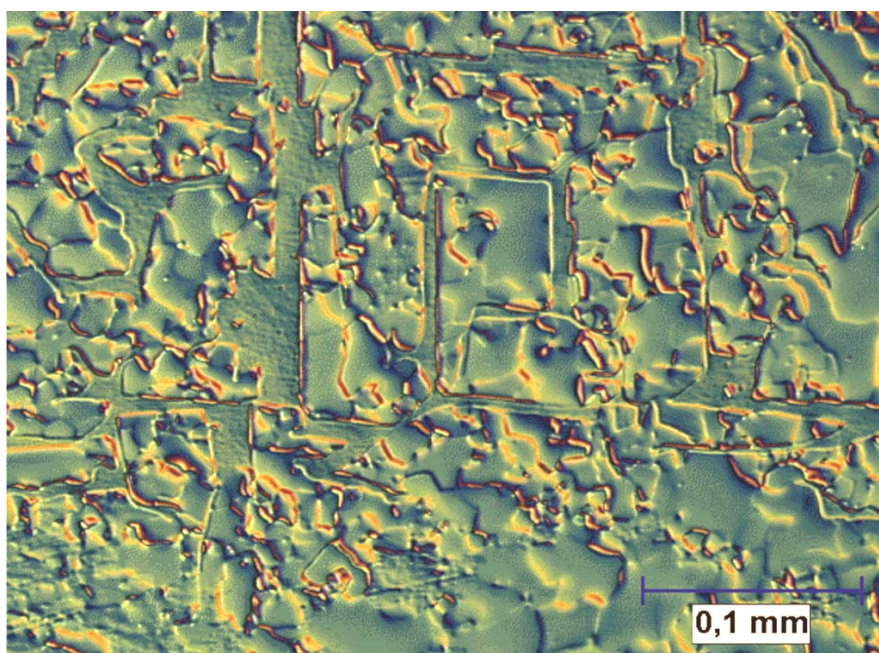




In/Bi couple
230°C; 30 min
E: mag. 200×
CL

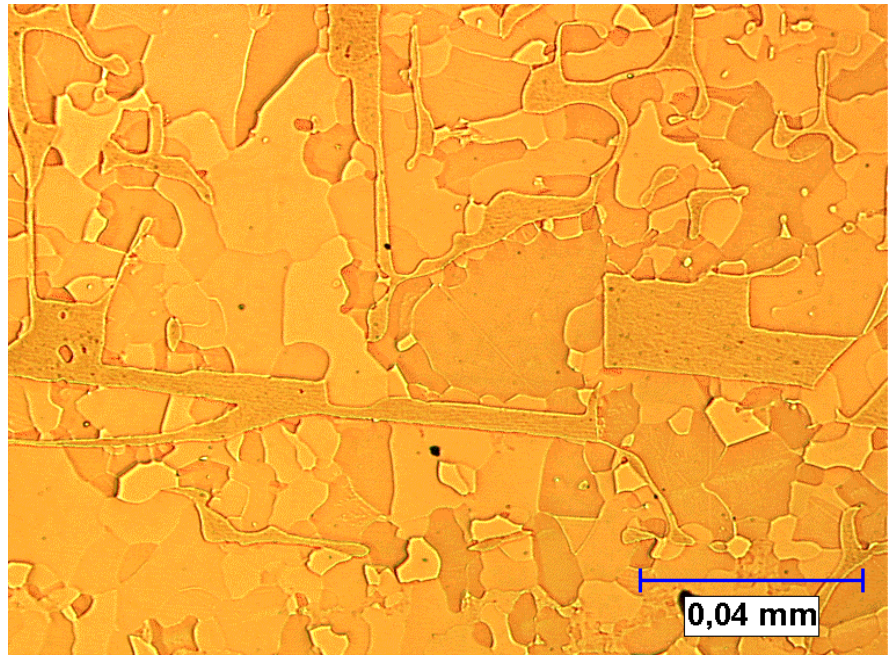


In/Bi couple
230°C; 30 min
E: mag. 200×
PL

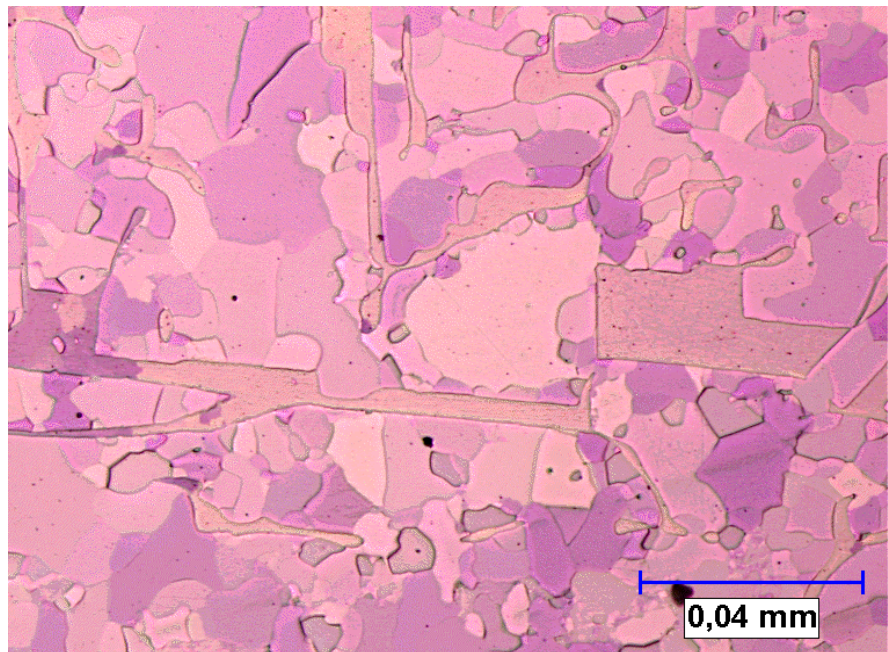


In/Bi couple
230°C; 30 min
E: mag. 200×
PC

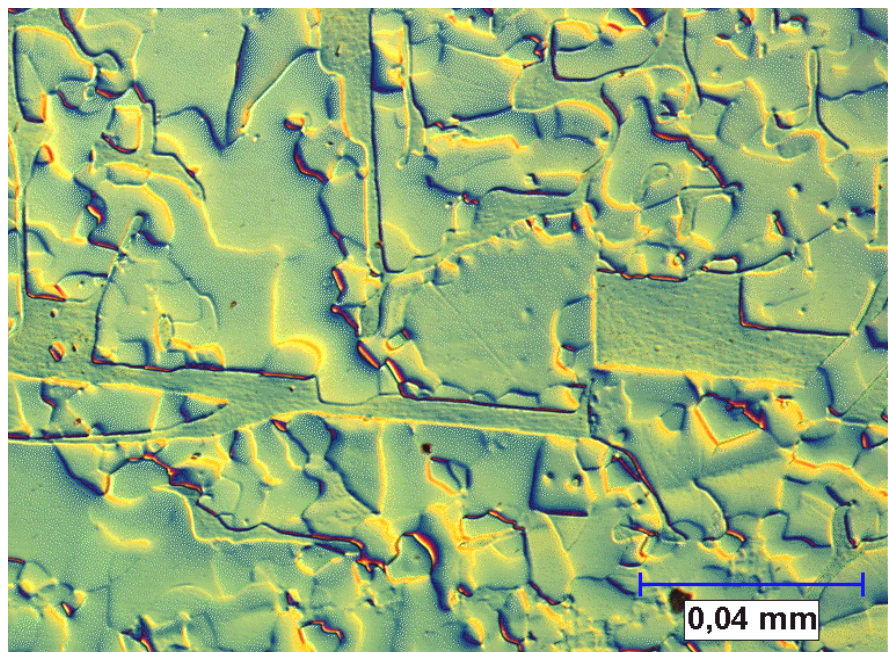
In/Bi couple
230°C; 30 min
E: mag. 500×
CL



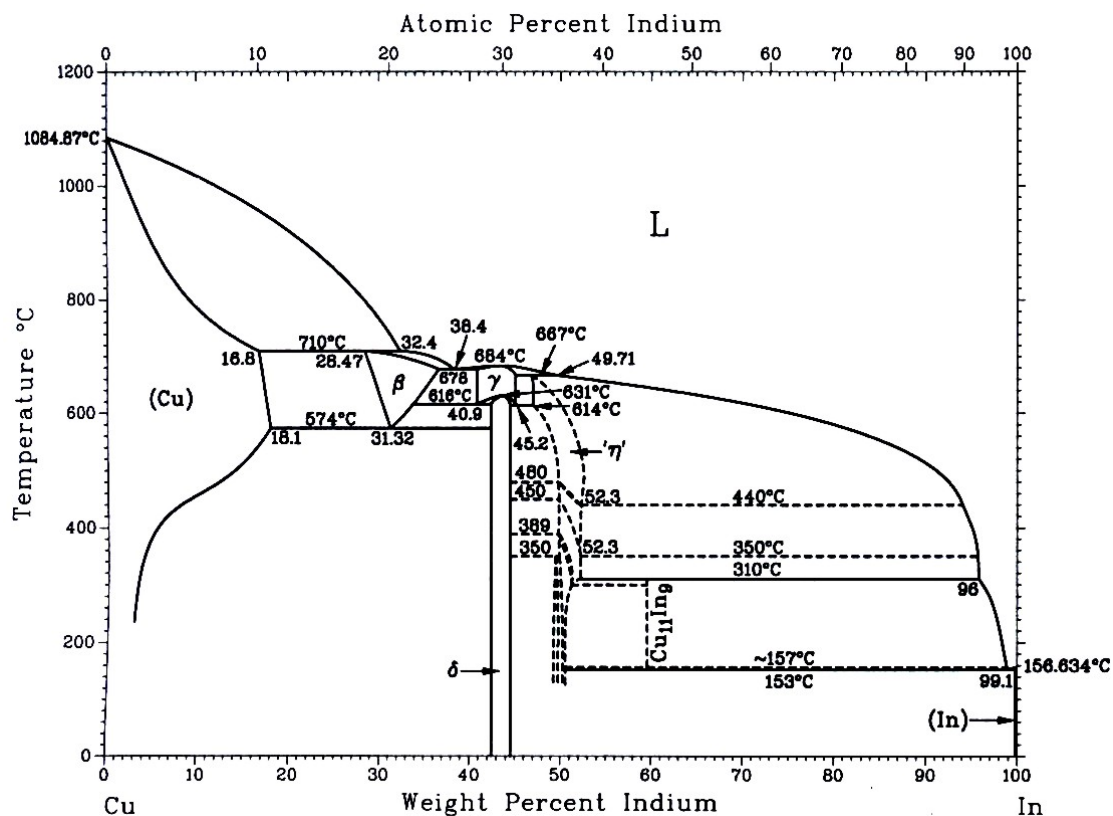
In/Bi couple
230°C; 30 min
E: mag. 500×
PL



In/Bi couple
230°C; 30 min
E: mag. 500×
PC



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•170)

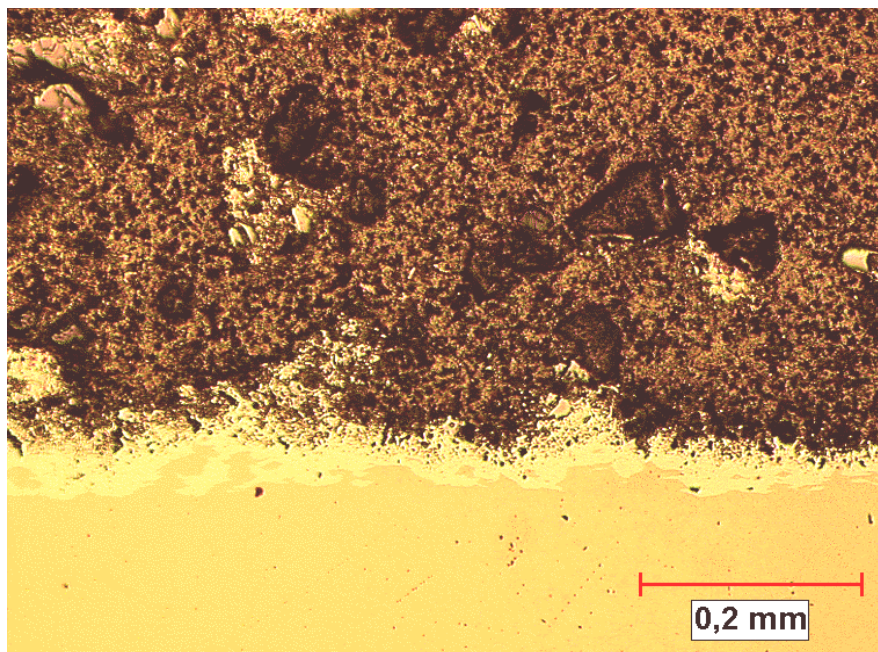
H. Okamoto, 1991

Phase	Composition, wt% In	Pearson symbol	Space group
(Cu)	0 to 18.1	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
β	28.47 to 37.0	<i>cI2</i>	<i>Im$\bar{3}m$</i>
γ	40.9 to 45.2	<i>cP52</i>	<i>P$\bar{4}3m$</i>
δ	42.52 to 44.3	<i>aP40</i>	<i>P$\bar{1}$</i>
“ η ”	47.00 to 52.3	<i>hP4</i>	<i>P6$_3$/mmc</i>
		<i>hP6</i>	<i>P6$_3$/mmc</i>
	49.5 to 52.3	<i>o**</i>	...
$\text{Cu}_{11}\text{In}_9$	~59	<i>mC20</i>	<i>C2/m</i>
(In)	~100	<i>tI2</i>	<i>I4/mmm</i>

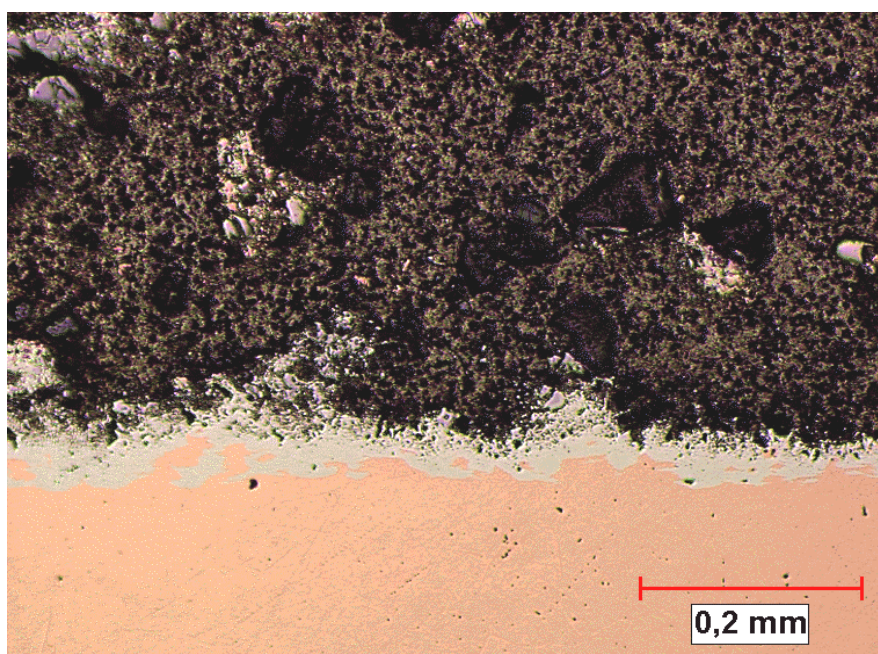
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•170)

Properties of solder/substrate couples

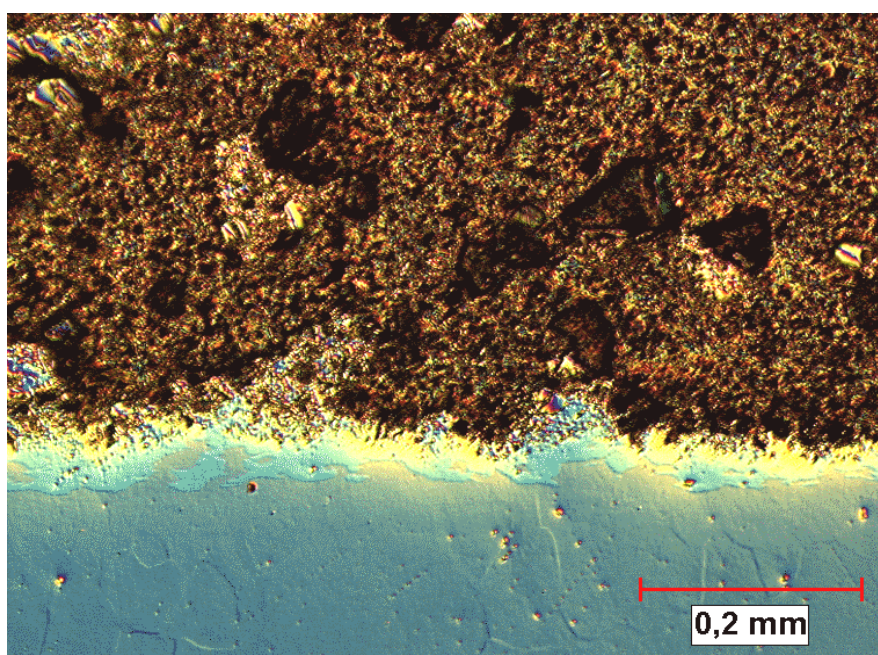
Couple	Conditions	θ , deg	τ , MPa
In / Cu	230°C, 5 min, flux	46°	3
In / Cu	230°C, 30 min, flux	49°	—



In/Cu couple
230°C; 5 min
E: mag. 100×
CL

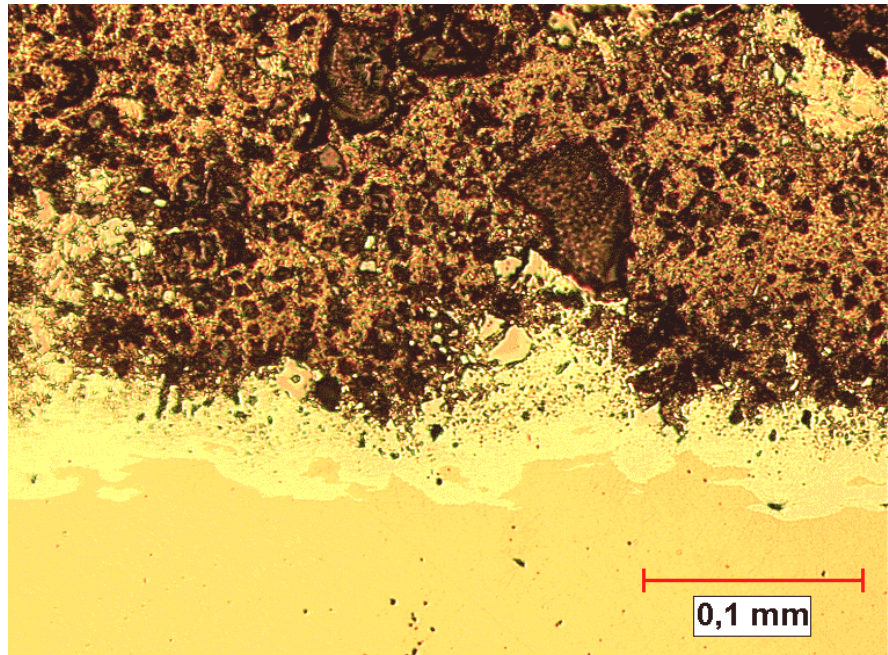


In/Cu couple
230°C; 5 min
E: mag. 100×
PL

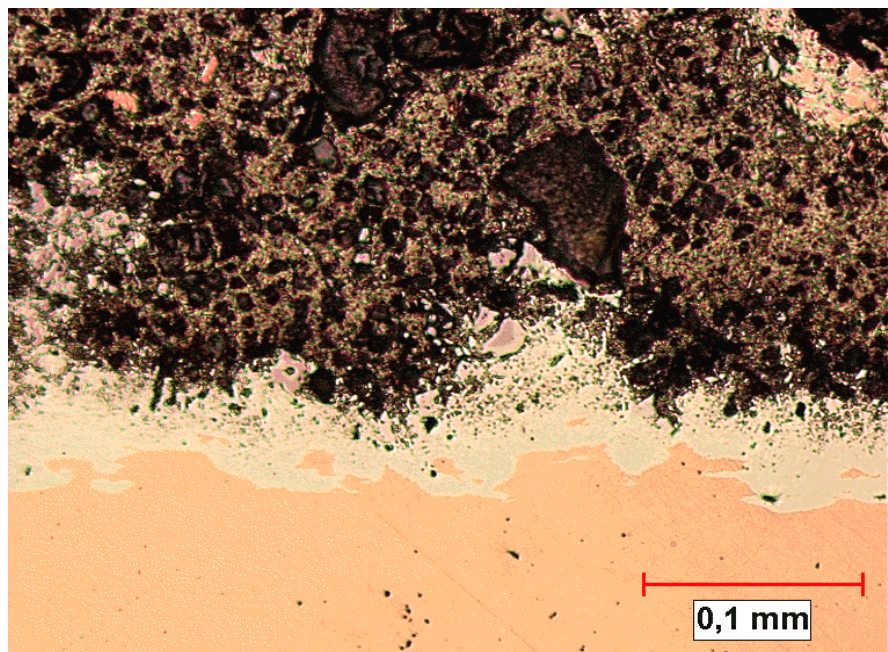


In/Cu couple
230°C; 5 min
E: mag. 100×
PC

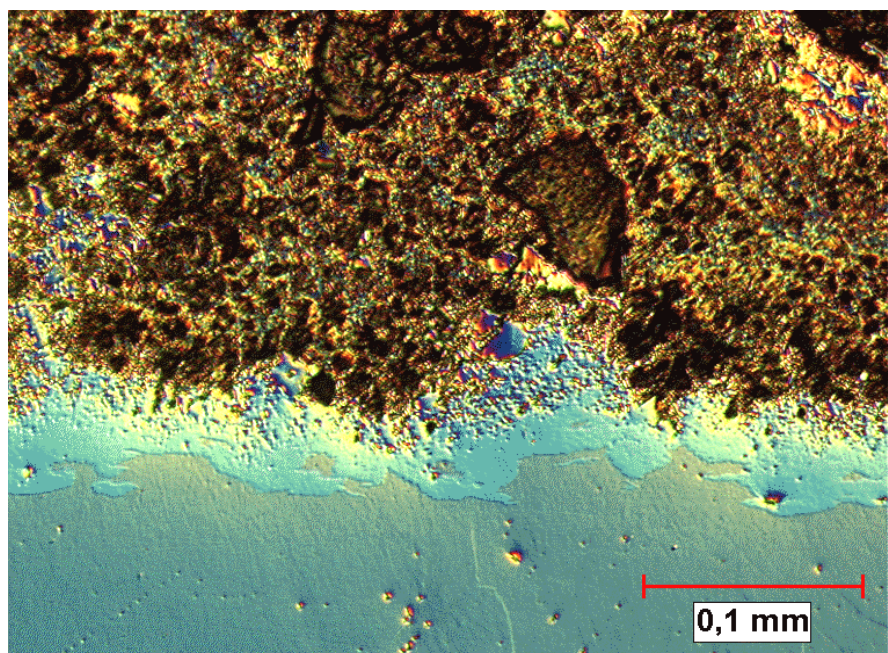
In/Cu couple
230°C; 5 min
E: mag. 200×
CL

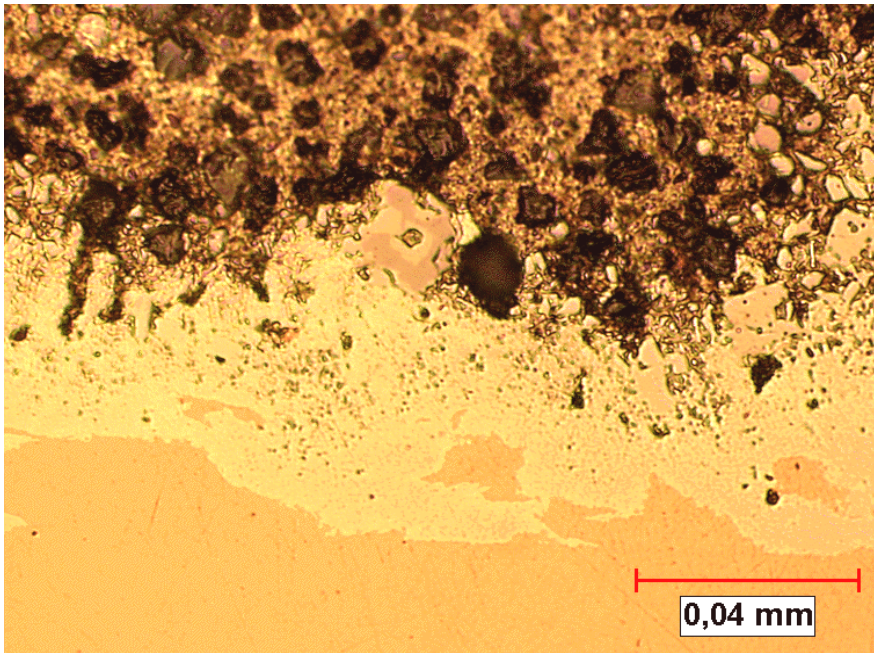


In/Cu couple
230°C; 5 min
E: mag. 200×
PL

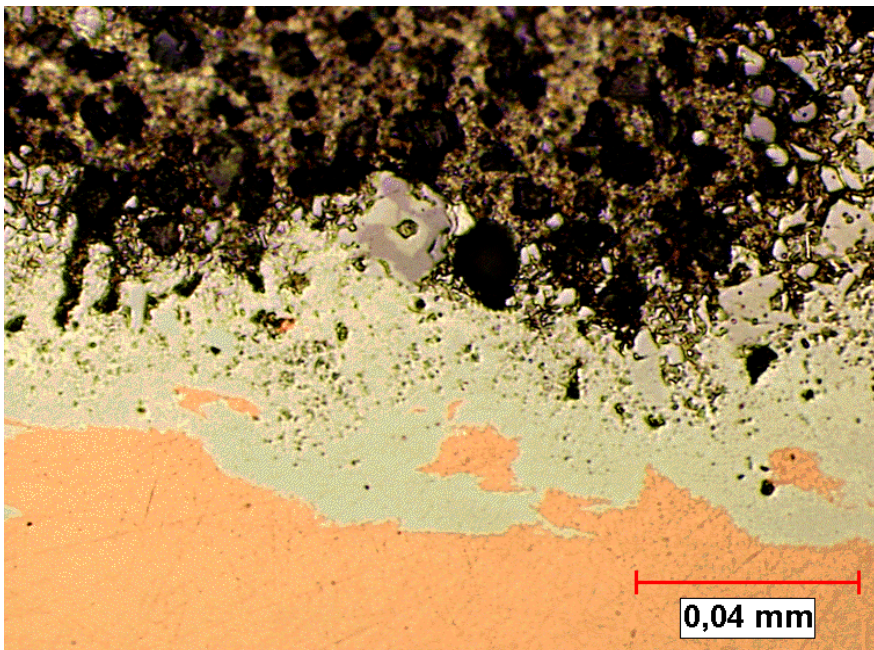


In/Cu couple
230°C; 5 min
E: mag. 200×
PC

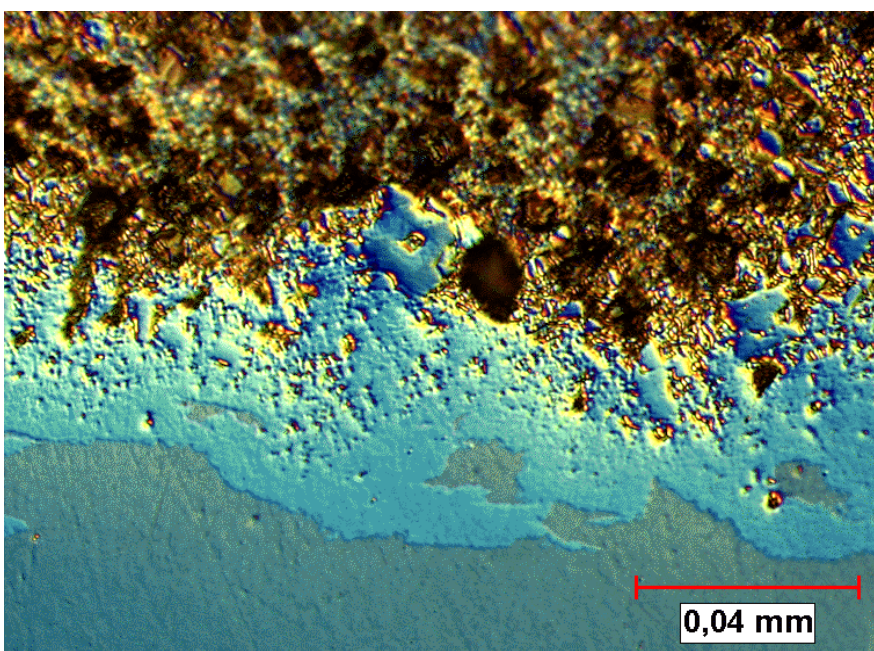




In/Cu couple
230°C; 5 min
E: mag. 500×
CL

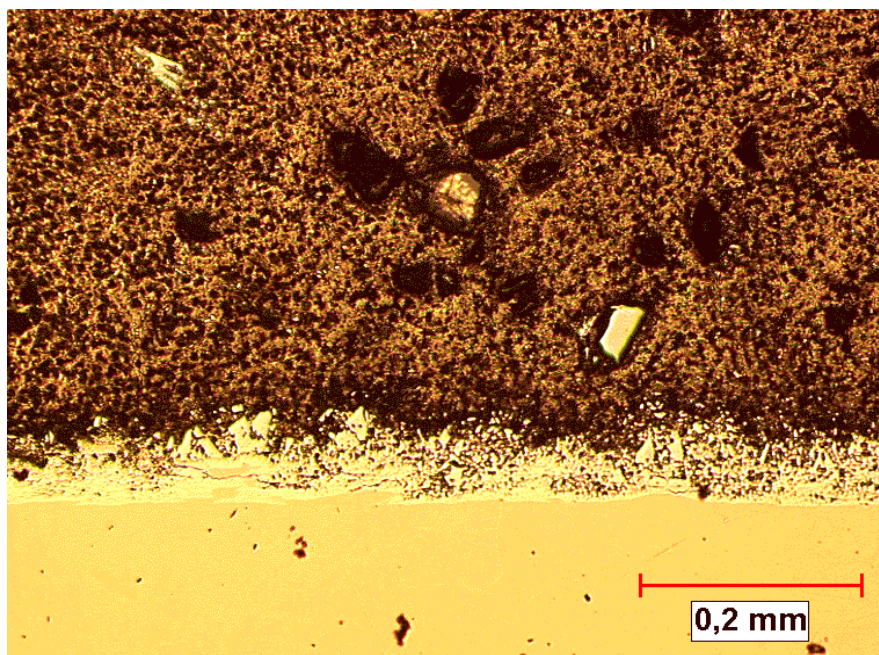


In/Cu couple
230°C; 5 min
E: mag. 500×
PL

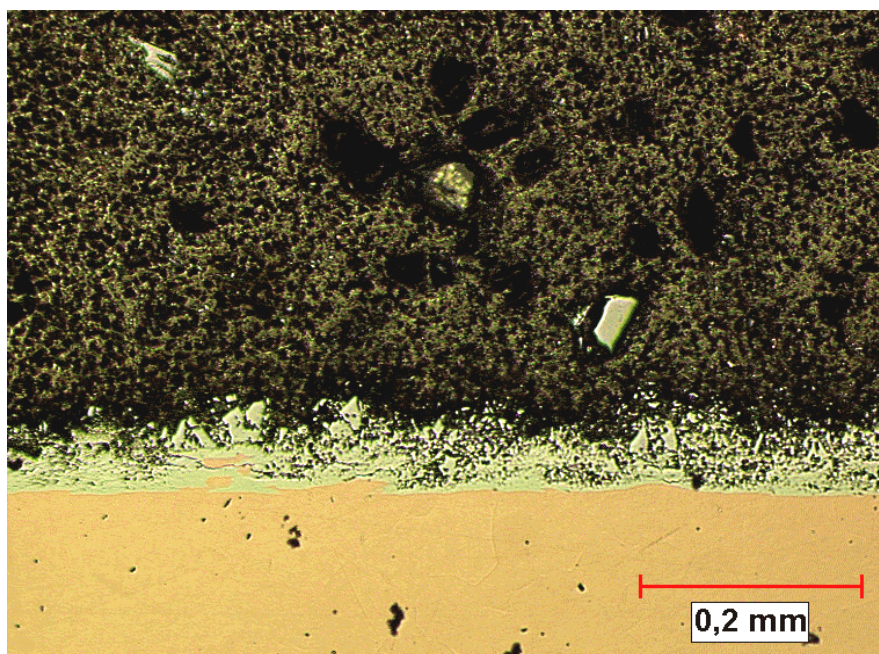


In/Cu couple
230°C; 5 min
E: mag. 500×
PC

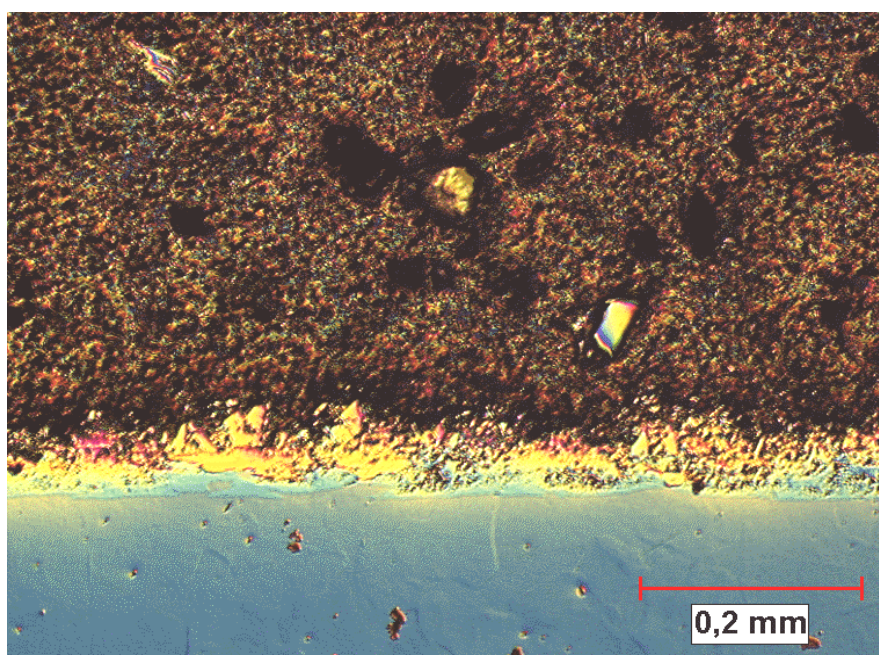
In/Cu couple
230°C; 30 min
E: mag. 100×
CL

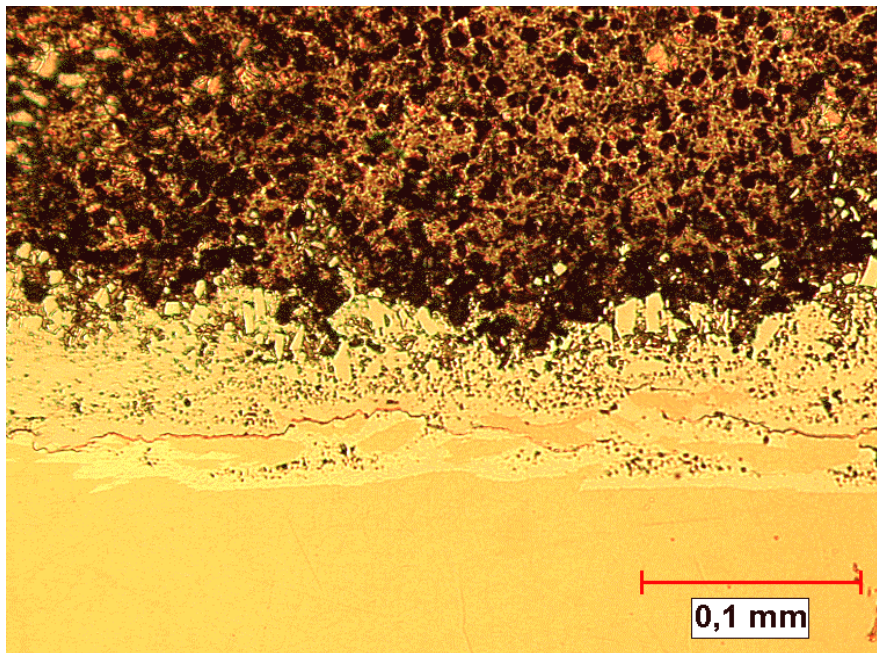


In/Cu couple
230°C; 30 min
E: mag. 100×
PL

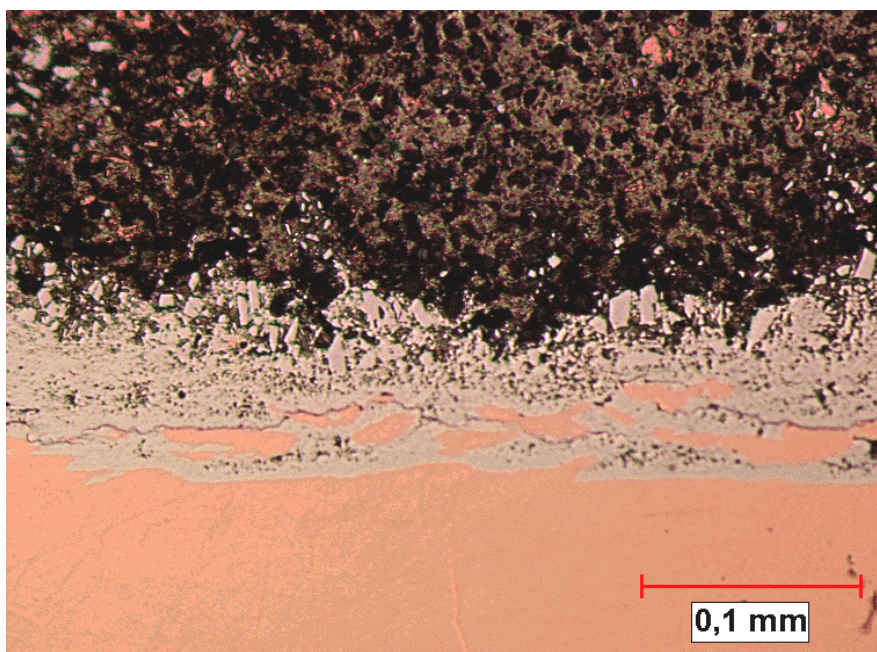


In/Cu couple
230°C; 30 min
E: mag. 100×
PC

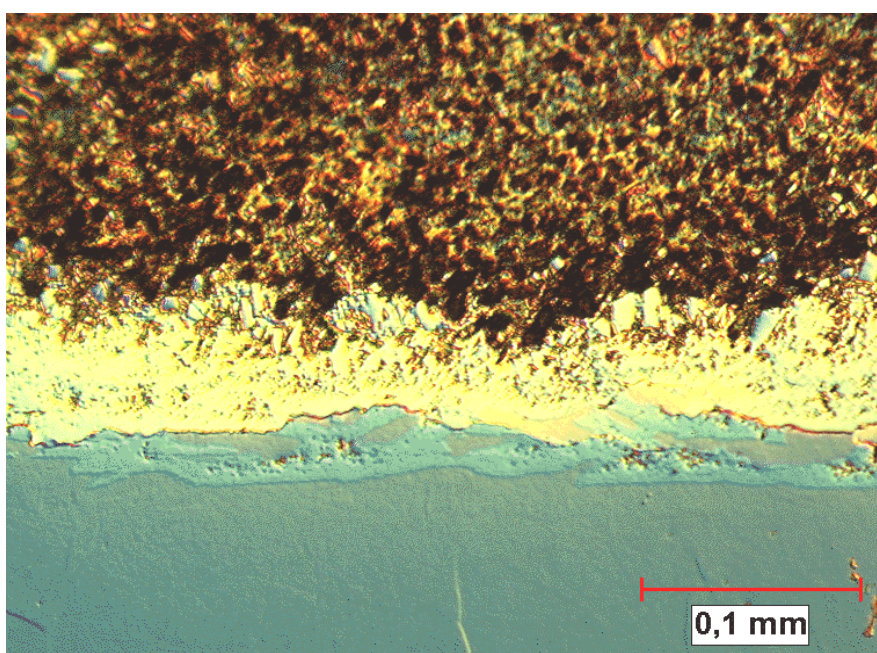




In/Cu couple
230°C; 30 min
E: mag. 200×
CL

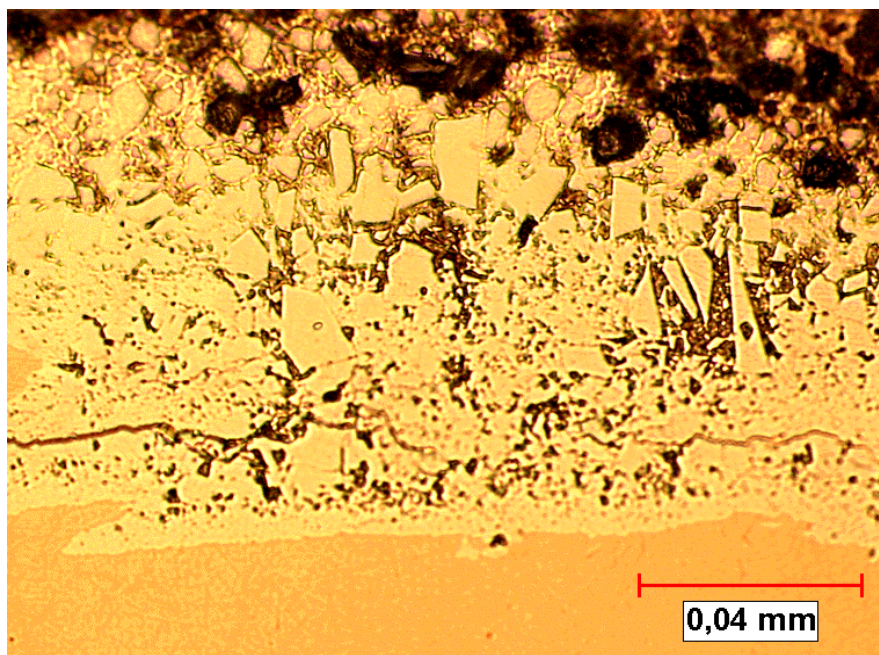


In/Cu couple
230°C; 30 min
E: mag. 200×
PL

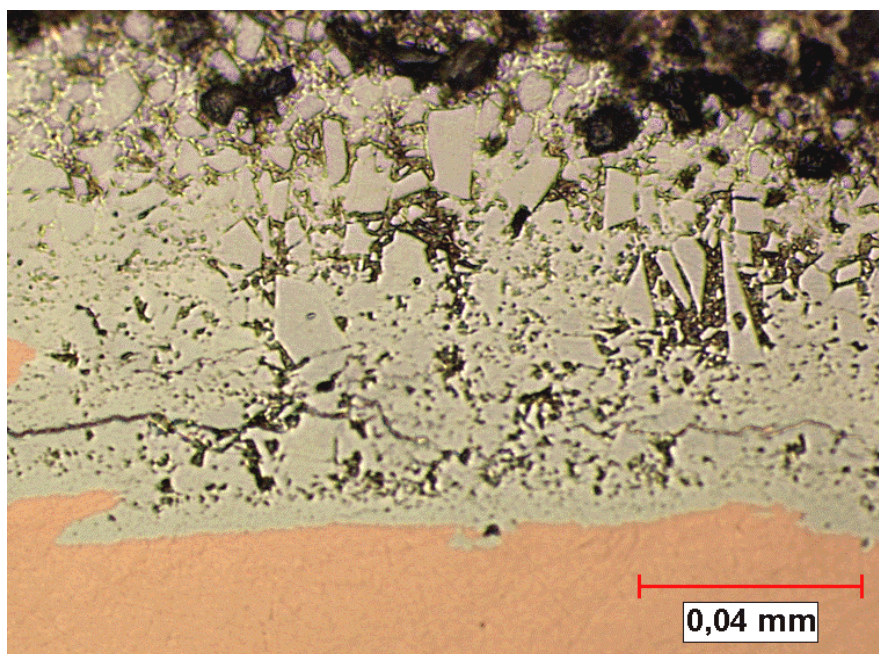


In/Cu couple
230°C; 30 min
E: mag. 200×
PC

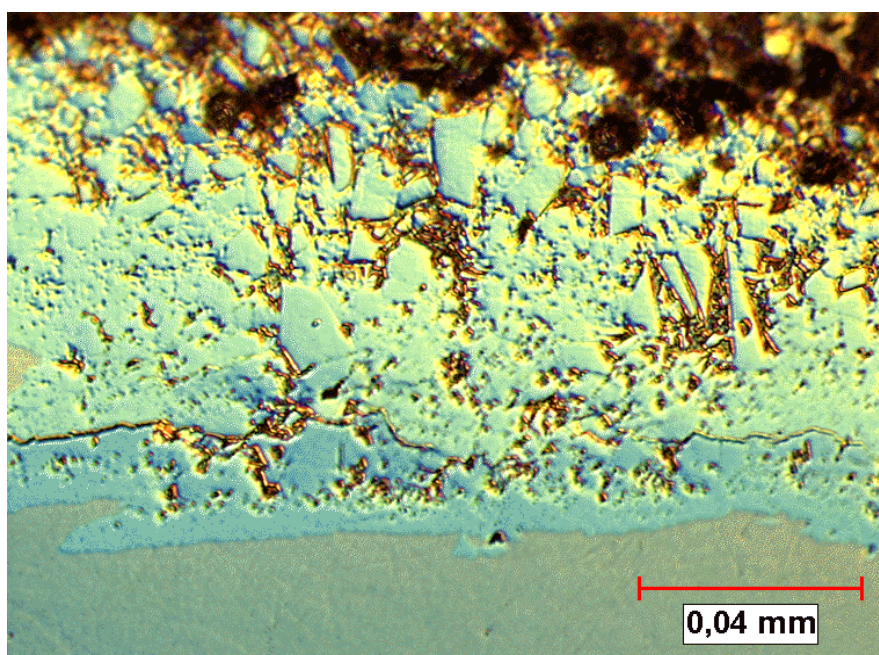
In/Cu couple
230°C; 30 min
E: mag. 500×
CL



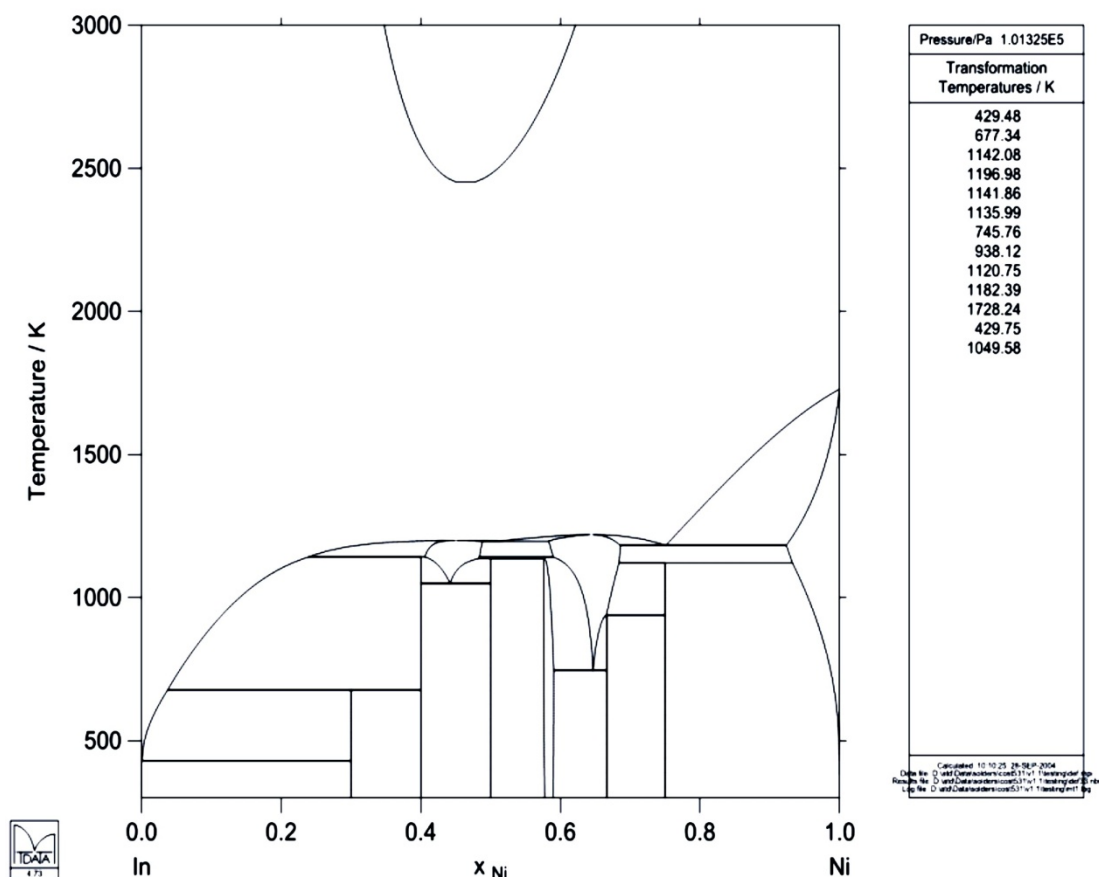
In/Cu couple
230°C; 30 min
E: mag. 500×
PL



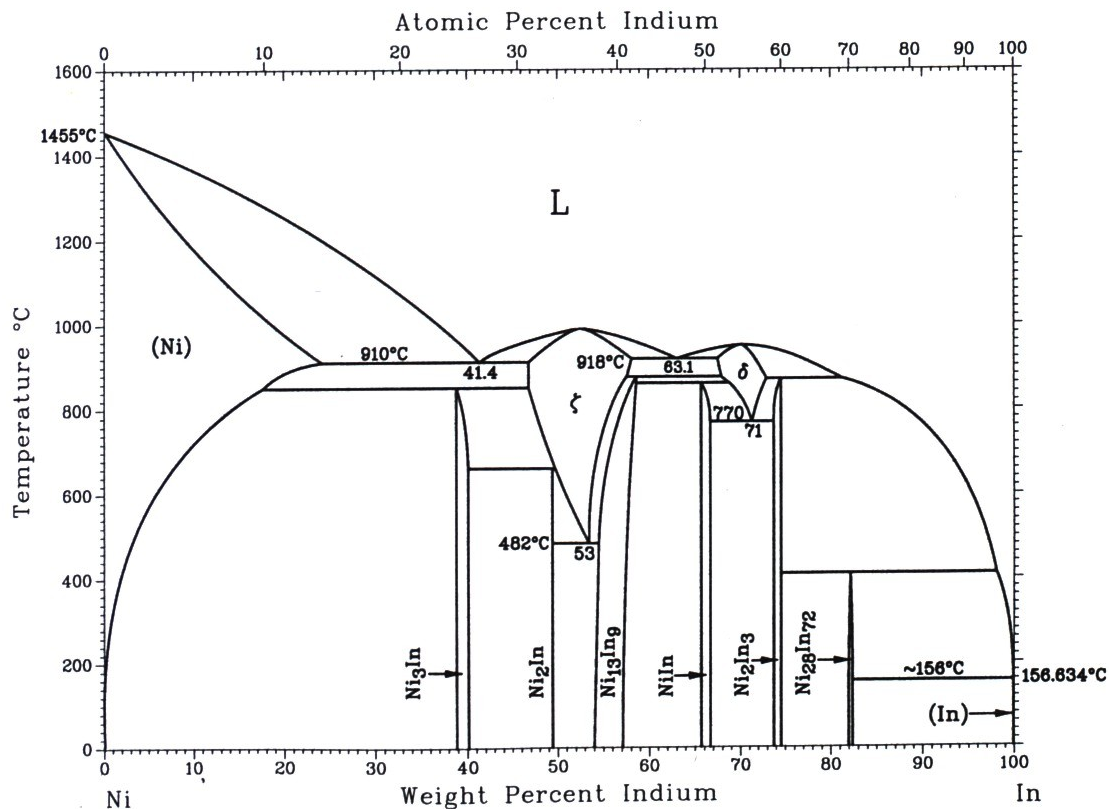
In/Cu couple
230°C; 30 min
E: mag. 500×
PC



In – Ni



Calculated Phase Diagram (data from COST 531 Binary Database: ver. I.I, 2004
by A. Dinsdale, A. Watson, A. Kroupa, J. Vrestal)



Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•255)

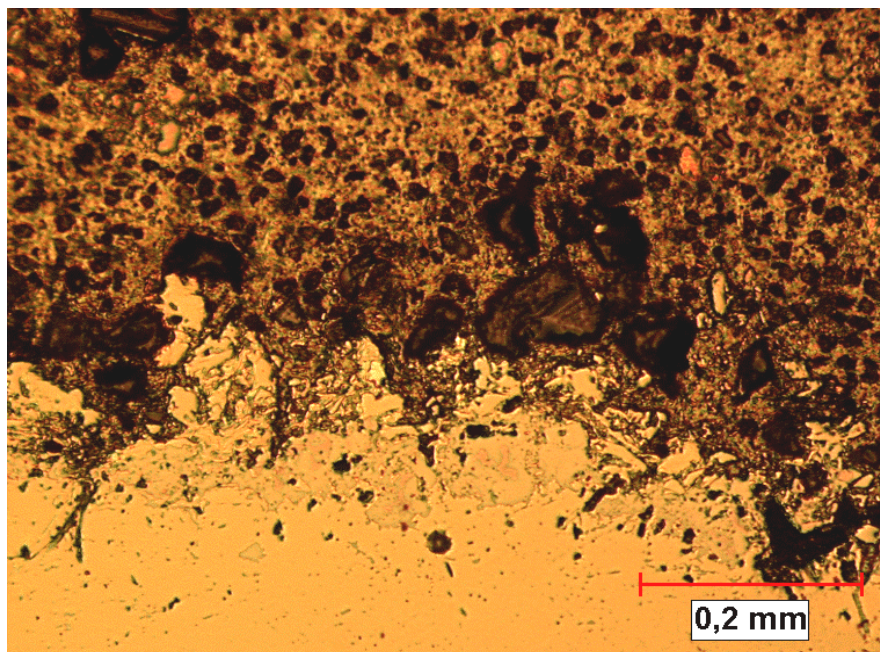
M.F. Singleton and P. Nash, 1992

Phase	Composition, wt% In	Pearson symbol	Space group
(Ni)	0 to 24.9	<i>cF4</i>	<i>Fm$\bar{3}m$</i>
Ni ₃ In	38.8 to 40.1	<i>hP8</i>	<i>P6₃/mmc</i>
η (Ni ₂ In)	49.4	<i>hP6</i>	<i>P6₃/mmc</i>
ζ	47 to 58.1	<i>hP4</i>	<i>P6₃/mmc</i>
ζ' (Ni ₁₃ In ₉)	55.1 to 58.8	...	...
ϵ (NiIn)	65.7 to 66.6	<i>hP6</i>	<i>P6/mmm</i>
δ (NiIn)	67.5 to 73	<i>cP2</i>	<i>Pm$\bar{3}m$</i>
Ni ₂ In ₃	74 to 75	<i>hP5</i>	<i>P$\bar{3}m1$</i>
Ni ₂₈ In ₇₂	82 to 82.4	...	...
(In)	~100	<i>tI2</i>	<i>I4/mmm</i>
Metastable phase			
ϵ'	27.7 to 40	<i>cI2</i>	<i>Im$\bar{3}m$</i>

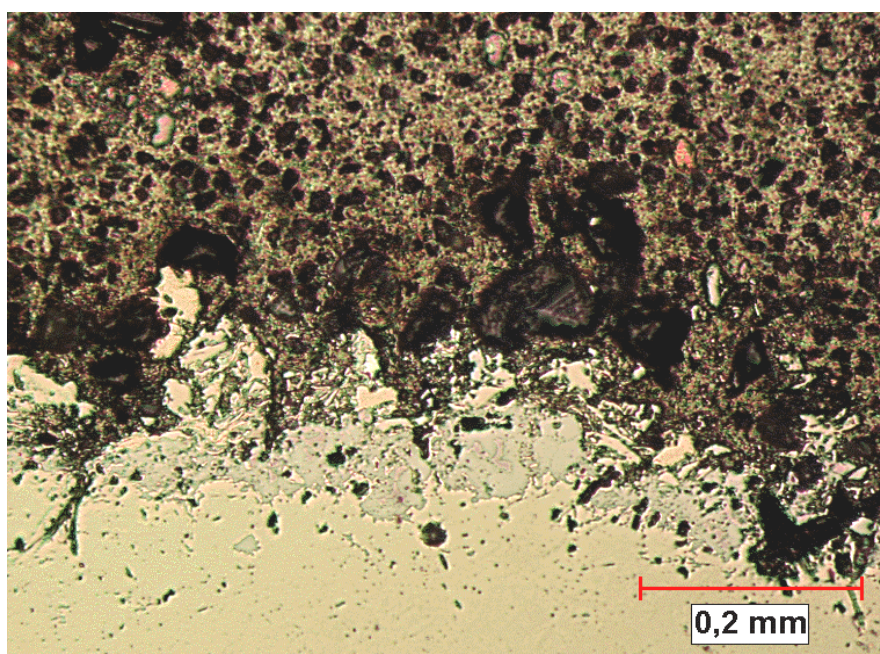
Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•255)

Properties of solder/substrate couples

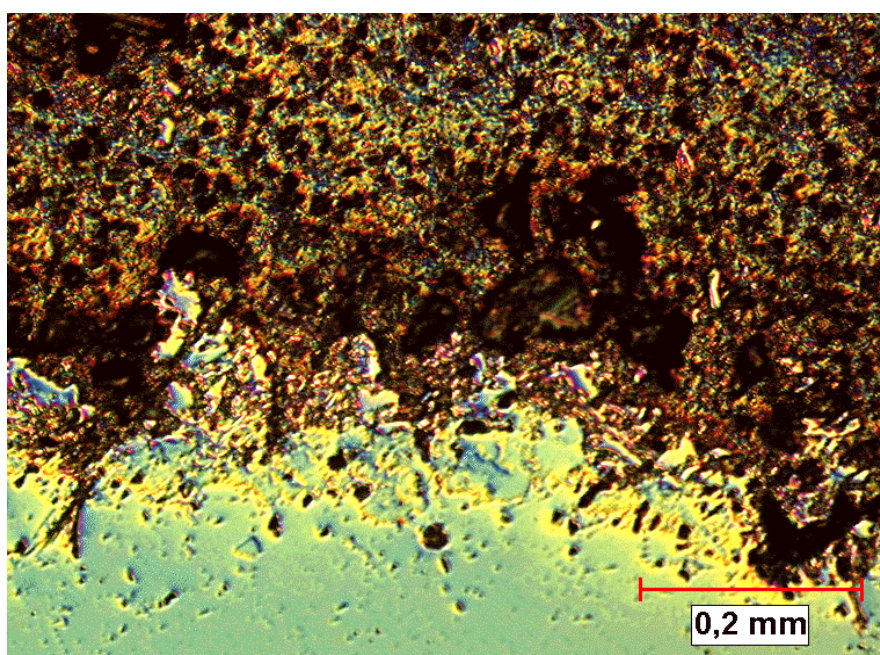
Couple	Conditions	θ , deg	τ , MPa
In / Ni	230°C, 5 min, flux	68°	23
In / Ni	230°C, 30 min, flux	87°	16



In/Ni couple
230°C; 30 min
E: mag. 100×
CL

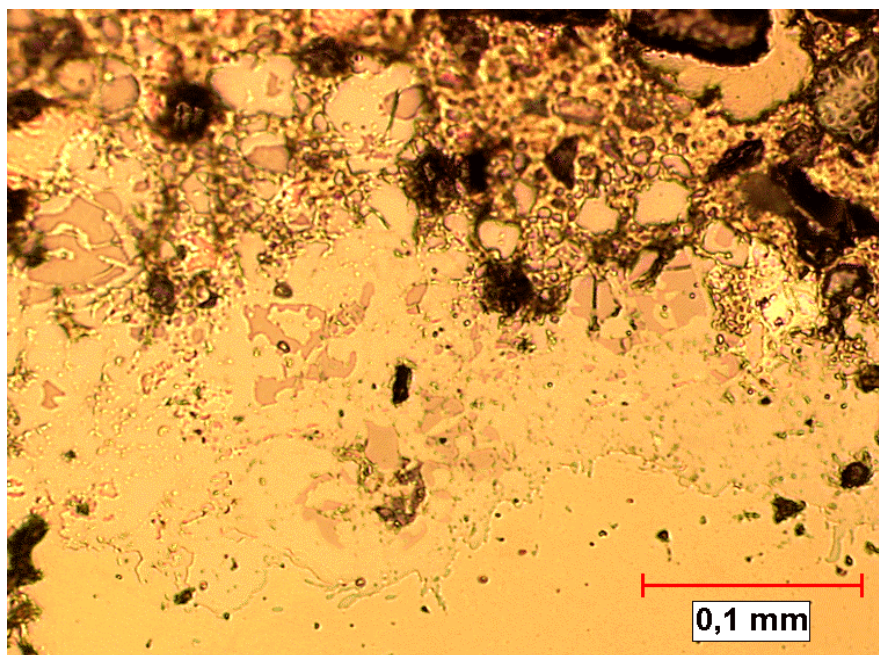


In/Ni couple
230°C; 30 min
E: mag. 100×
PL

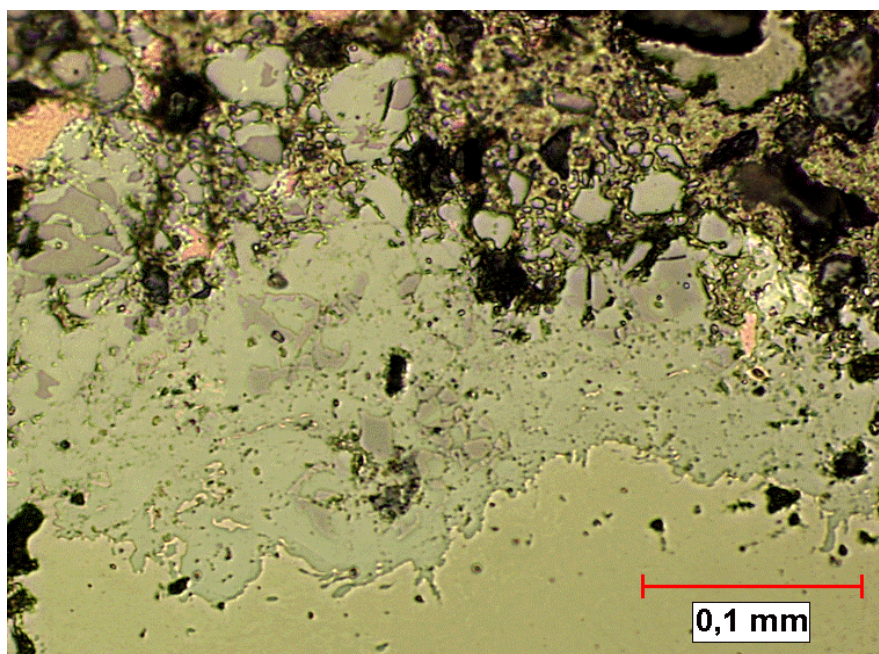


In/Ni couple
230°C; 30 min
E: mag. 100×
PC

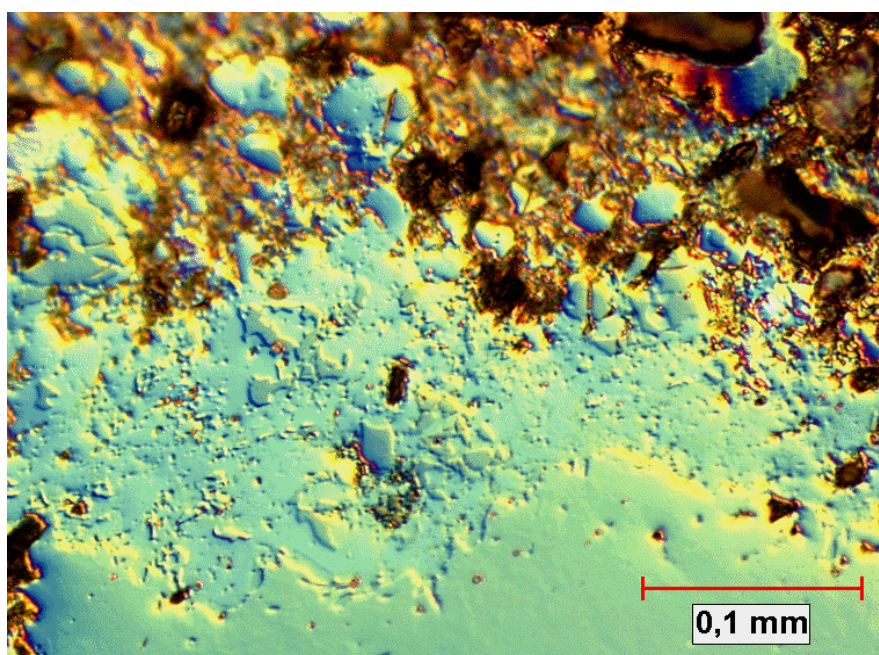
In/Ni couple
230°C; 30 min
E: mag. 200×
CL

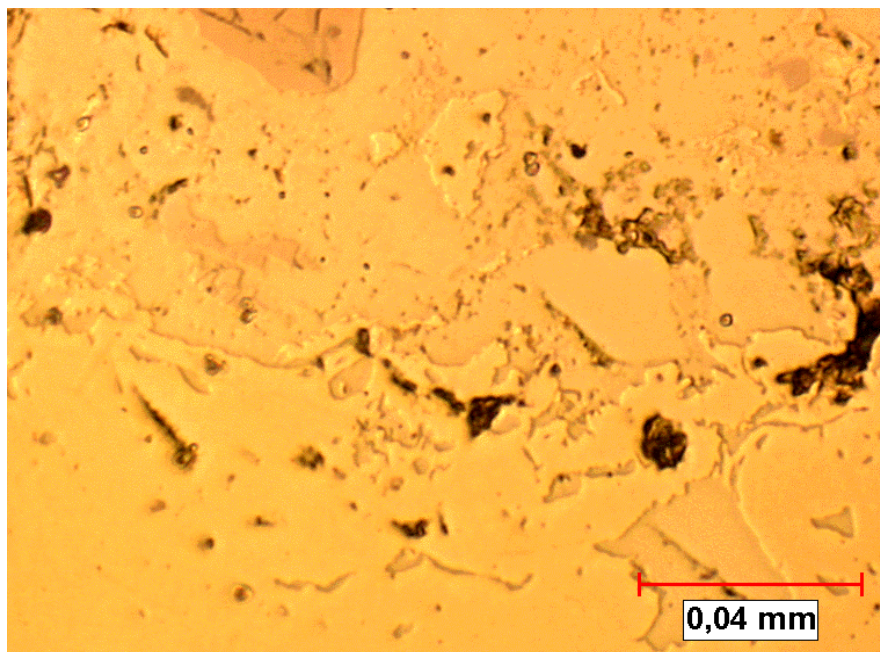


In/Ni couple
230°C; 30 min
E: mag. 200×
PL

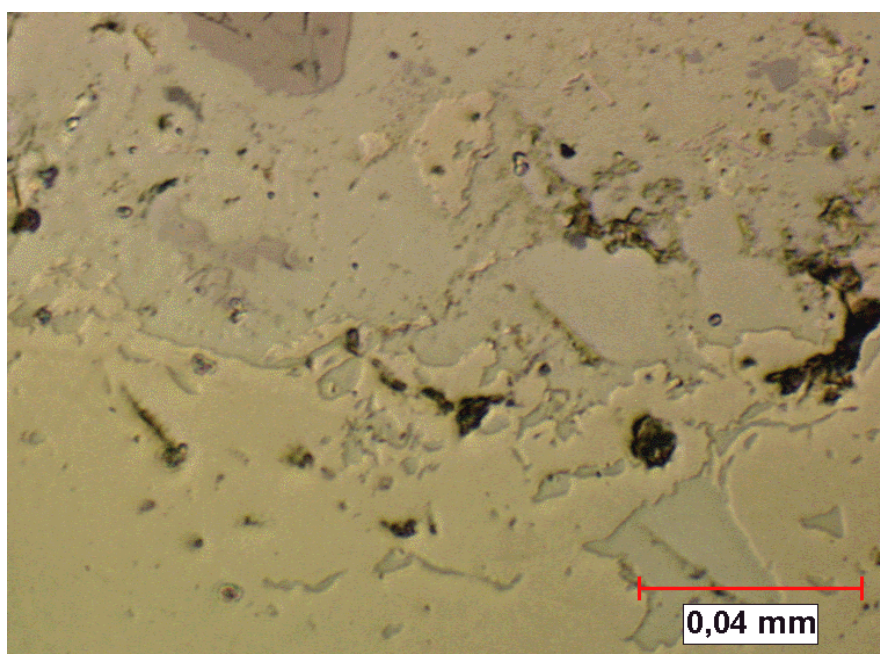


In/Ni couple
230°C; 30 min
E: mag. 200×
PC

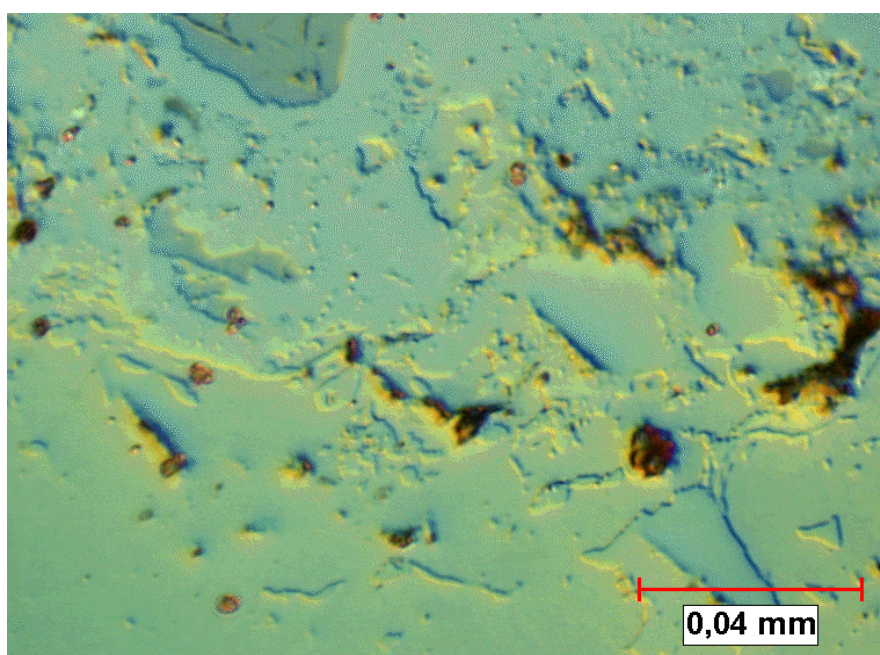




In/Ni couple
230°C; 30 min
E: mag. 500×
CL



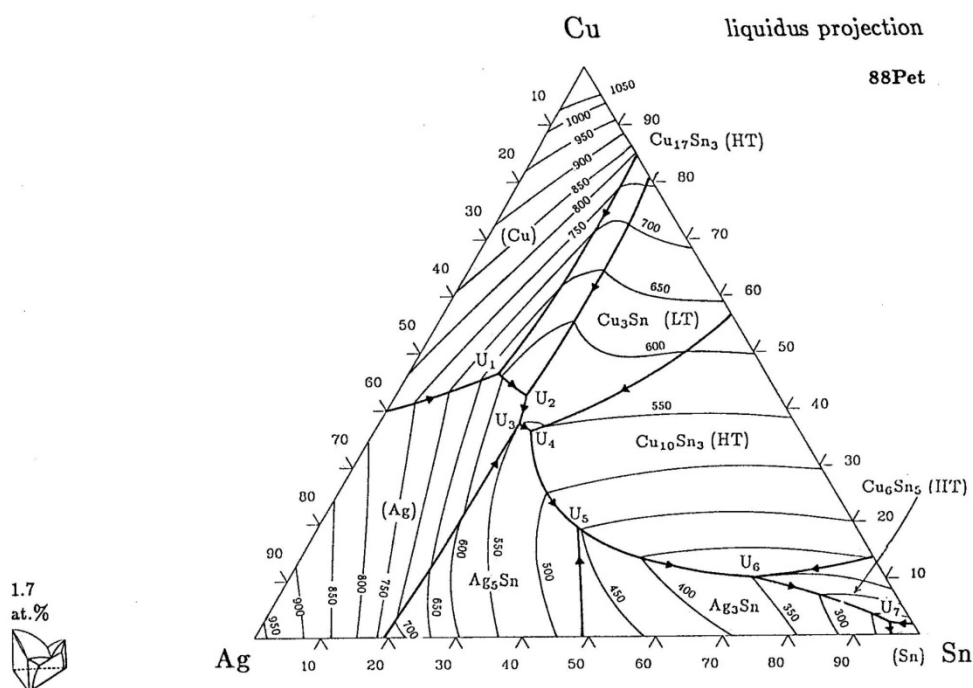
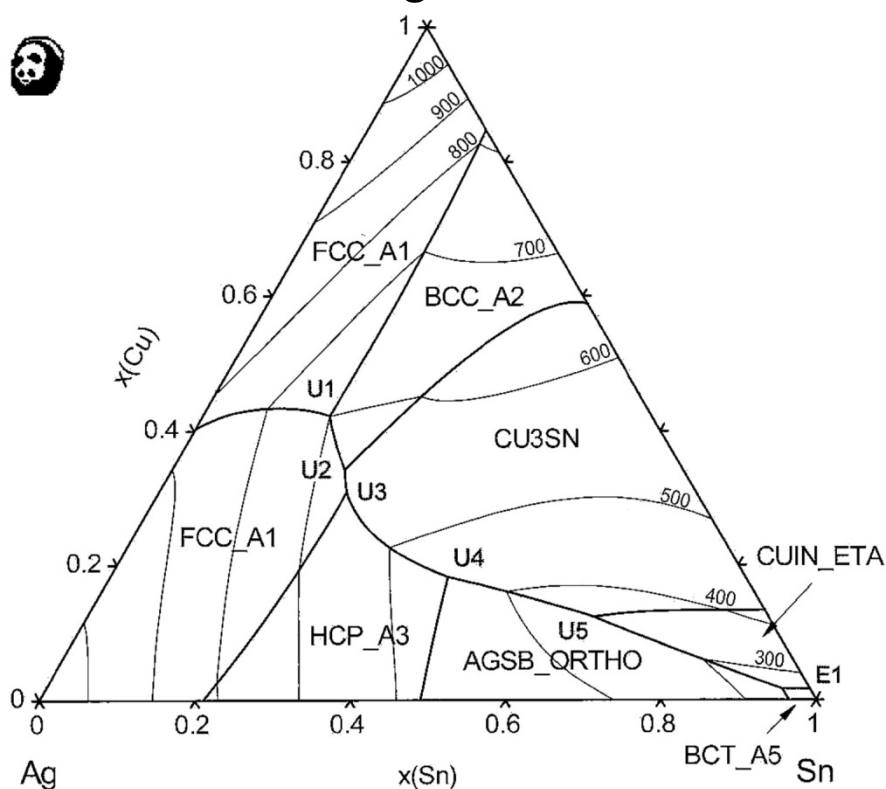
In/Ni couple
230°C; 30 min
E: mag. 500×
PL



In/Ni couple
230°C; 30 min
E: mag. 500×
PC

5. Ternary Systems

Sn – Ag – Cu



Reaction Scheme

Ag-Cu-Sn

- U₁: L + (Cu) ⇌ (Ag) + Cu₁₇Sn₃(HT)
- U₂: L + Cu₁₇Sn₃(HT) ⇌ (Ag) + Cu₃Sn(LT)
- U₃: L + (Ag) ⇌ Ag₅Sn + Cu₃Sn(LT)
- U₄: L + Cu₃Sn(LT) ⇌ Ag₅Sn + Cu₁₀Sn₃(HT)
- U₅: L + Ag₅Sn ⇌ Ag₃Sn + Cu₁₀Sn₃(HT)
- U₆: L + Cu₁₀Sn₃(HT) ⇌ Ag₃Sn + Cu₆Sn₅(HT)
- U₇: L + Ag₃Sn ⇌ Cu₆Sn₅(HT) + (Sn)

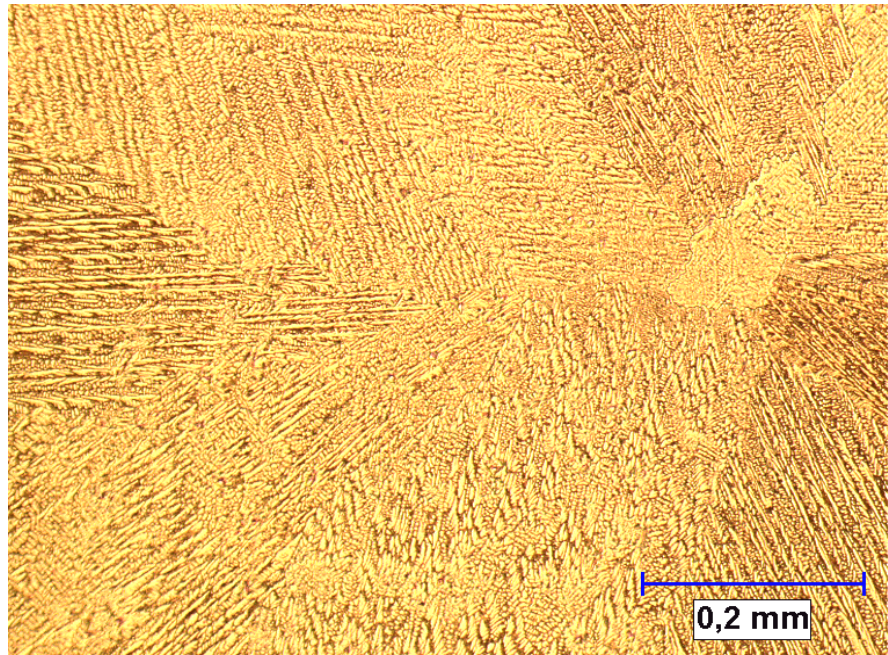
88Pet

- 605°C L = 39.5 at.% Ag, 46.7 at.% Cu
- 560°C L = 37.7 at.% Ag, 42.4 at.% Cu
- 550°C L = 41.2 at.% Ag, 37.5 at.% Cu
- 540°C L = 40.4 at.% Ag, 35.7 at.% Cu
- 440°C L = 41.7 at.% Ag, 19.5 at.% Cu
- 350°C L = 20.5 at.% Ag, 10.5 at.% Cu
- 225°C L = 4.4 at.% Ag, 0.9 at.% Cu

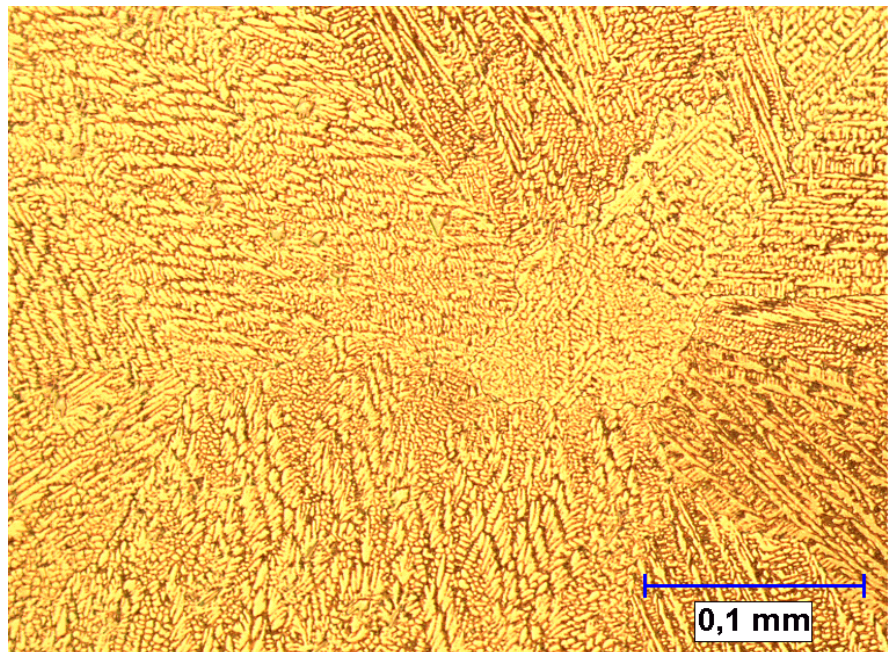
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
SnAg4 / Cu	230°C, 5 min, flux	40°	32
SnAg4 / Cu	230°C, 5 min, vac	49°	18
SnAg3.5 / Cu	230°C, 5 min, flux	40°	35
SnAg3.5 / Cu	230°C, 5 min, vac	50°	54
SnAg3.95Cu0.65/Cu	230°C, 5 min, flux	33°	28
SnAg3.95Cu0.65/Cu	230°C, 5 min, vac	59°	22
SnAg3.5Cu0.5/Cu	230°C, 5 min, flux	31°	19
SnAg3.5Cu0.5/Cu	230°C, 5 min, vac	53°	29

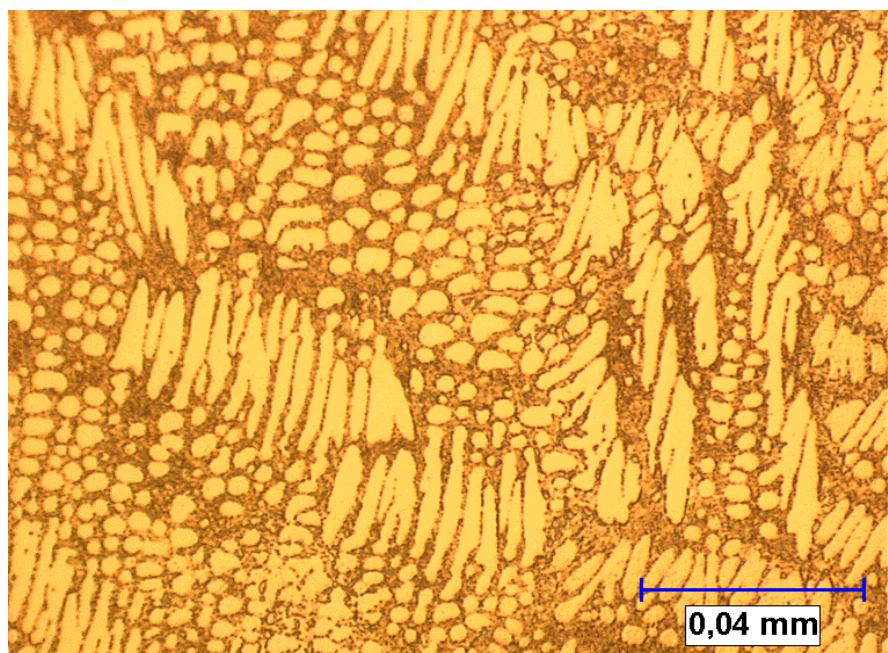
SnAg3.95Cu0.65 alloy
E: mag. 100×
CL

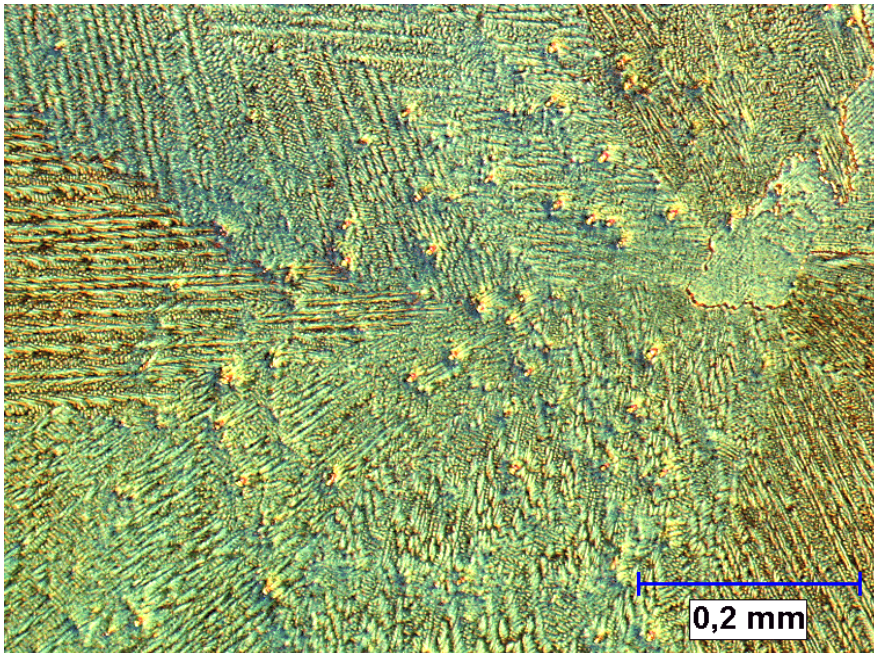
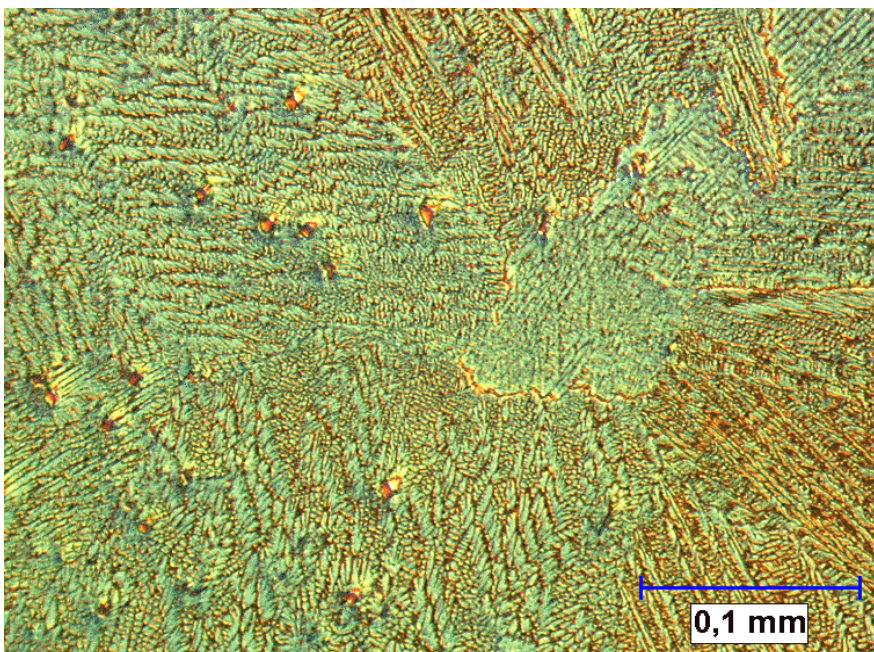
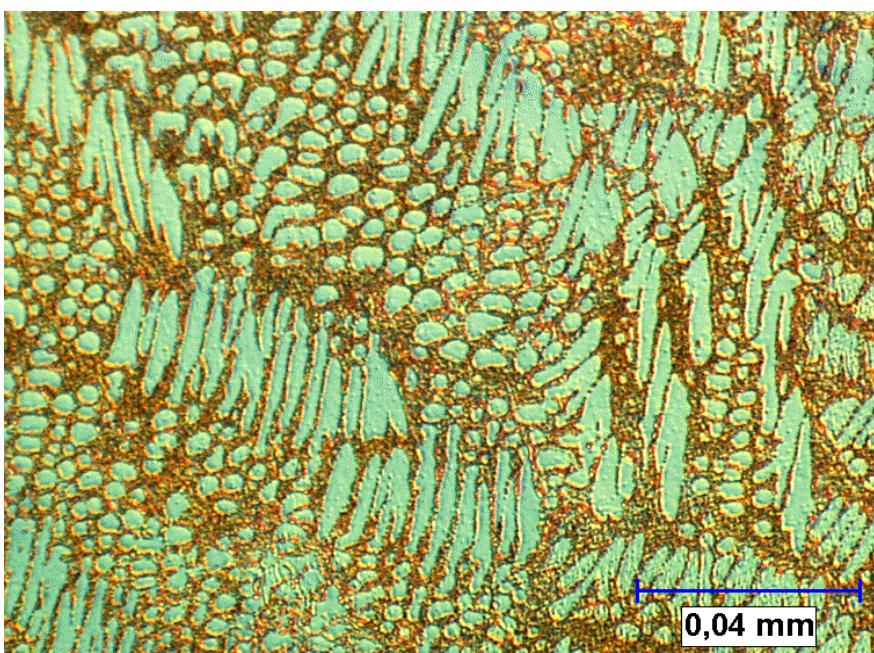


SnAg3.95Cu0.65 alloy
E: mag. 200×
CL

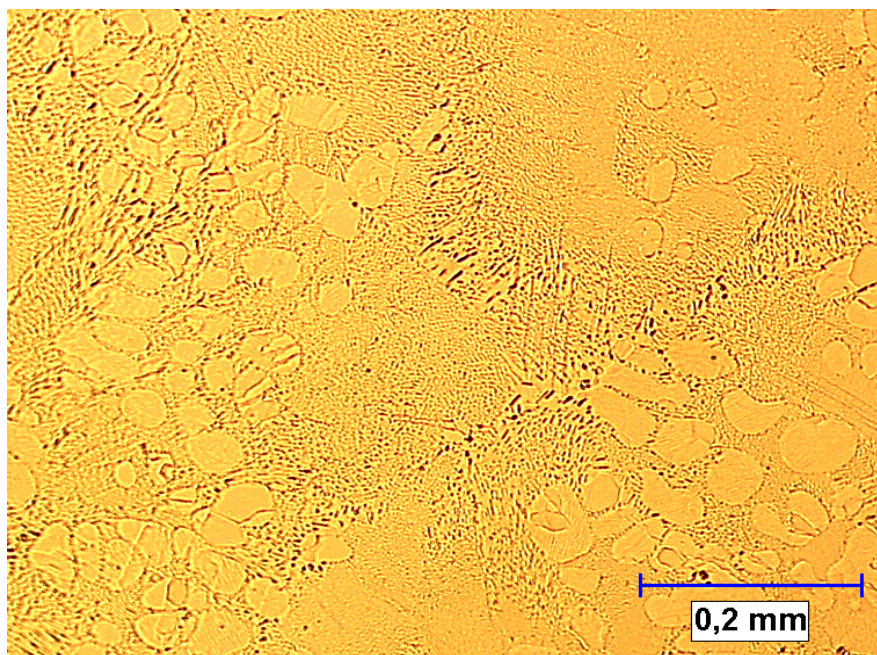


SnAg3.95Cu0.65 alloy
E: mag. 500×
CL



**SnAg3.95Cu0.65 alloy****E: mag. 100×****PC****SnAg3.95Cu0.65 alloy****E: mag. 200×****PC****SnAg3.95Cu0.65 alloy****E: mag. 500×****PC**

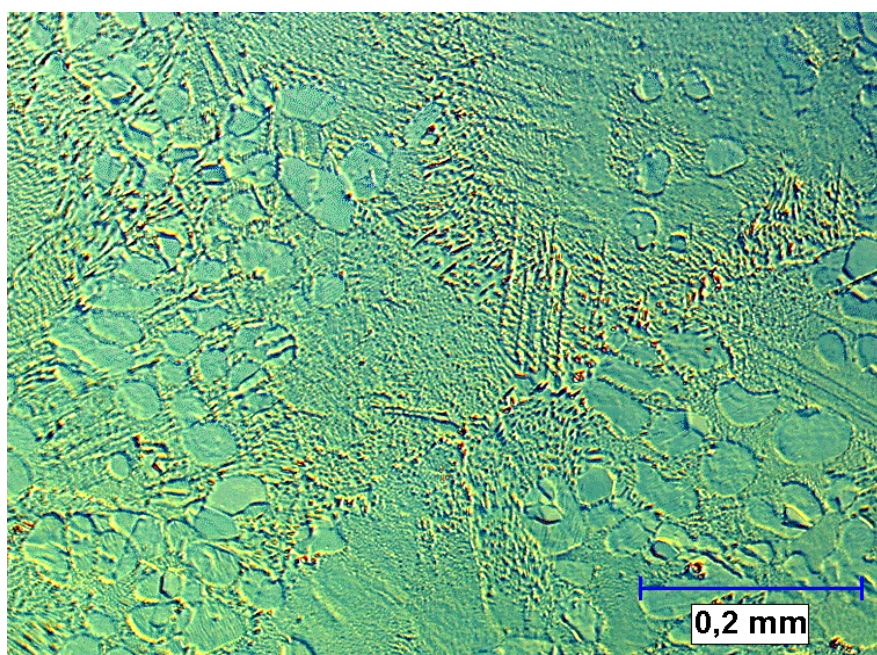
SnAg3.5Cu0.5 alloy
NE: mag. 100×
CL

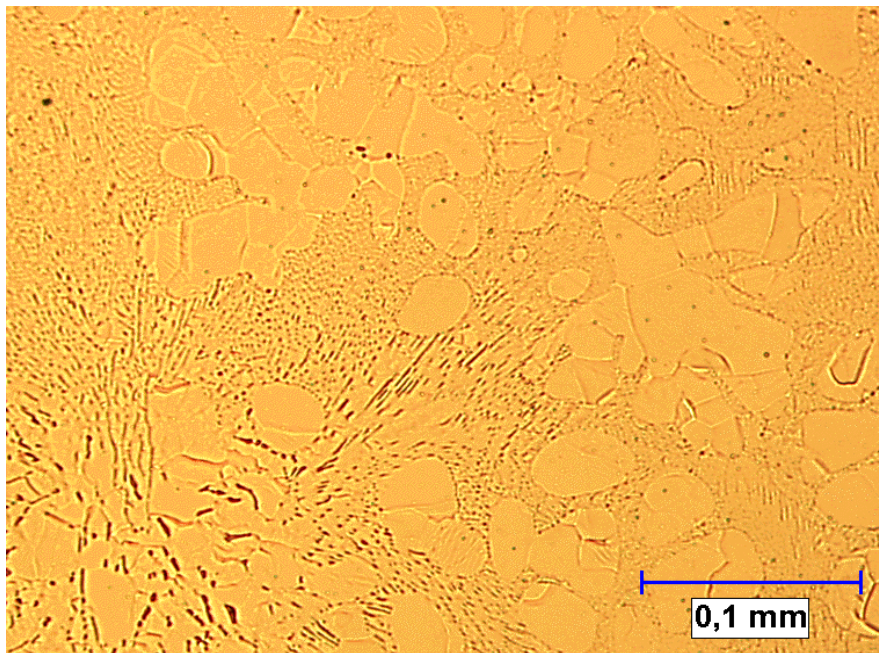


SnAg3.5Cu0.5 alloy
NE: mag. 100×
PL

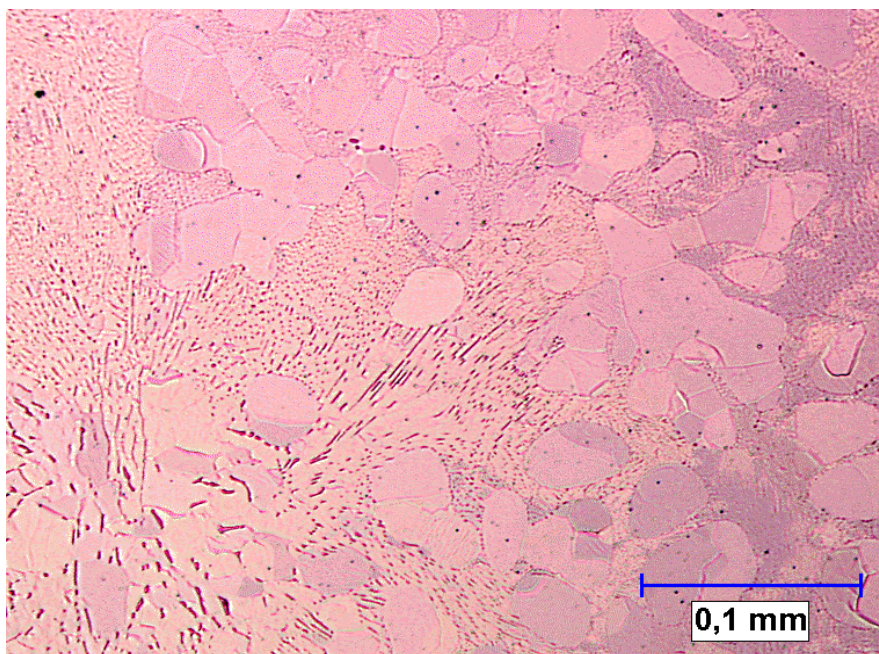


SnAg3.5Cu0.5 alloy
NE: mag. 100×
PC

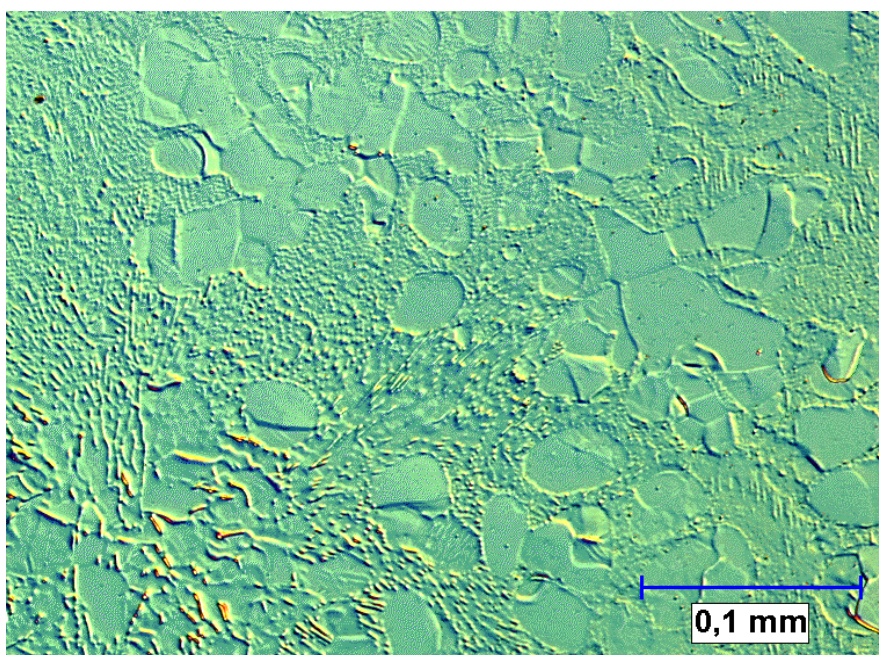




SnAg3.5Cu0.5 alloy
NE: mag. 200×
CL

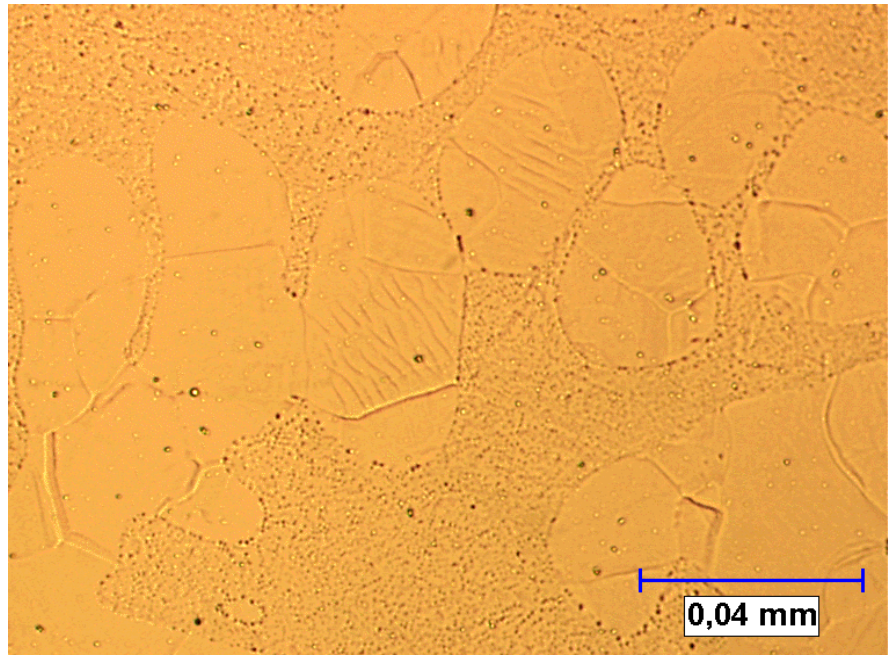


SnAg3.5Cu0.5 alloy
NE: mag. 200×
PL



SnAg3.5Cu0.5 alloy
NE: mag. 200×
PC

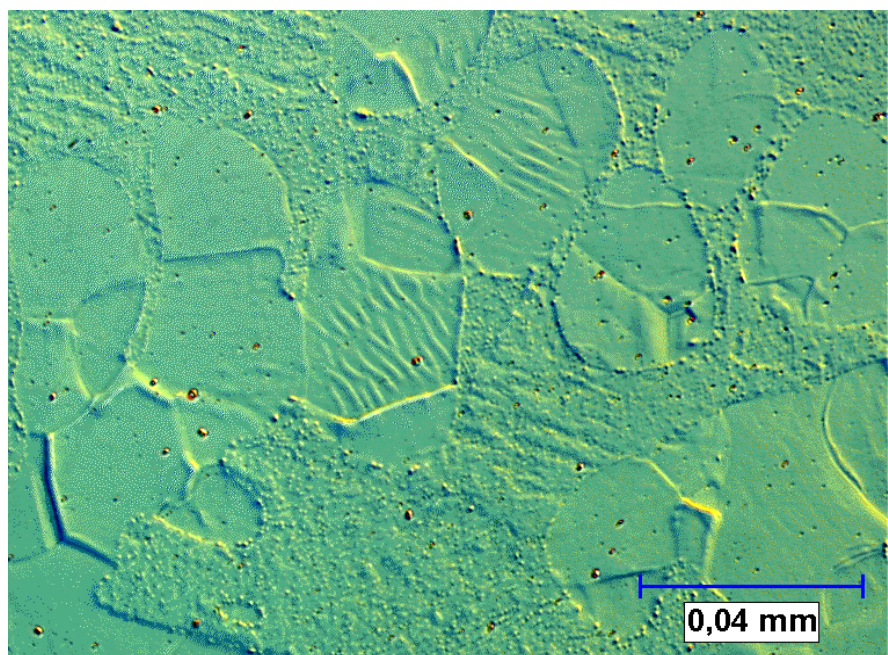
SnAg3.5Cu0.5 alloy
NE: mag. 500×
CL

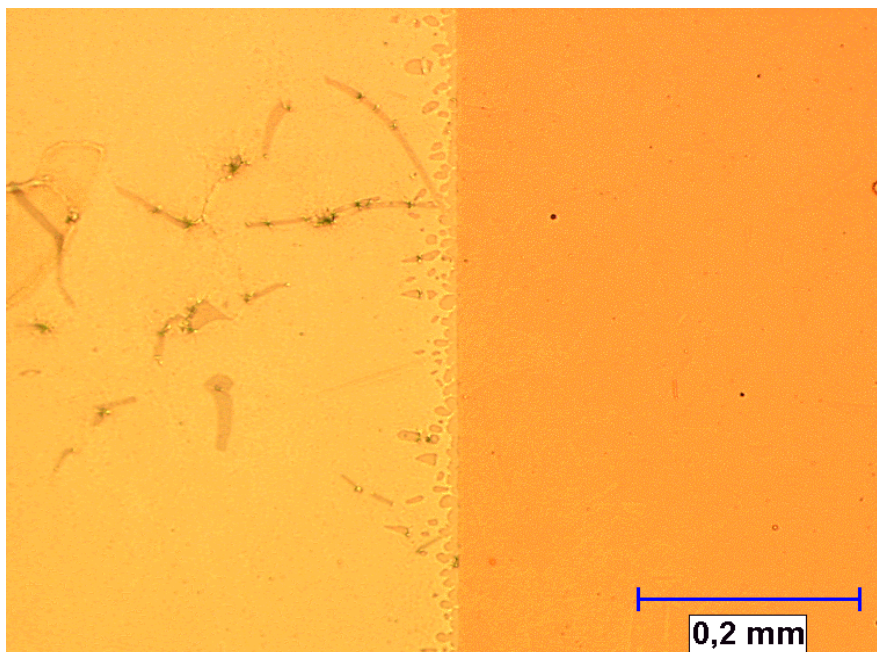


SnAg3.5Cu0.5 alloy
NE: mag. 500×
PL

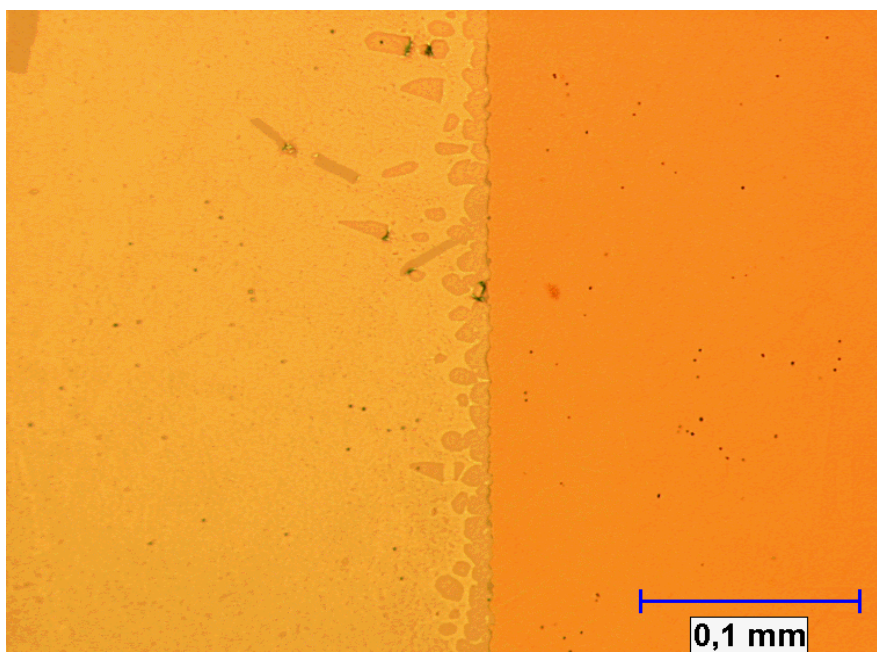


SnAg3.5Cu0.5 alloy
NE: mag. 500×
PC

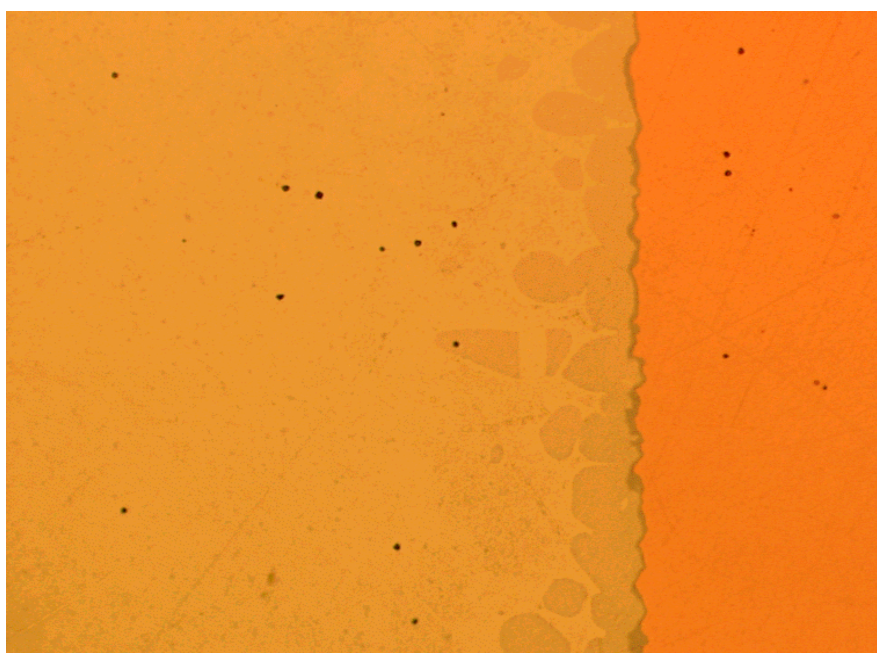




SnAg4/Cu couple
230°C; 5 min
NE: mag. 100×
CL

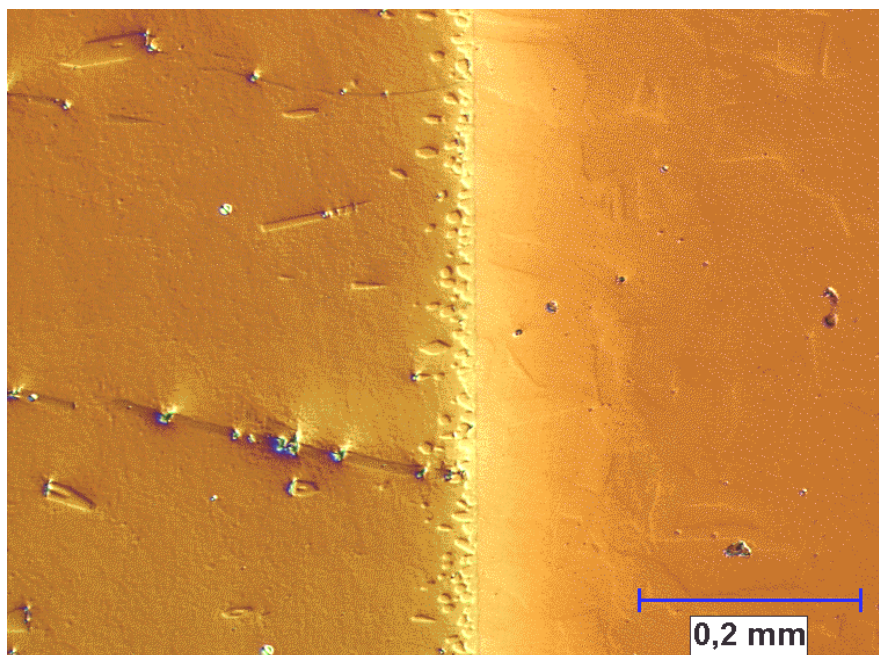


SnAg4/Cu couple
230°C; 5 min
NE: mag. 200×
CL

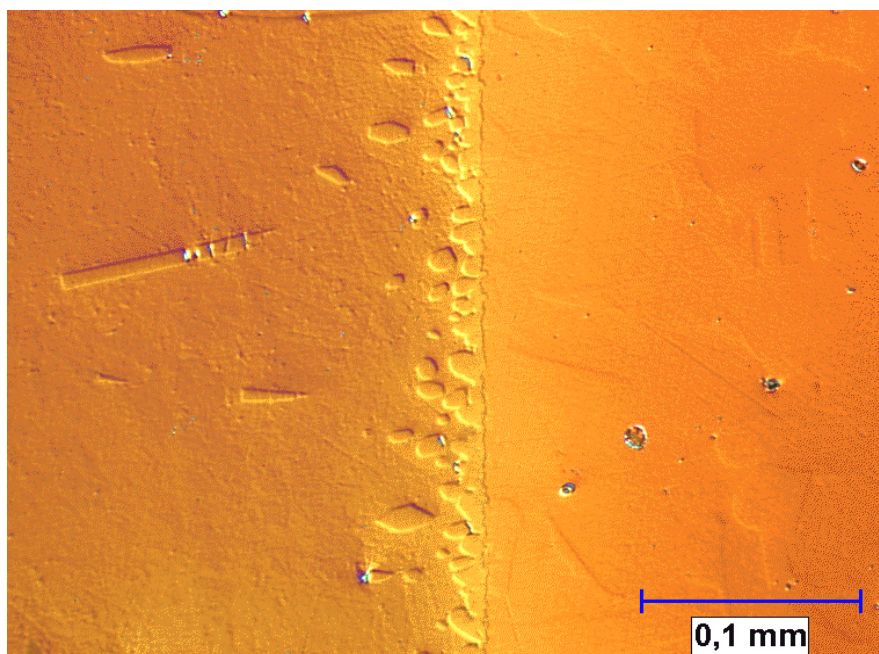


SnAg4/Cu couple
230°C; 5 min
NE: mag. 500×
CL

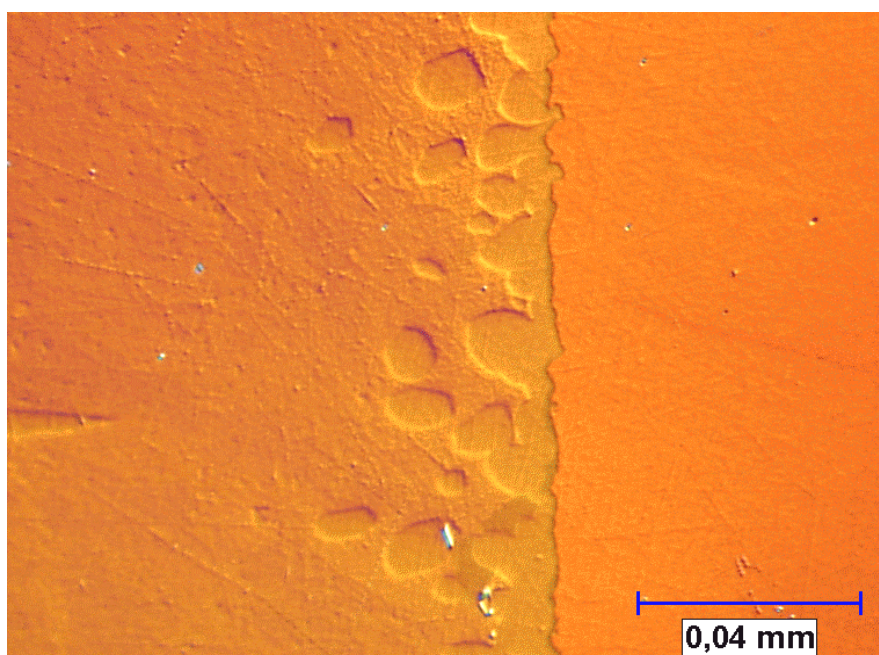
SnAg4/Cu couple
230°C; 5 min
NE: mag. 100×
PC

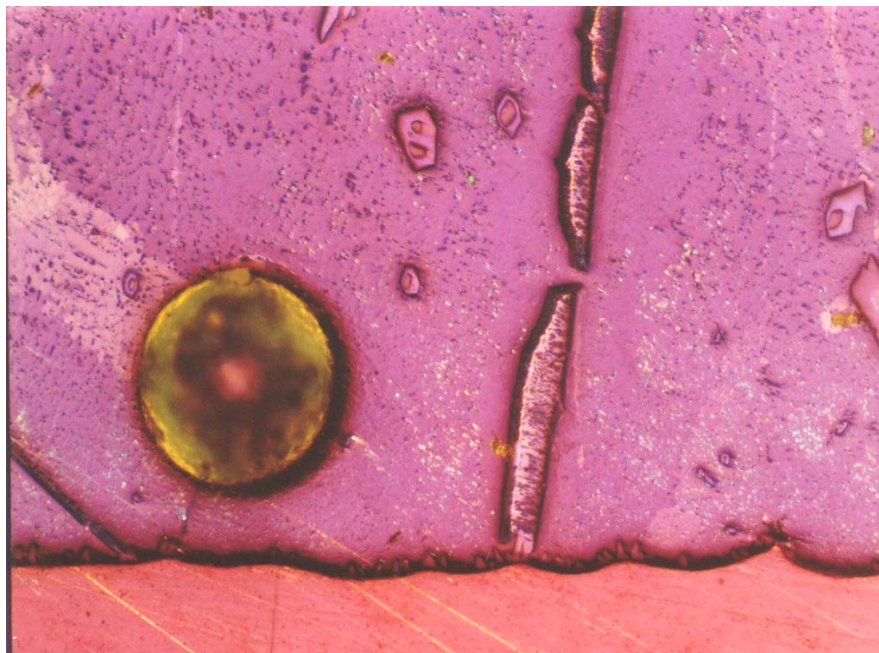


SnAg4/Cu couple
230°C; 5 min
NE: mag. 200×
PC

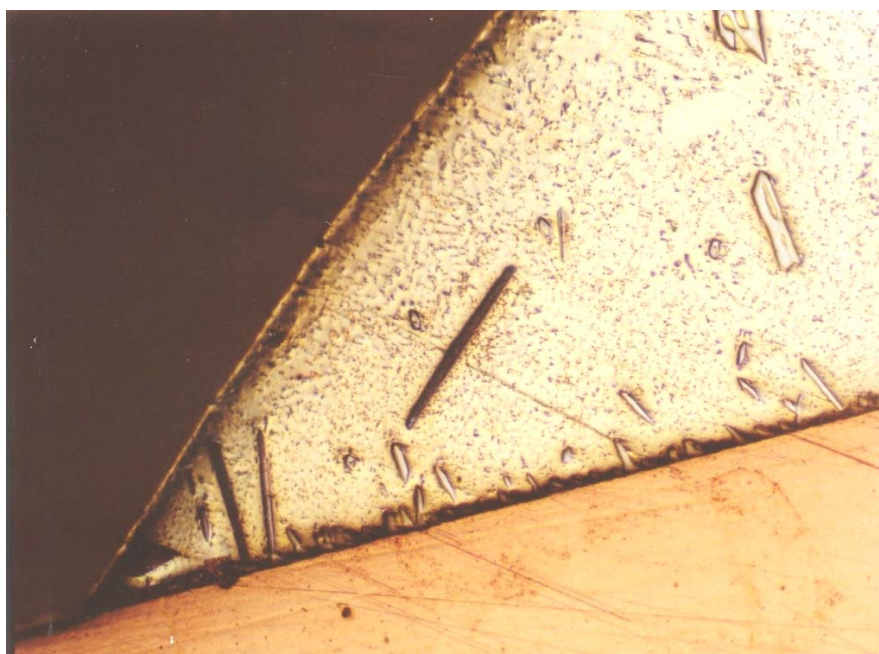


SnAg4/Cu couple
230°C; 5 min
NE: mag. 500×
PC

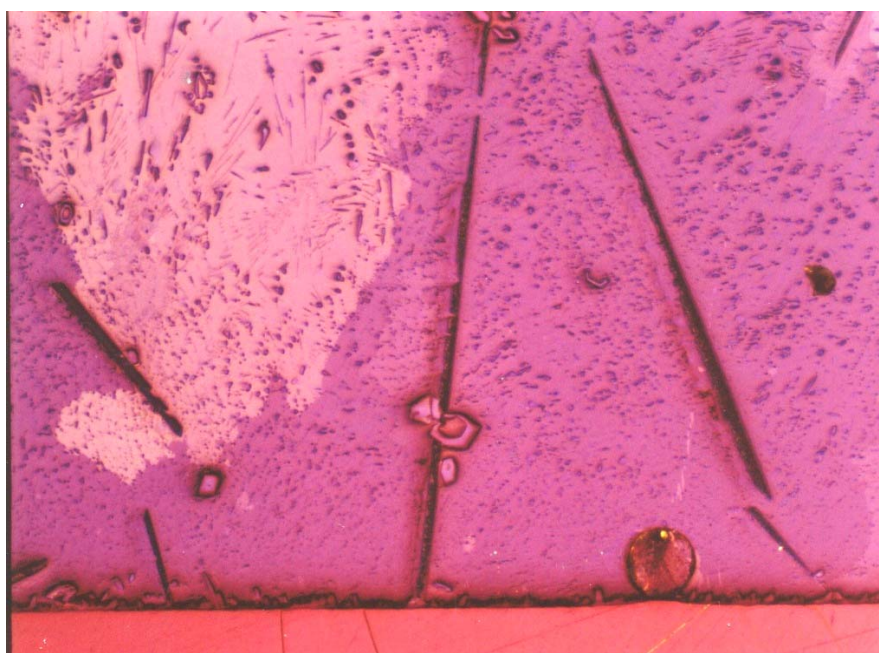




SnAg3.95Cu0.65/Cu couple
230°C; 5 min
NE: mag. 100×

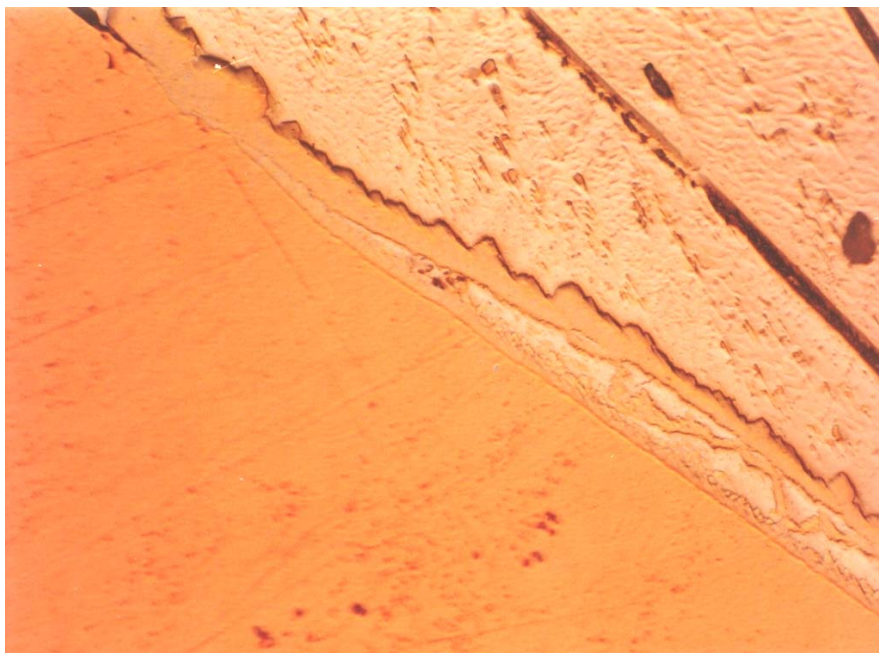


SnAg3.95Cu0.65/Cu couple
230°C; 5 min
NE: mag. 100×

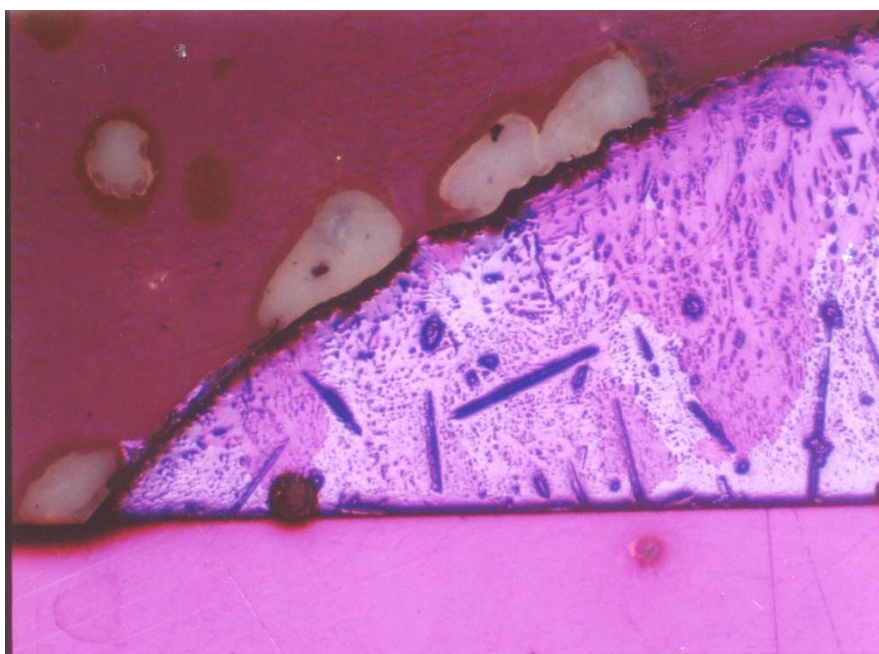


SnAg3.95Cu0.65/Cu couple
230°C; 5 min
NE: mag. 100×

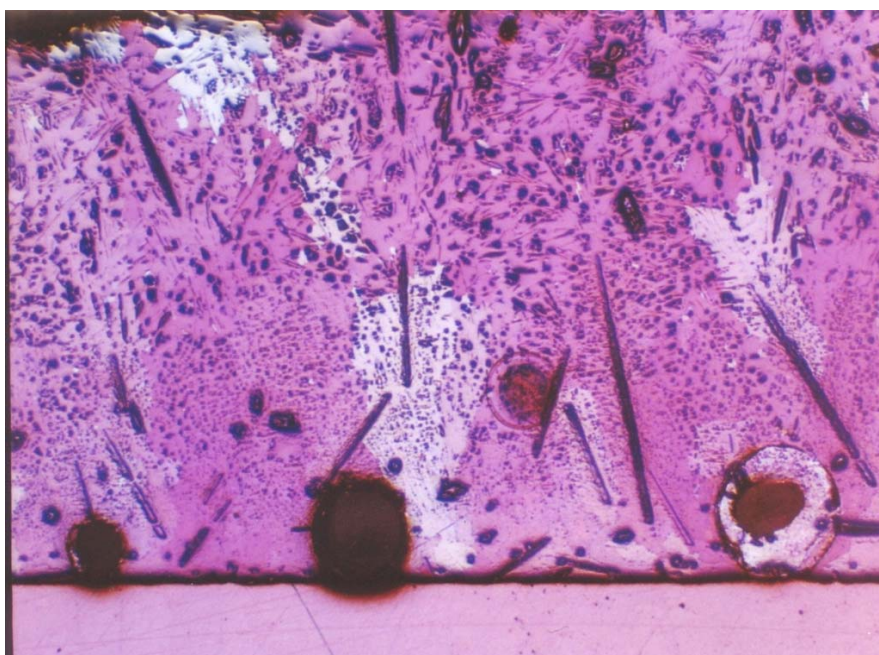
SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 250×

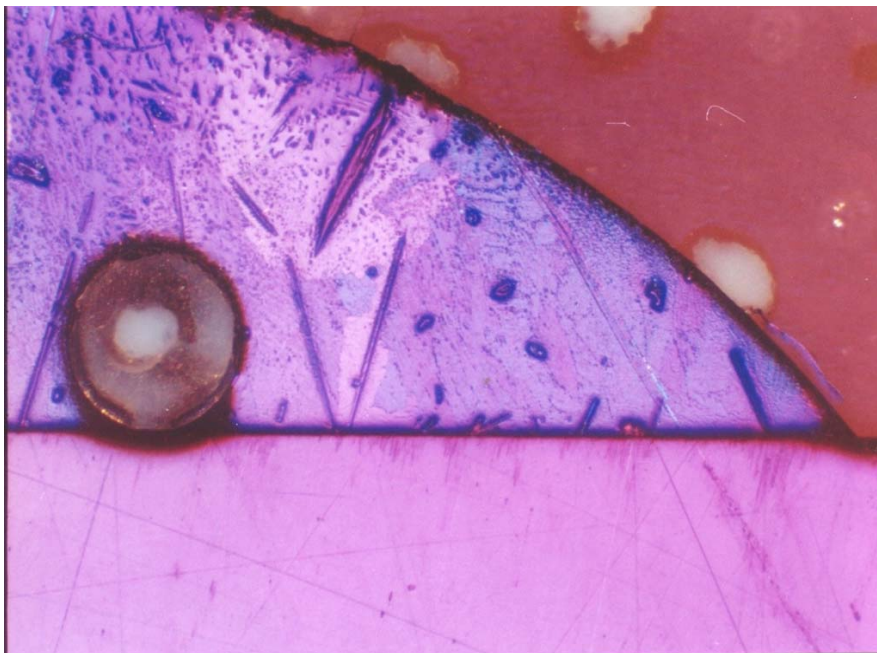


SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 32×

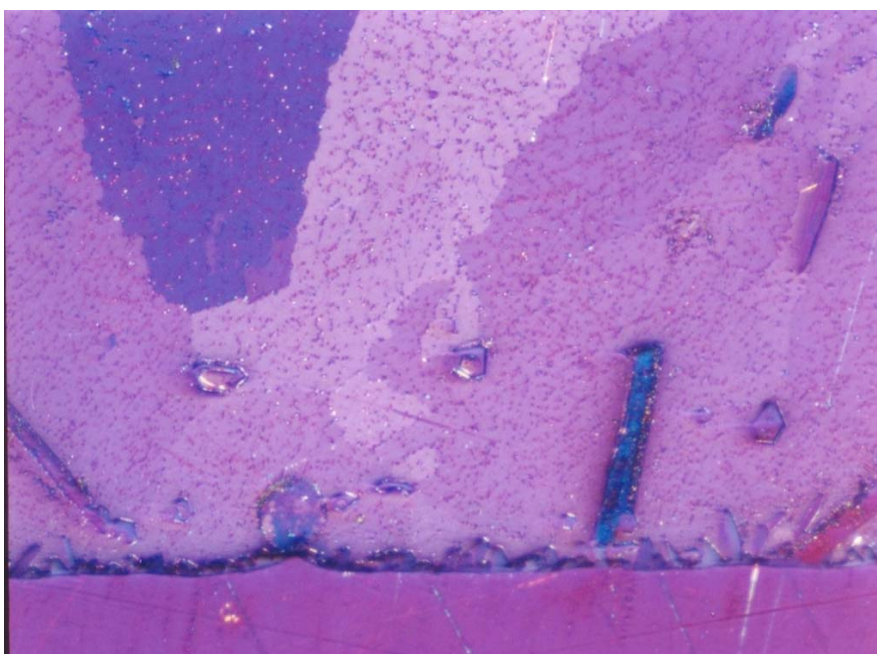


SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 32×

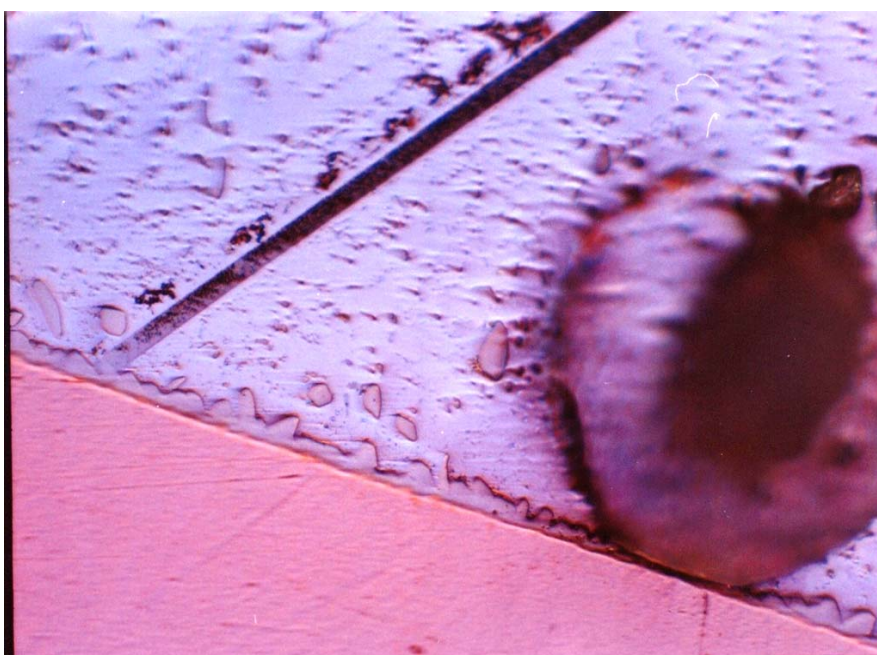




SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 32×

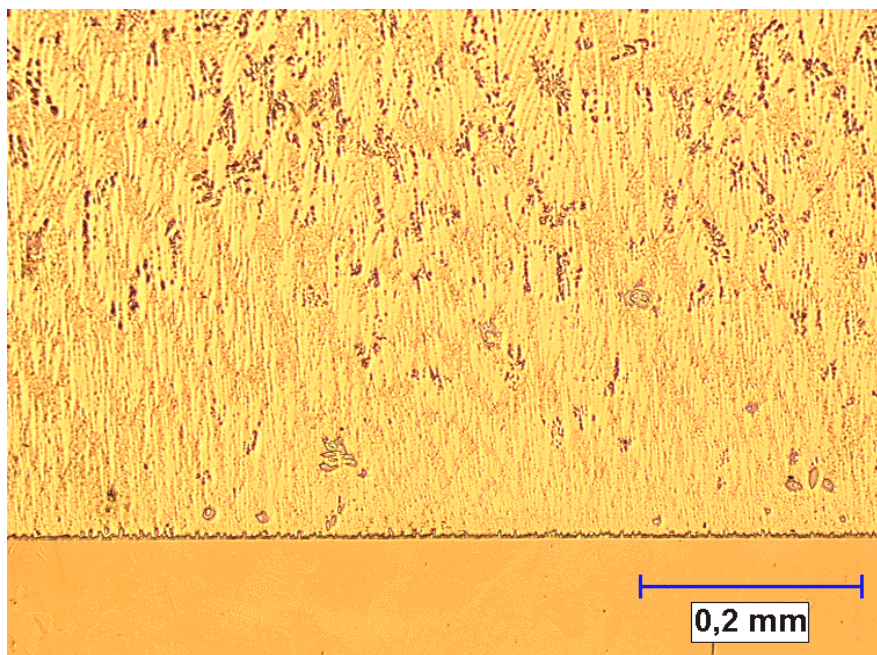


SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 200×

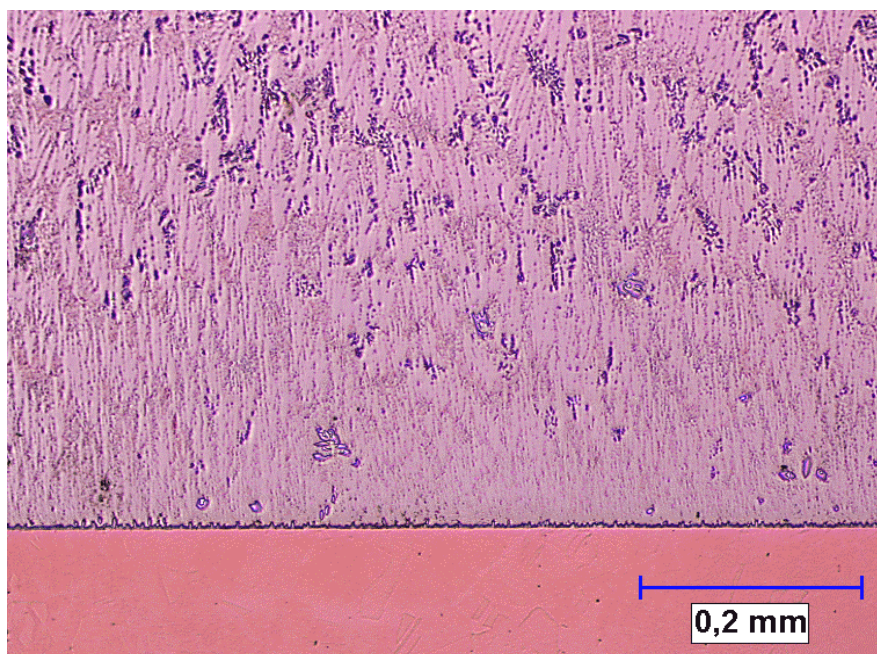


SnAg3.95Cu0.65/Cu couple
221°C; 5 min
NE: mag. 320×

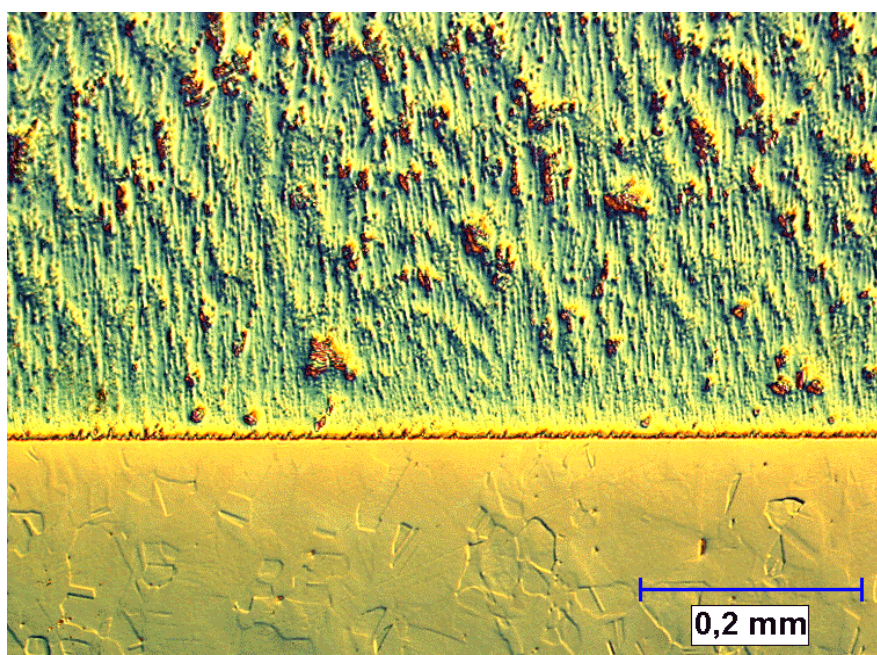
Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
CL

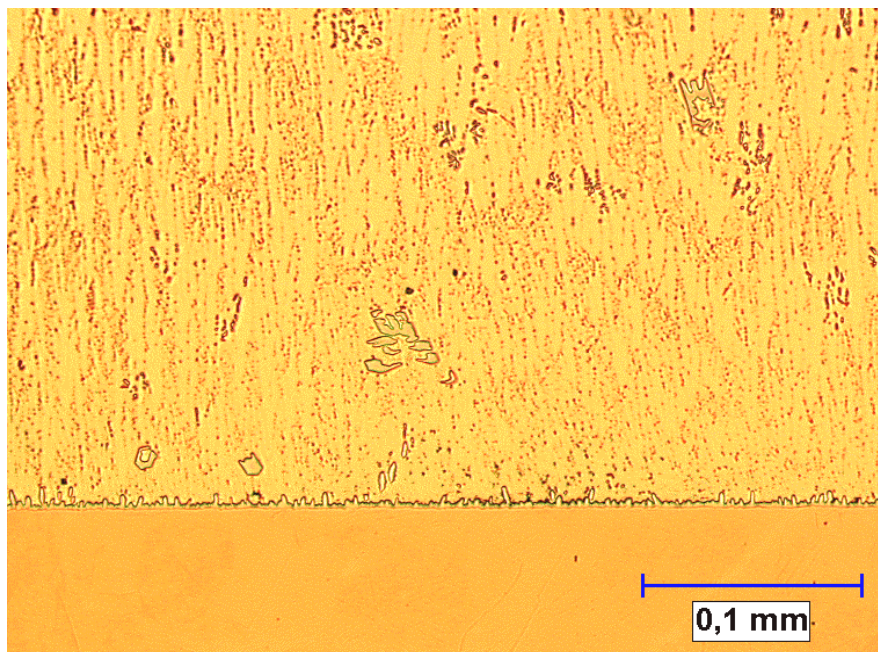


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
PL

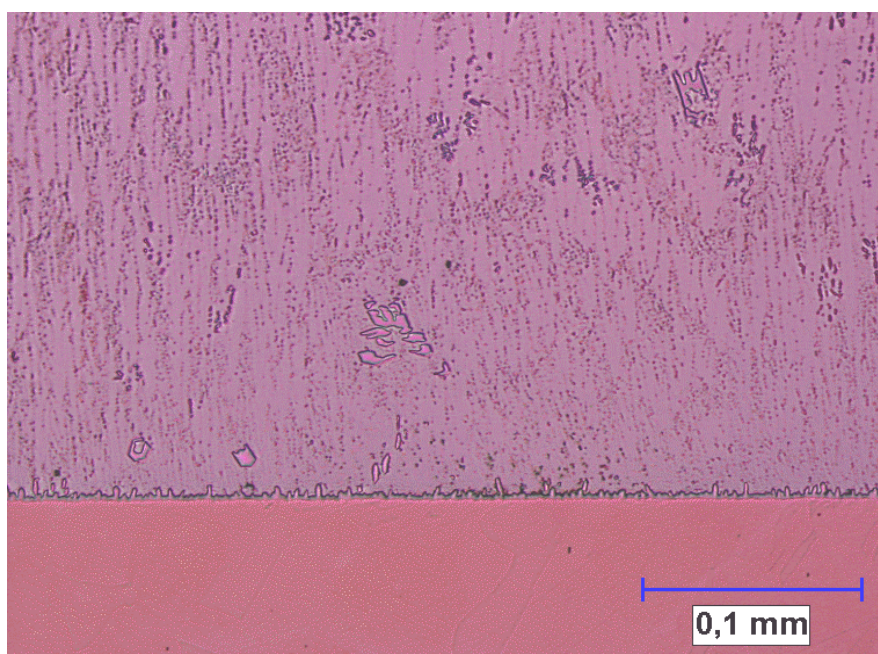


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
PC

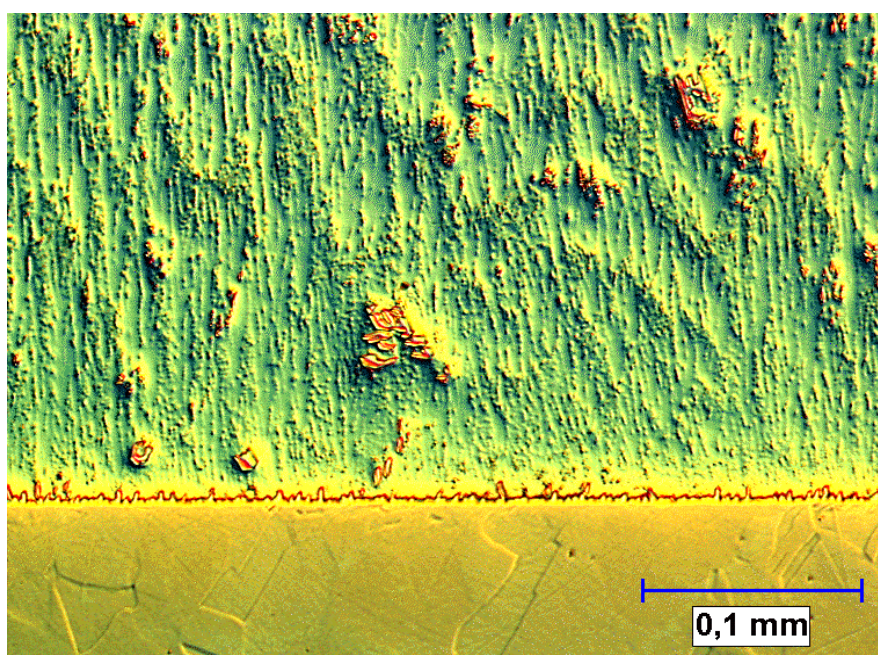




Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
CL

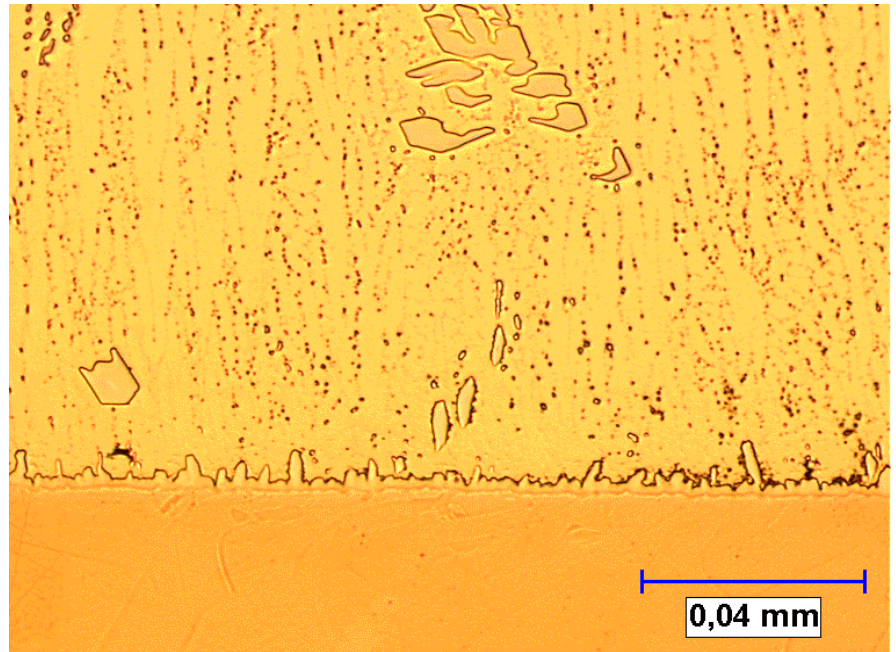


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
PL

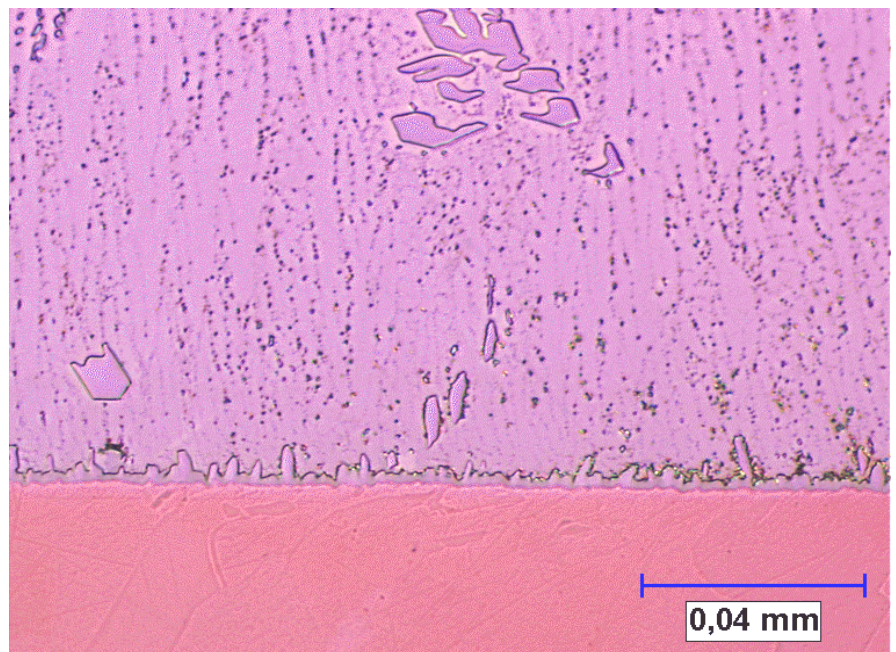


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
PC

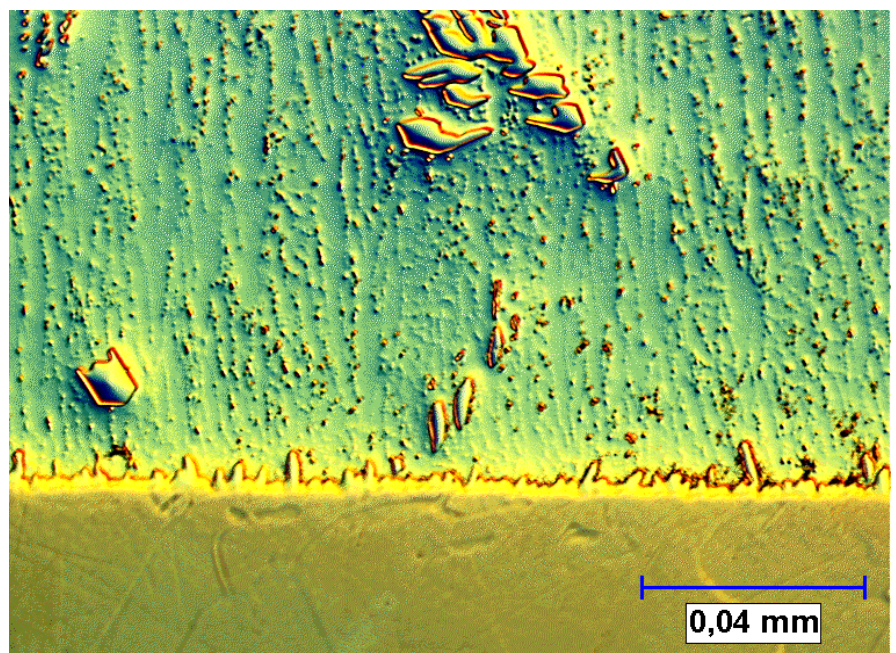
Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 500×
CL

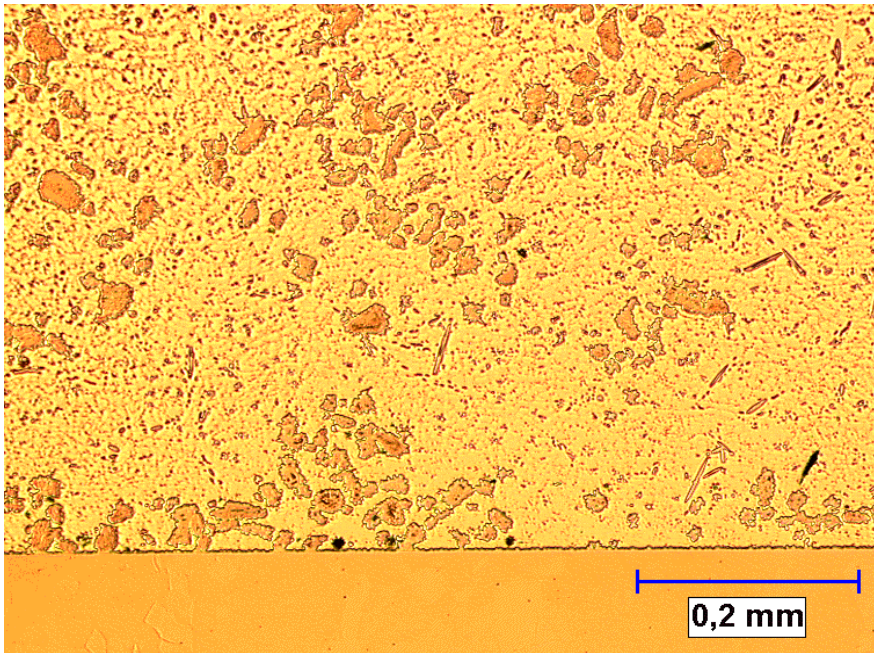


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 500×
PL

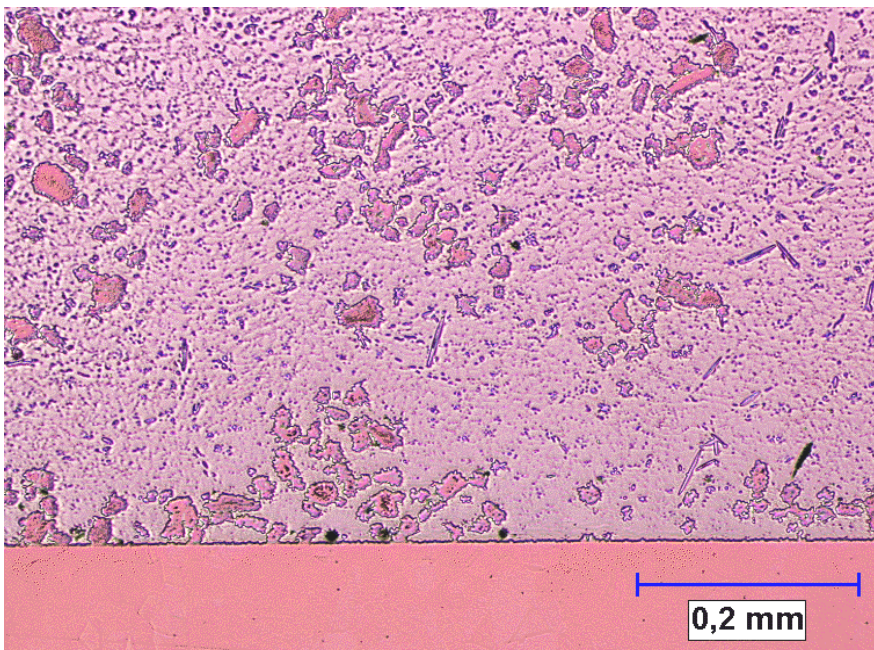


Paste SAC*/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 500×
PC

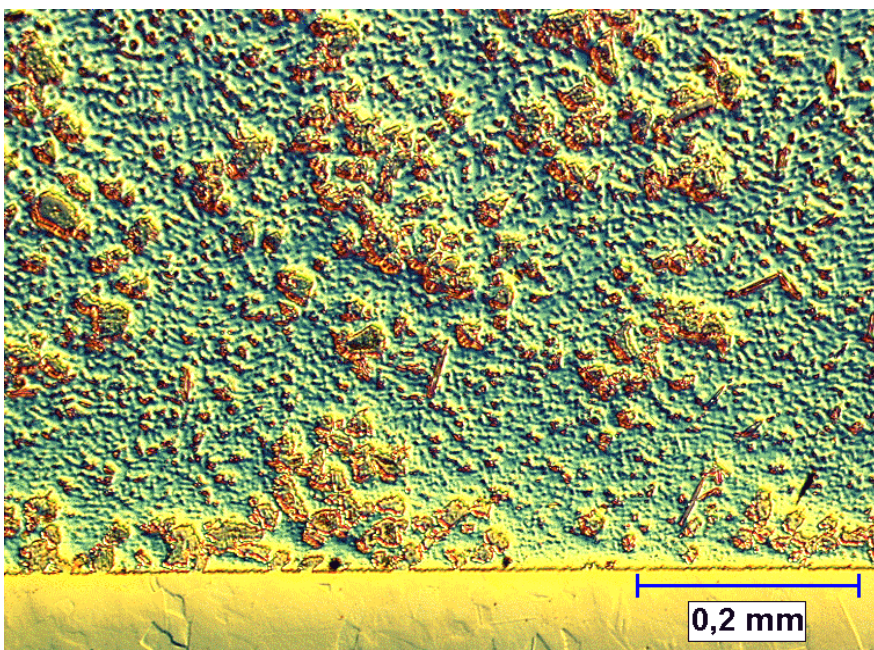




Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
CL

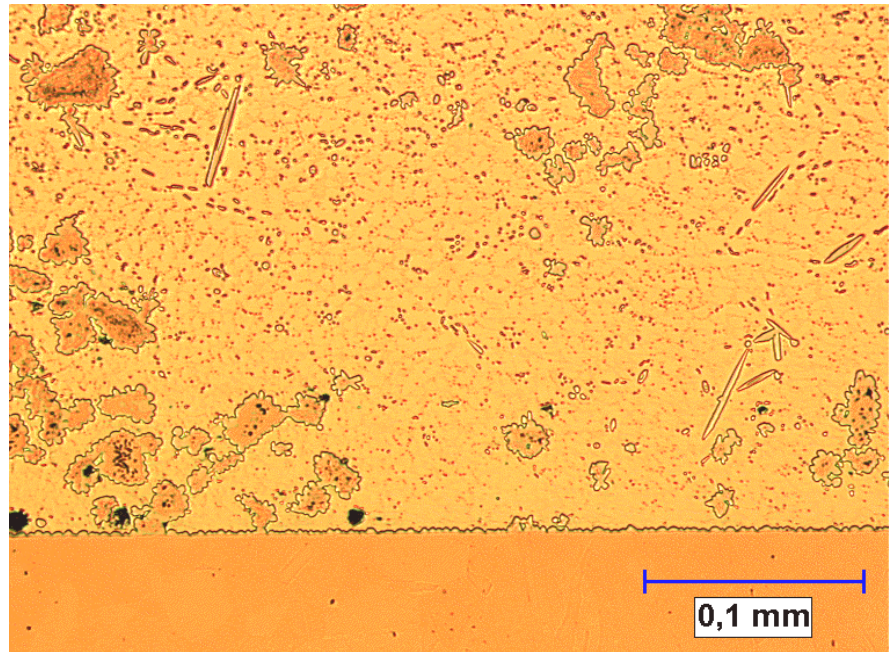


Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
PL

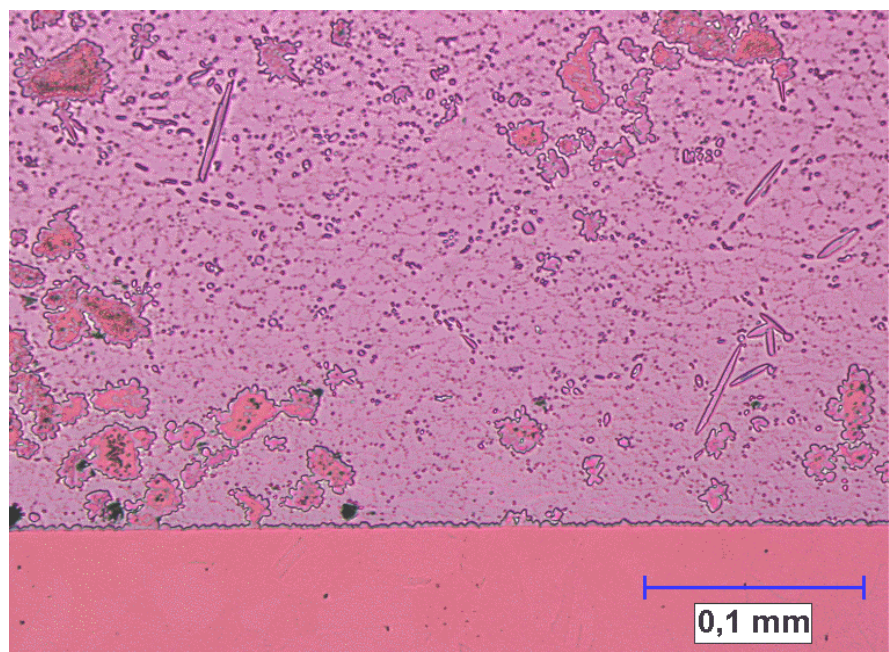


Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 100×
PC

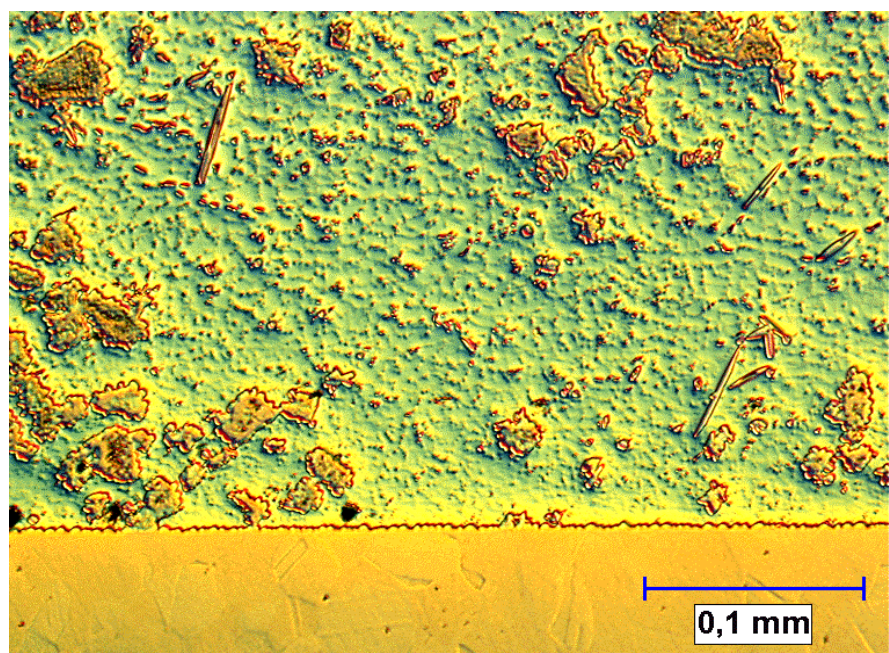
Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
CL

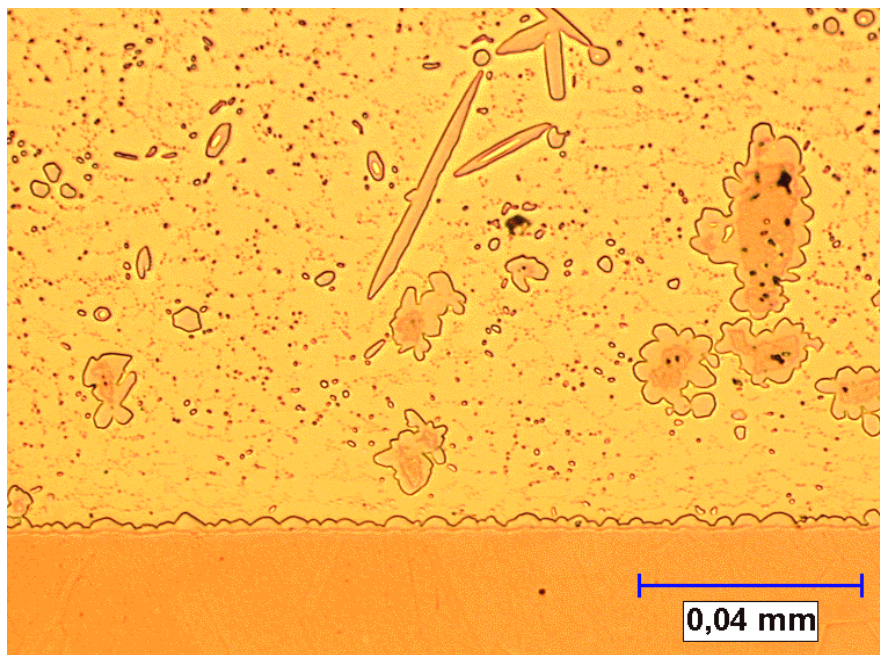


Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
PL



Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5
230°C; 1 min
E: mag. 200×
PC



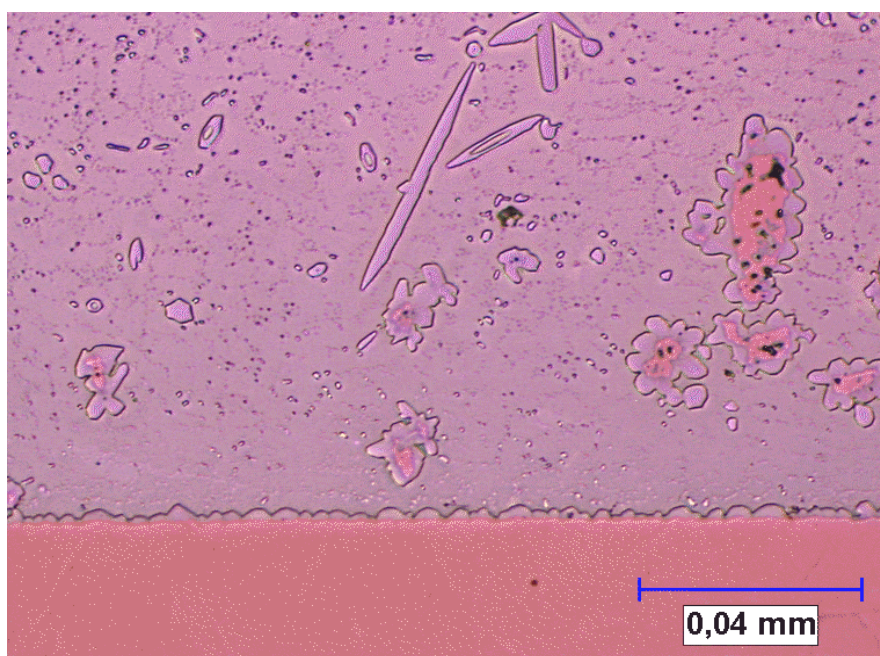


Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5

230°C; 1 min

E: mag. 500×

CL

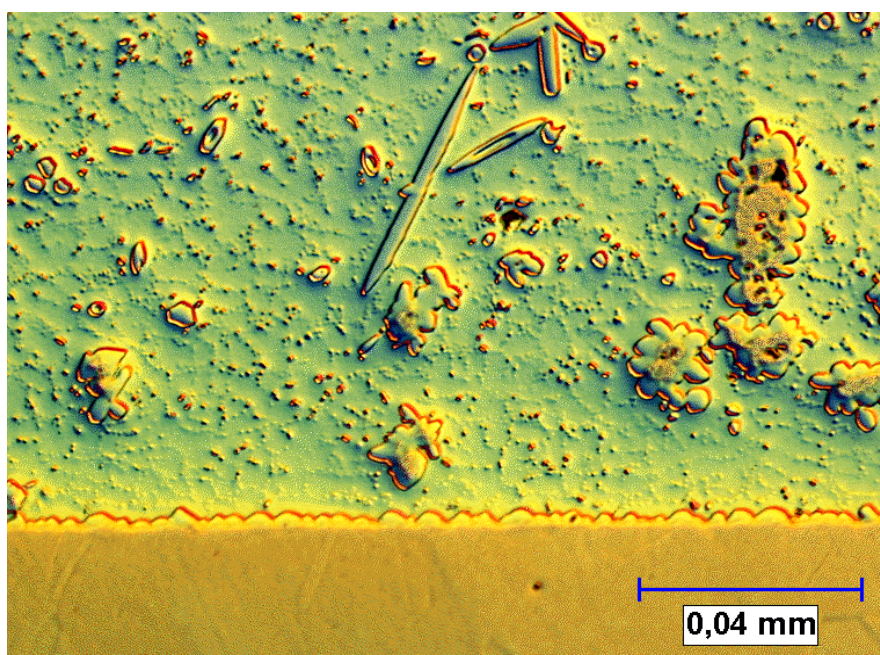


Paste SAC+10%Cu/Cu
*SnAg3Cu0.5

230°C; 1 min

E: mag. 500×

PL

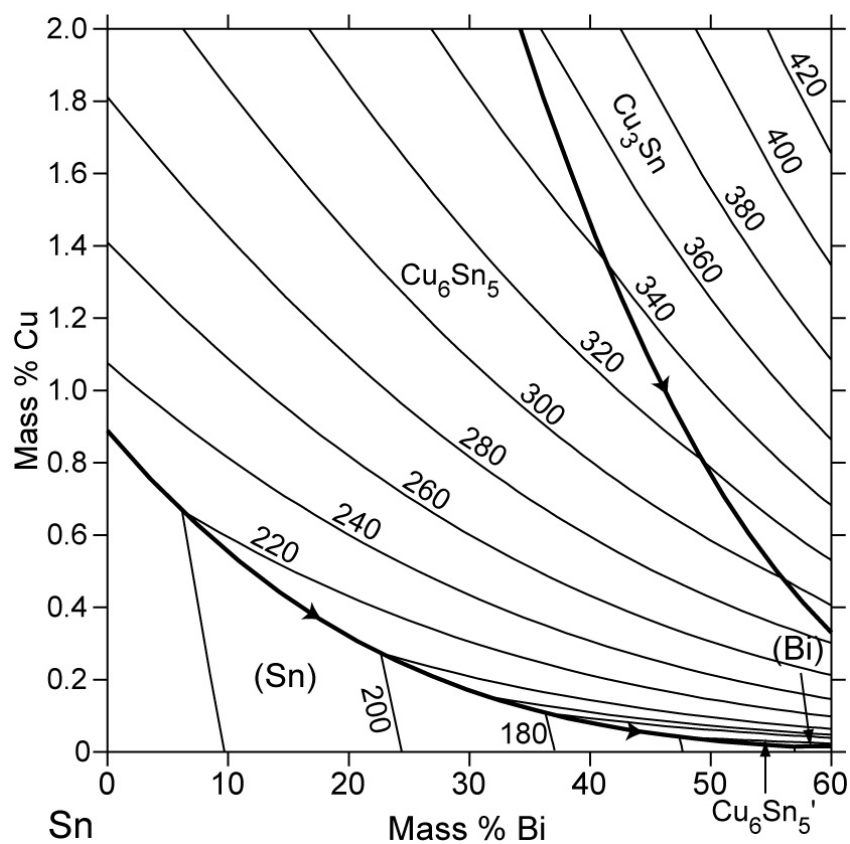
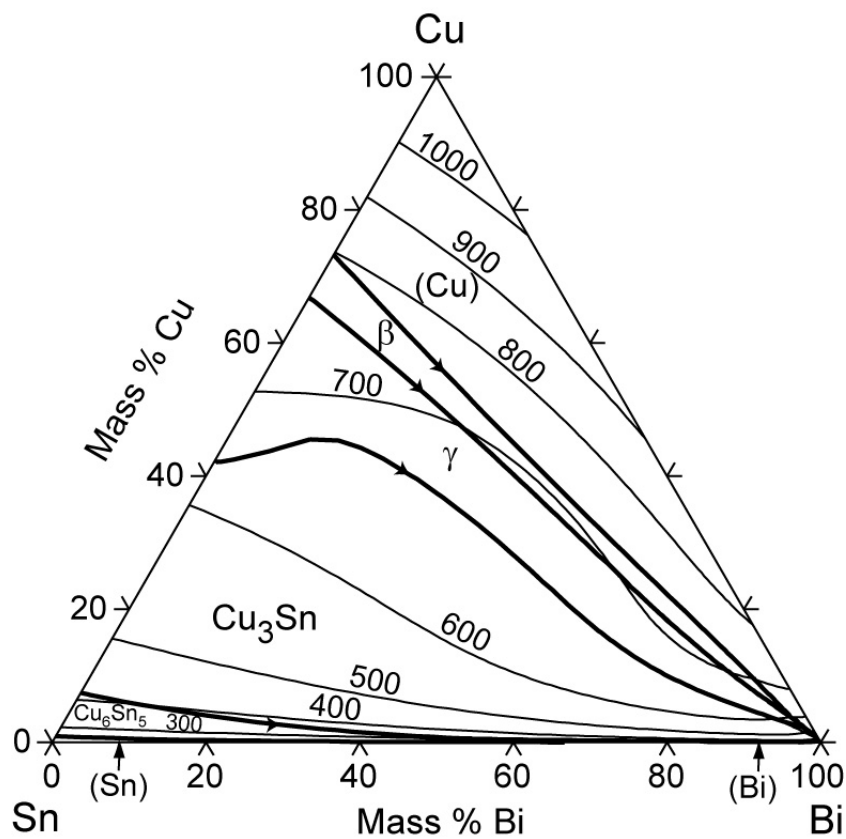


Paste SAC*+10%Cu/Cu
*SnAg3Cu0.5

230°C; 1 min

E: mag. 500×

PC

Sn – Bi – Cu

Phases, Crystal Structures and Model Descriptions

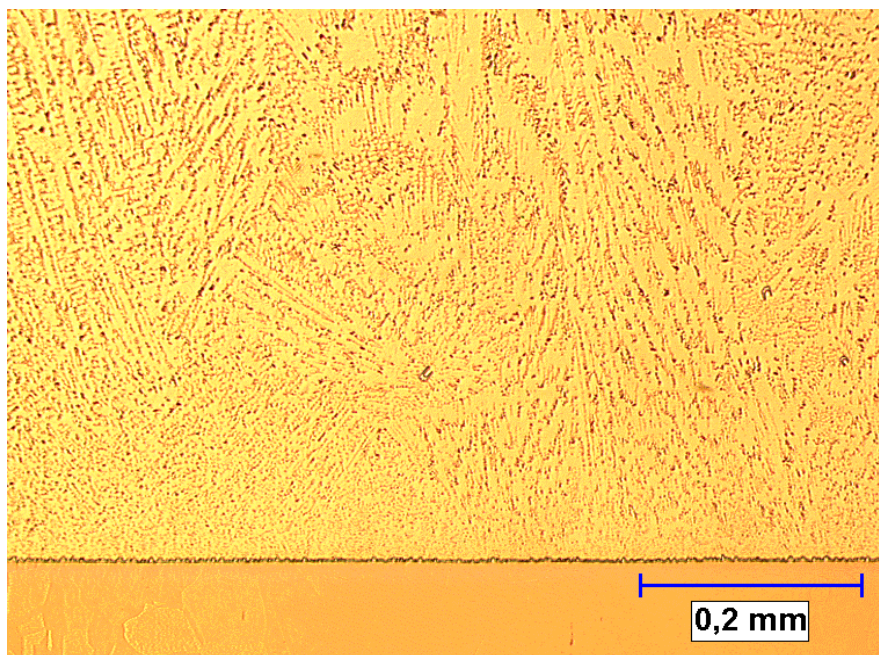
Phase	Strukturbericht Symbol	Common Names	Prototype	Spacegroup	Model*
Liquid	n/a	L	n/a	n/a	(Bi,Cu,Sn) ₁
Fcc	A1	(Cu)	Cu	Fm-3m	(Bi, Cu ,Sn) ₁ (Va) ₁
Bcc	A2	(beta Cu), beta	W	Im-3m	(Cu ,Sn) ₁ (Va) ₃
Bct	A5	(Sn), (beta Sn)	beta Sn	I4 ₁ /amd	(Ag,Bi,Cu,Pb, Sn) ₁
Rho	A7	(Bi)	alpha As	R-3m	(Bi ,Pb,Sn) ₁
Cu ₃ Sn.h	D0 ₃	gamma	BiF ₃	Fm-3m	(Cu ,Sn) _{0.75} (Cu,Sn) _{0.25}
Cu ₄₁ Sn ₁₁	...	delta	...	F-43m	Cu _{0.788} Sn _{0.212}
Cu ₁₀ Sn ₃	...	zeta	...	P6 ₃	Cu _{0.769} Sn _{0.231}
Cu ₃ Sn	...	epsilon	...	Cmcm	Cu _{0.75} Sn _{0.25}
Cu ₆ Sn ₅	B8 ₁	eta, Cu ₆ Sn ₅ .h	NiAs	P6 ₃ /mmc	Cu _{0.545} Sn _{0.455}
Cu ₆ Sn ₅ '	...	eta ', Cu ₆ Sn ₅ .l	...	...	Cu _{0.545} Sn _{0.455}

*Major species are printed bold face

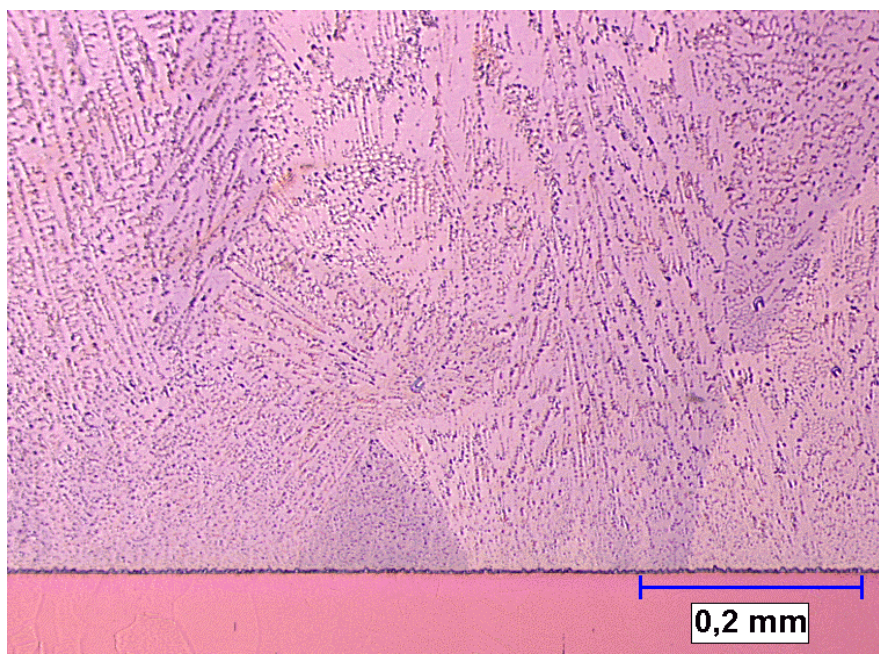
Calculated Phase Diagram (data from <http://www.metallurgy.nist.gov/phase/solder/bicusn.html>)*Properties of solder/substrate couples*

Couple	Conditions	θ, deg	τ, MPa
SnBi2.5 / Cu	230°C, 5 min, flux	51°	51
SnBi5 / Cu	230°C, 5 min, flux	45°	50
SnBi10 / Cu	230°C, 5 min, flux	40°	53
SnBi15 / Cu	230°C, 5 min, flux	37°	47

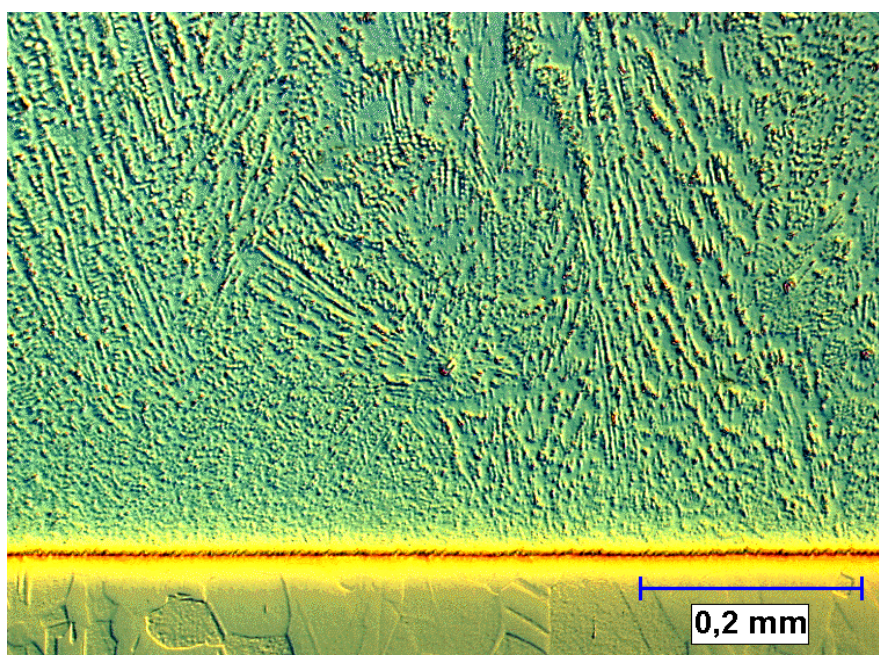
SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
CL

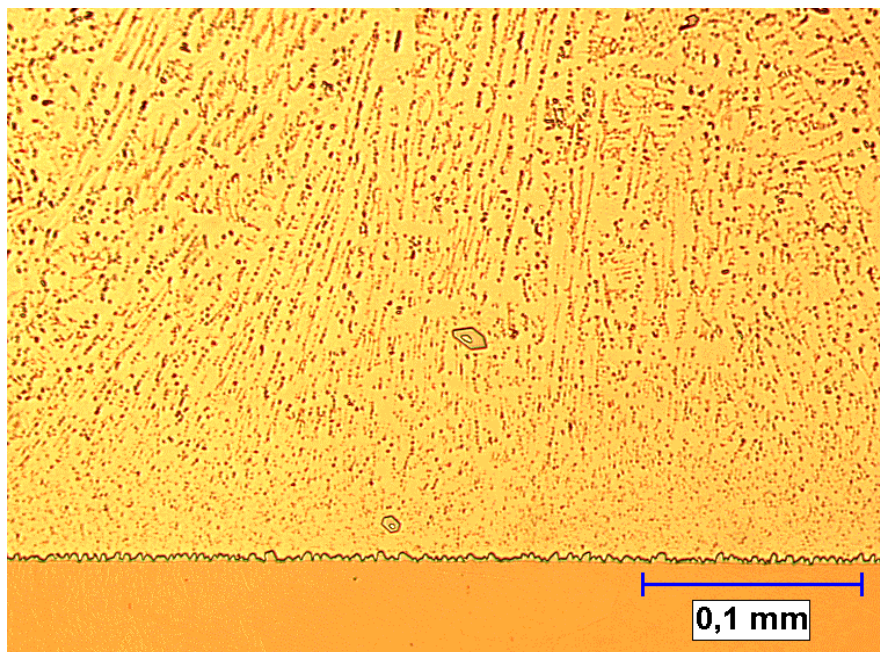


SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
PL

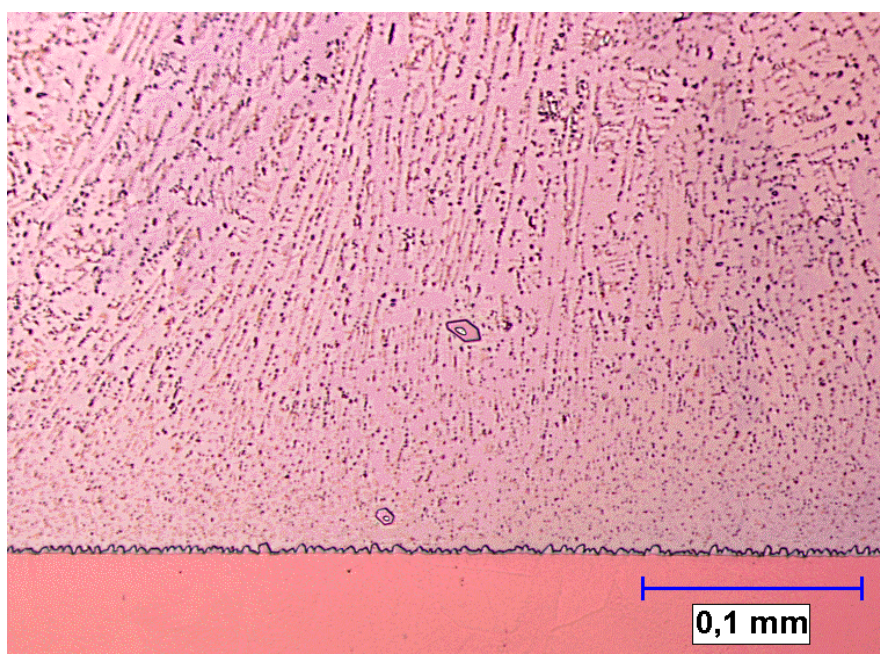


SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
PC

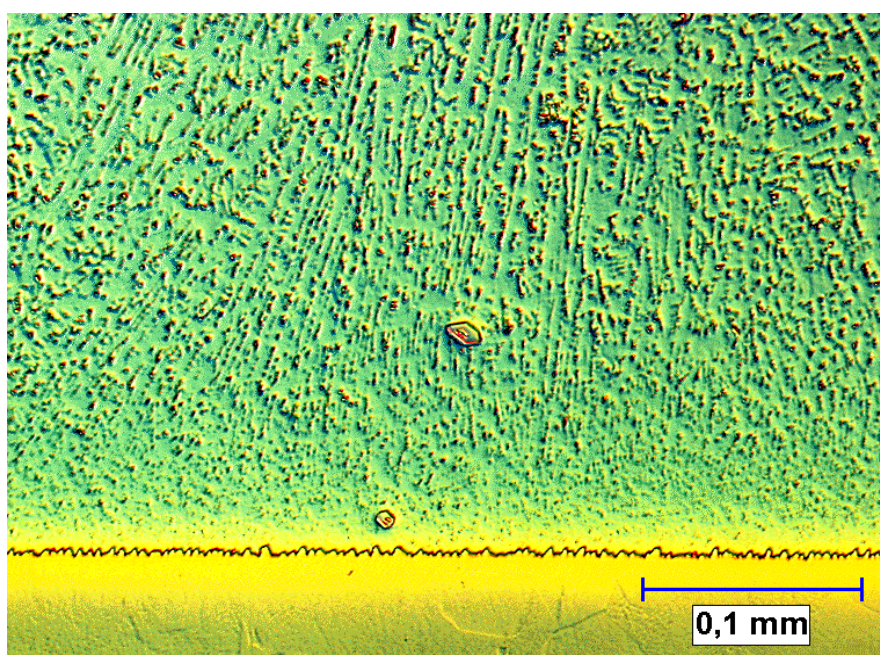




SnBi_{2.5}/Cu couple
230°C; 5 min
E: mag. 200×
CL

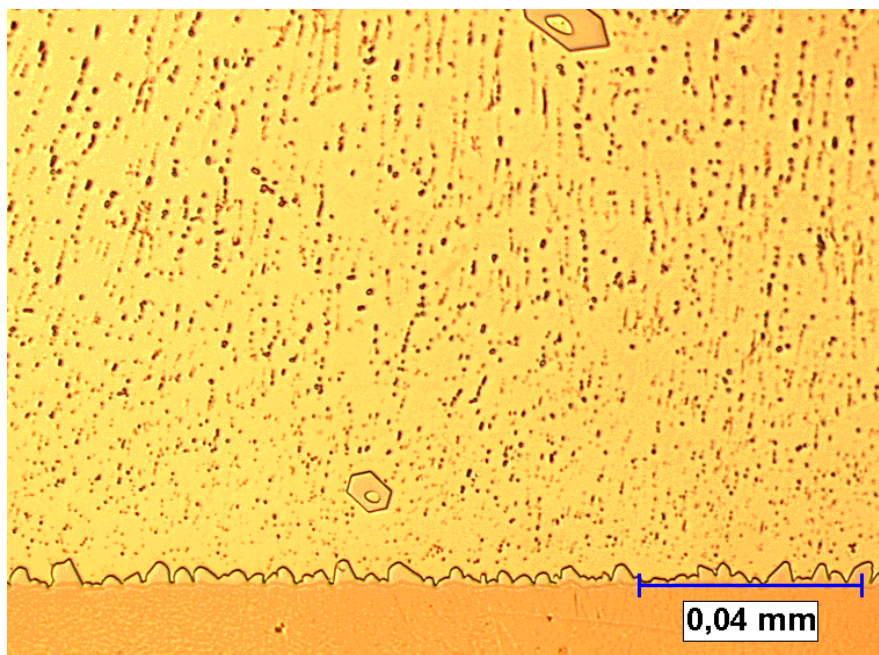


SnBi_{2.5}/Cu couple
230°C; 5 min
E: mag. 200×
PL

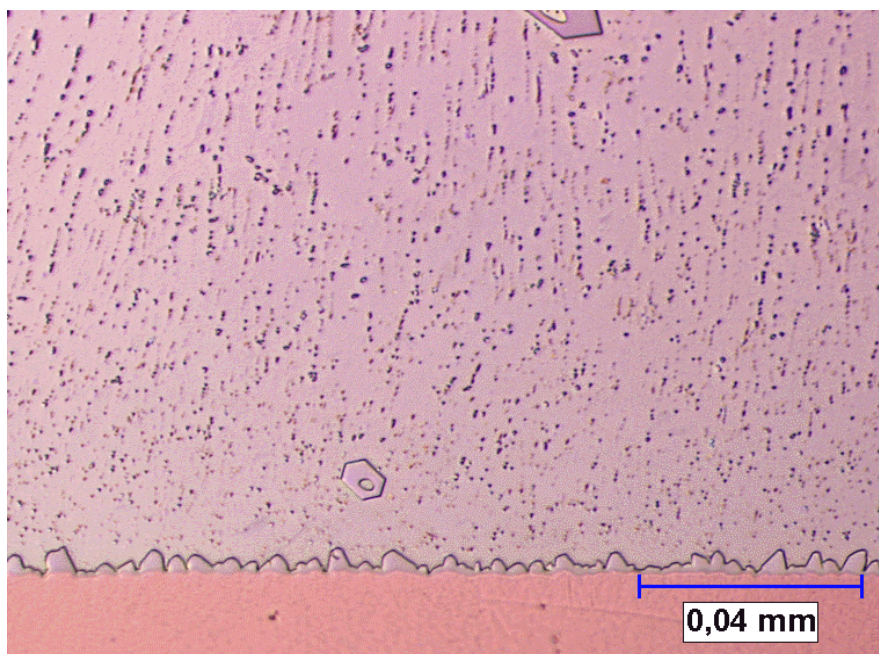


SnBi_{2.5}/Cu couple
230°C; 5 min
E: mag. 200×
PC

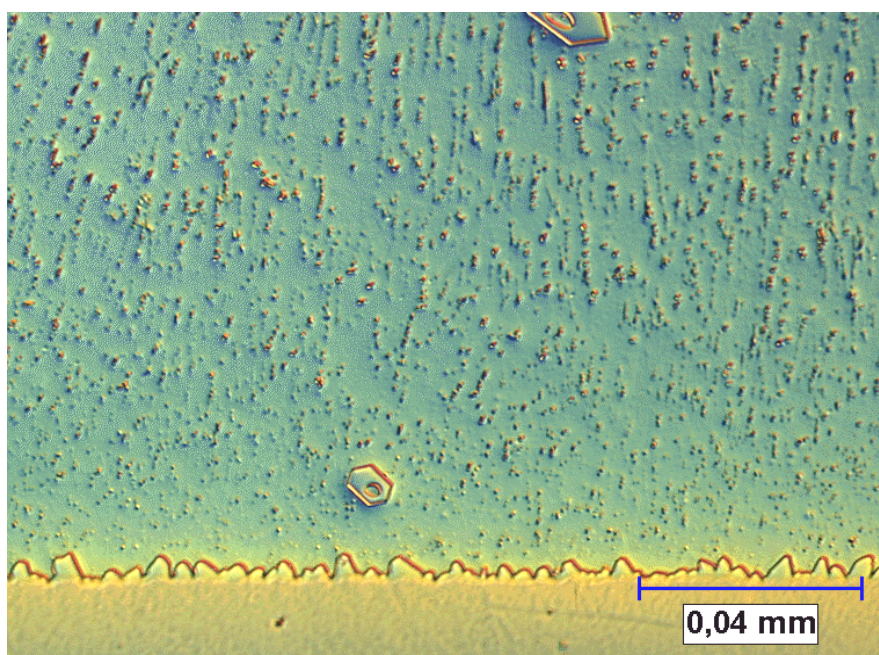
SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
CL

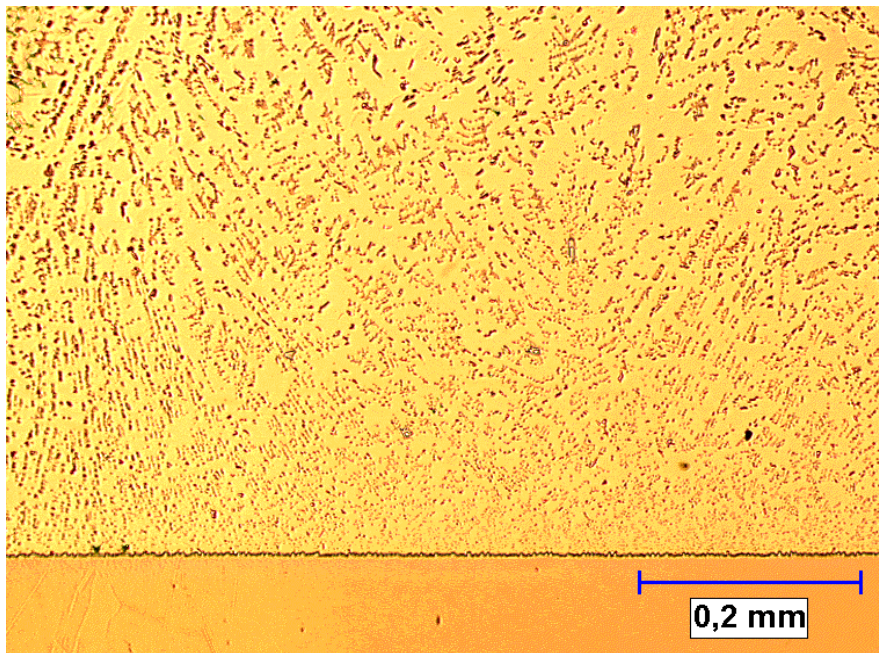


SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
PL

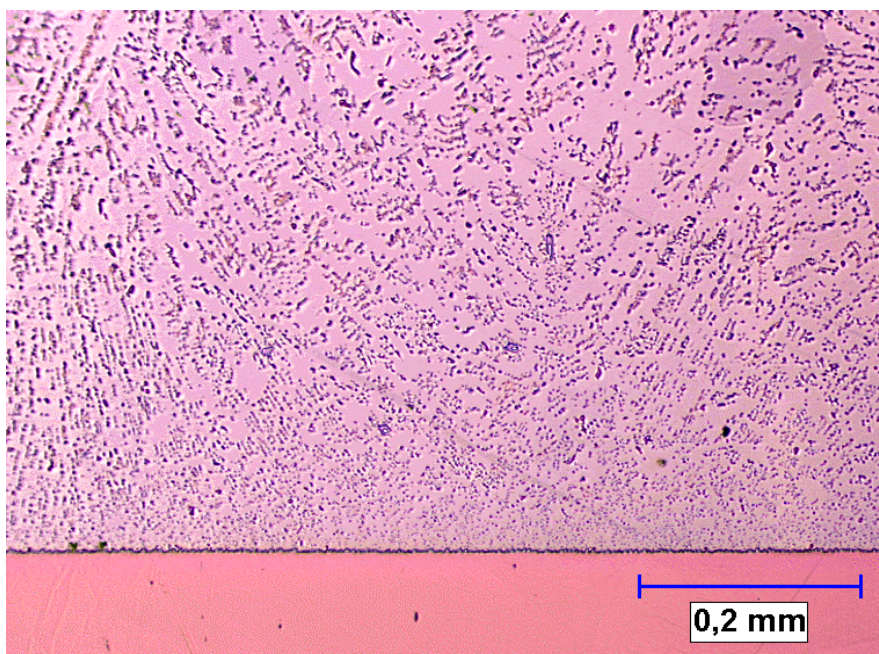


SnBi2.5/Cu couple
230°C; 5 min
E: mag. 100×
PC

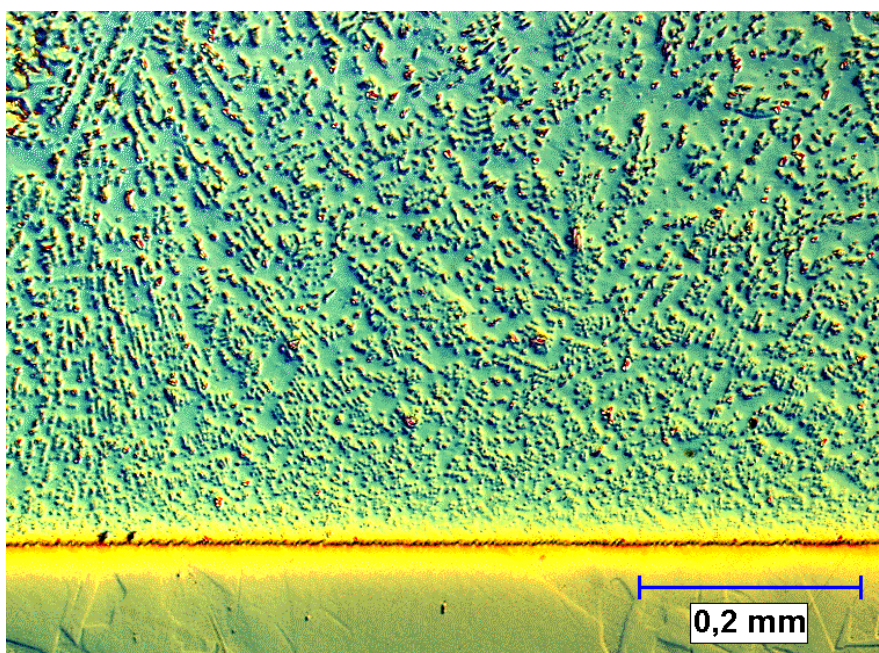




SnBi5/Cu couple
230°C; 5 min
E: mag. 100×
CL

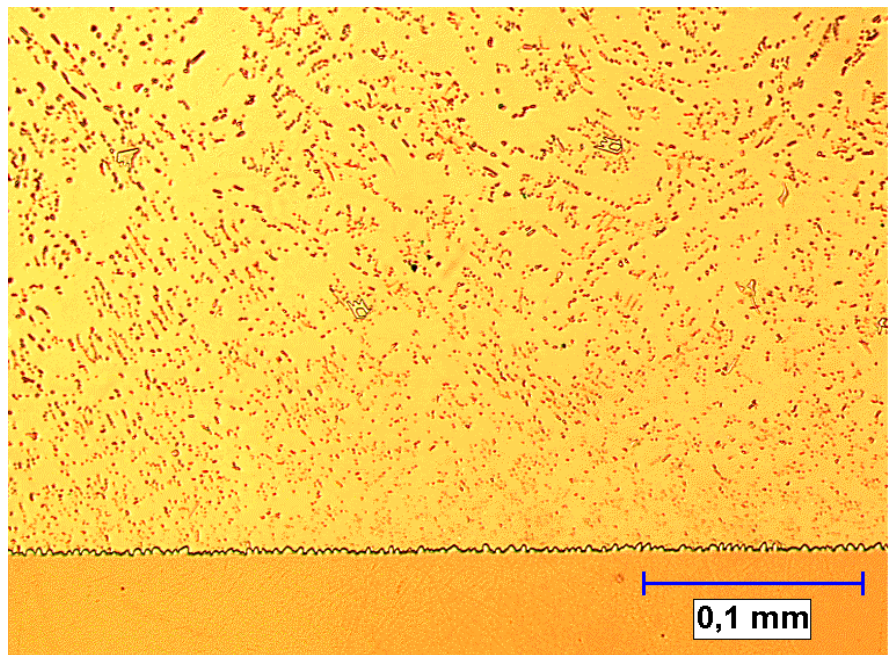


SnBi5/Cu couple
230°C; 5 min
E: mag. 100×
PL

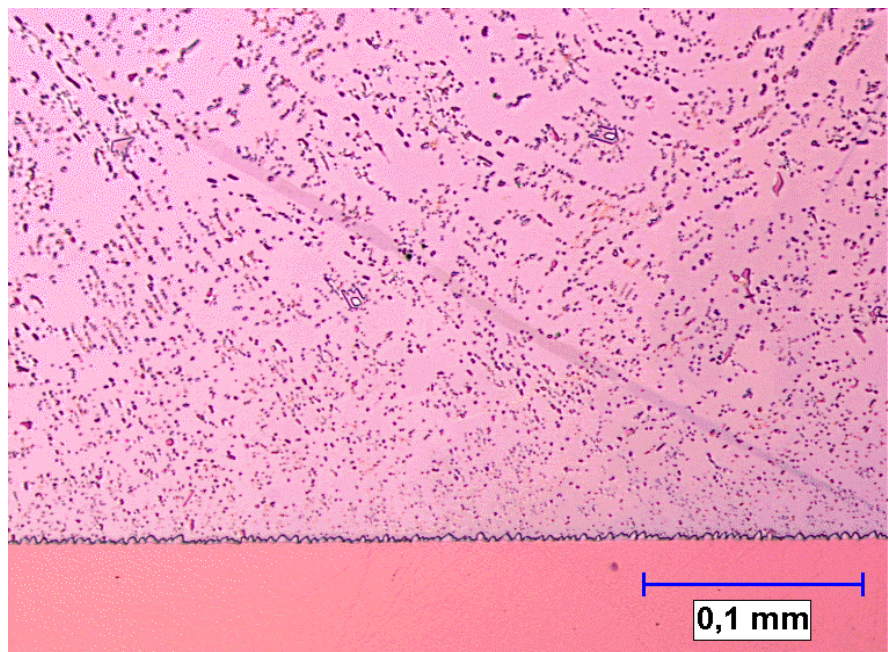


SnBi5/Cu couple
230°C; 5 min
E: mag. 100×
PC

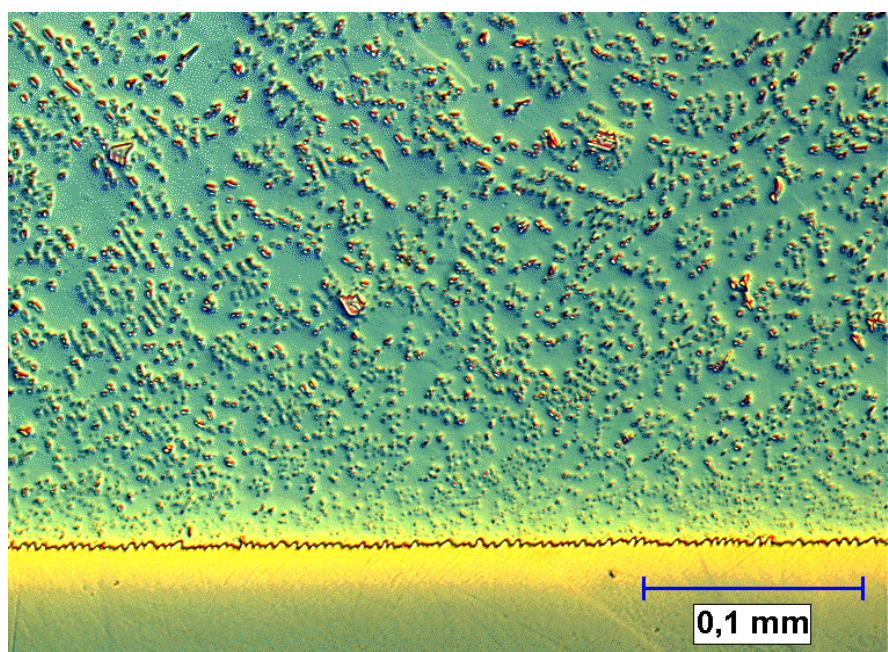
SnBi5/Cu couple
230°C; 5 min
E: mag. 200×
CL

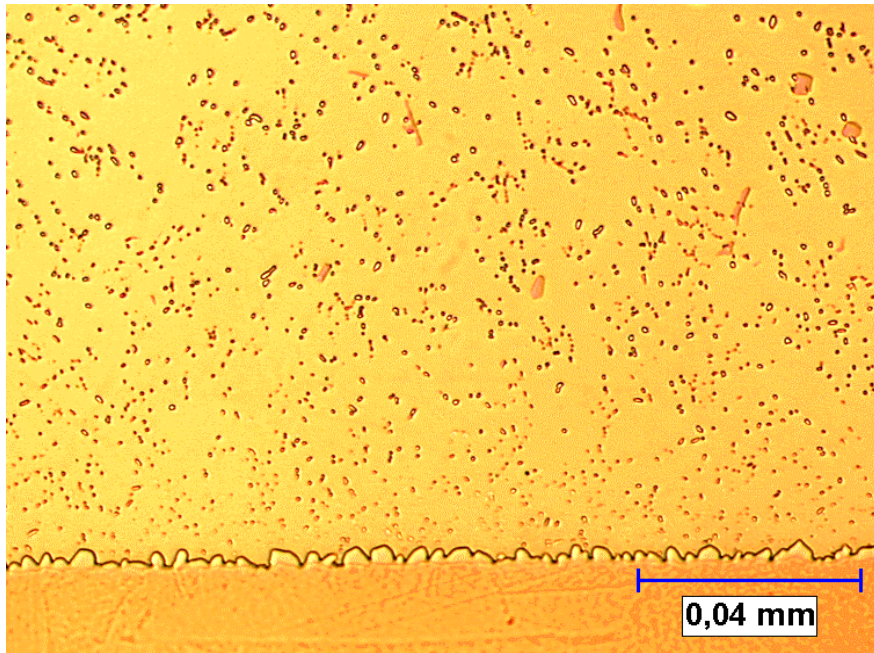


SnBi5/Cu couple
230°C; 5 min
E: mag. 200×
PL

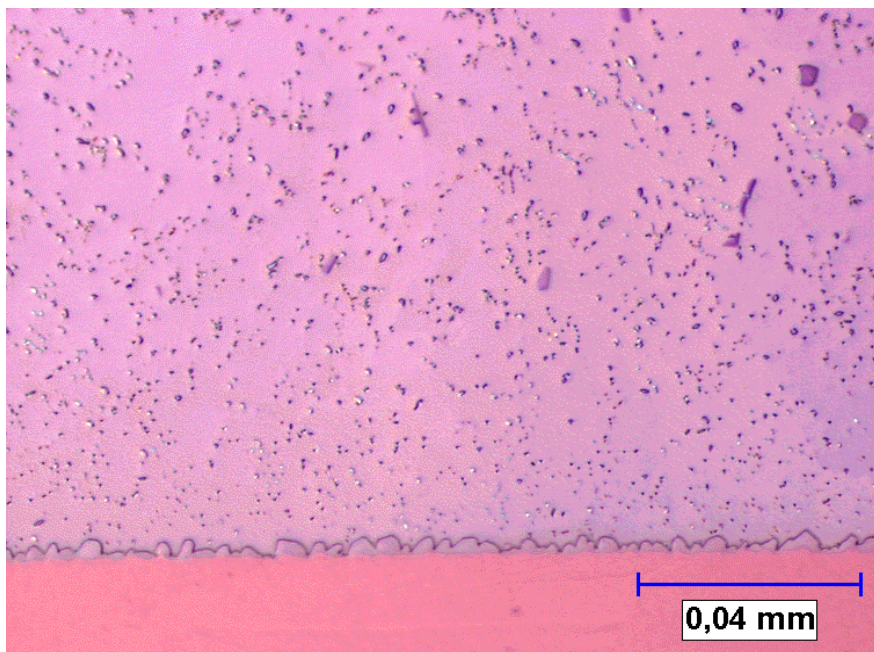


SnBi5/Cu couple
230°C; 5 min
E: mag. 200×
PC

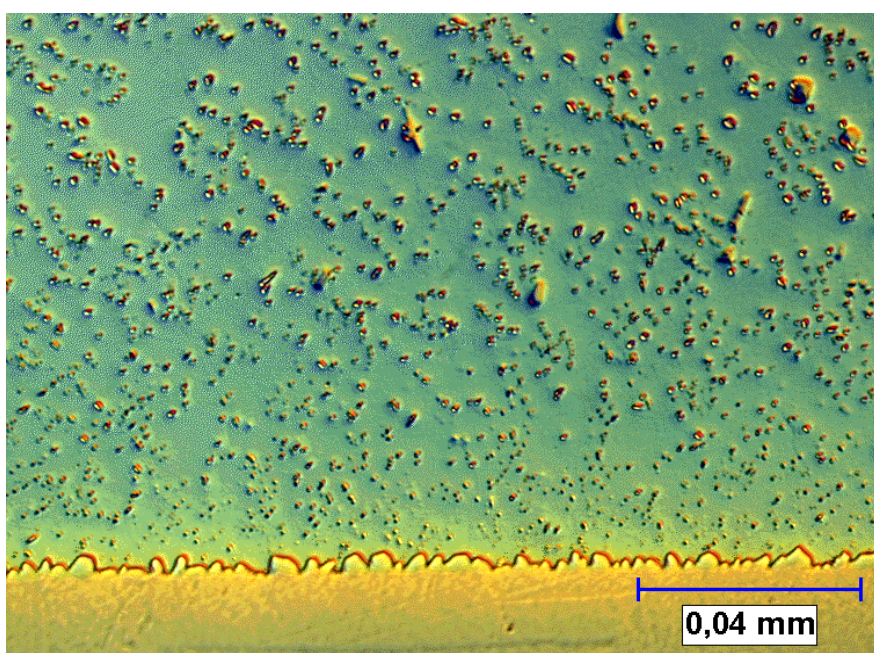




SnBi5/Cu couple
230°C; 5 min
E: mag. 500×
CL

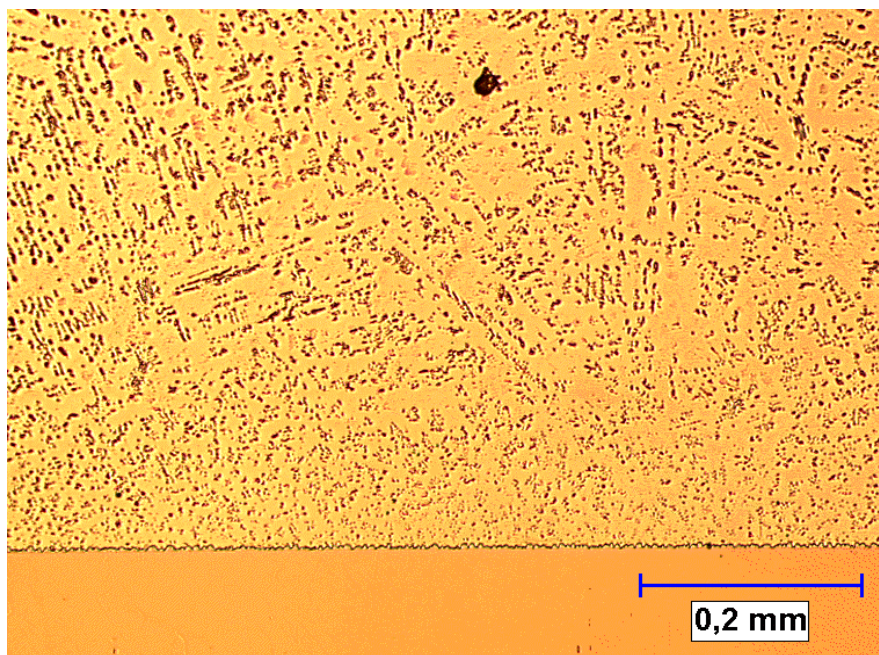


SnBi5/Cu couple
230°C; 5 min
E: mag. 500×
PL

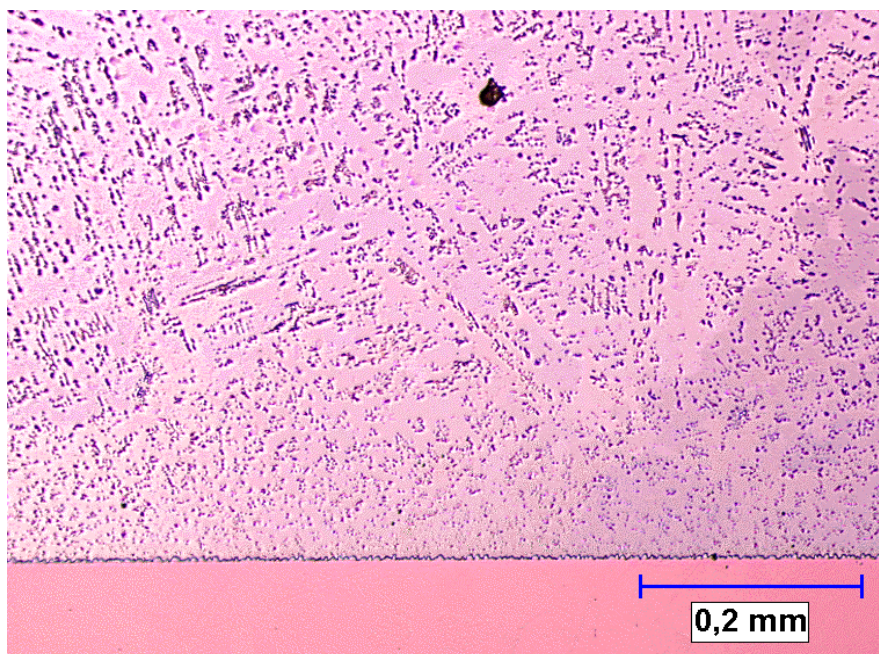


SnBi5/Cu couple
230°C; 5 min
E: mag. 500×
PC

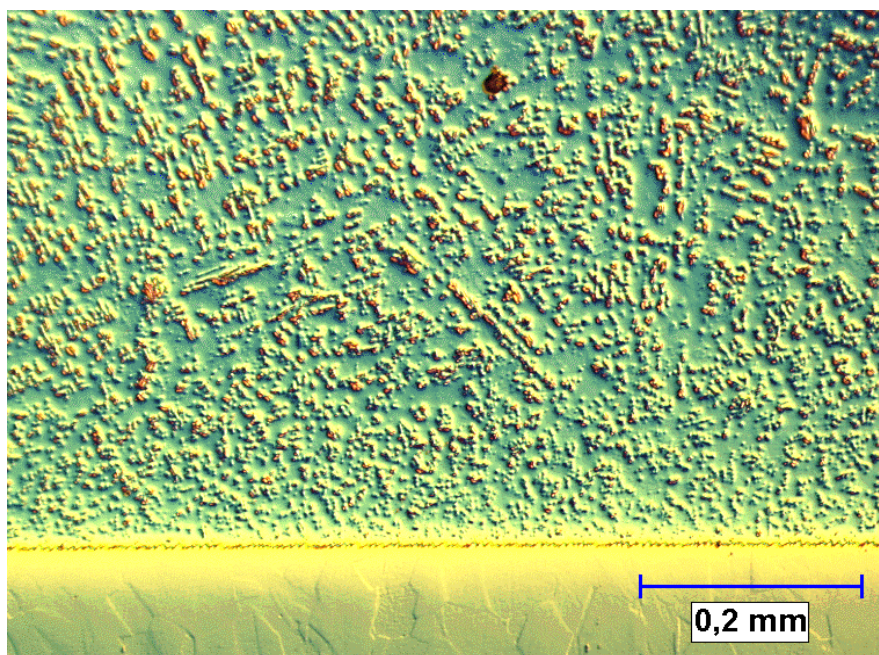
SnBi10/Cu couple
230°C; 5 min
E: mag. 100×
CL

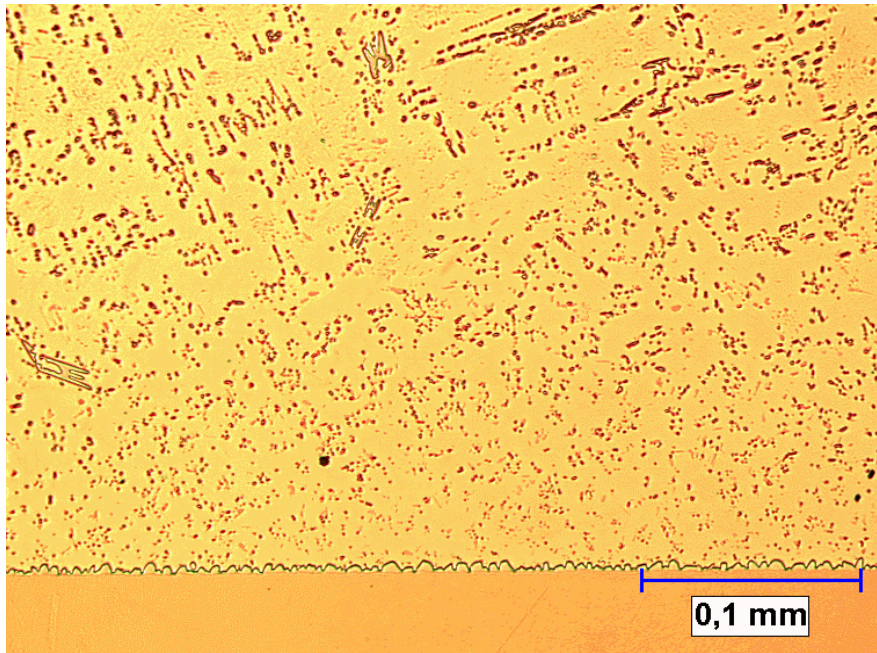


SnBi10/Cu couple
230°C; 5 min
E: mag. 100×
PL

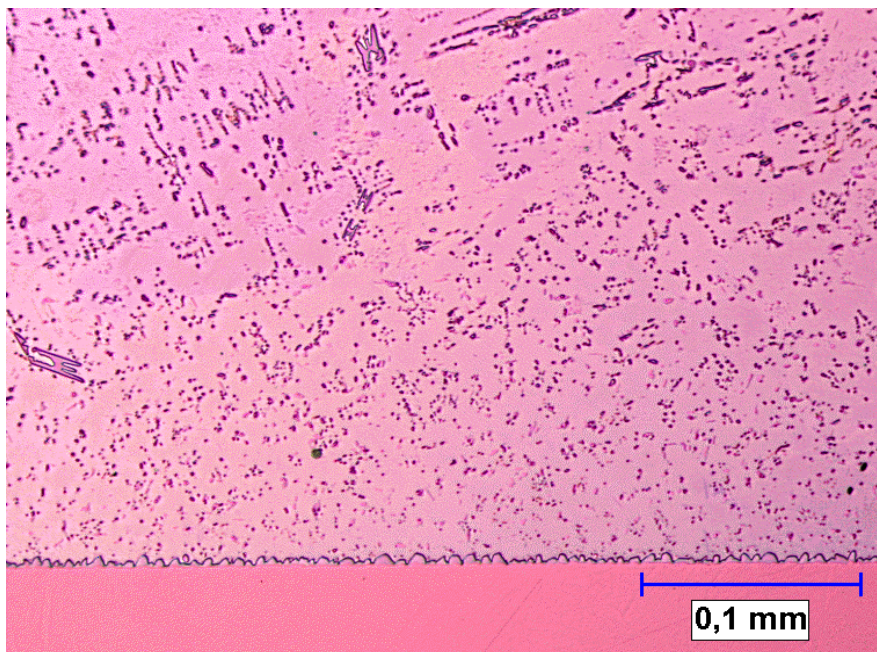


SnBi10/Cu couple
230°C; 5 min
E: mag. 100×
PC

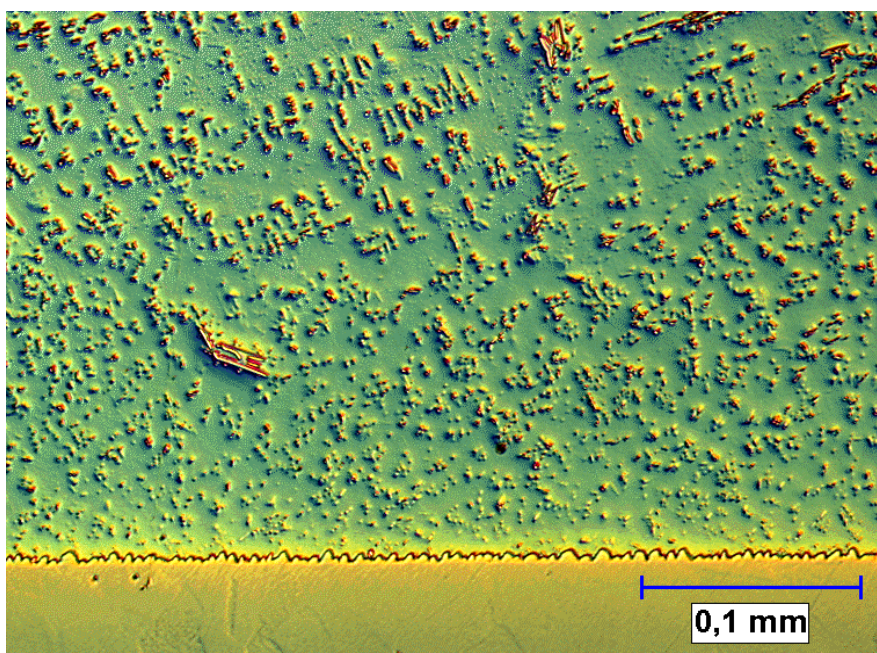




SnBi10/Cu couple
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E: mag. 200×
CL

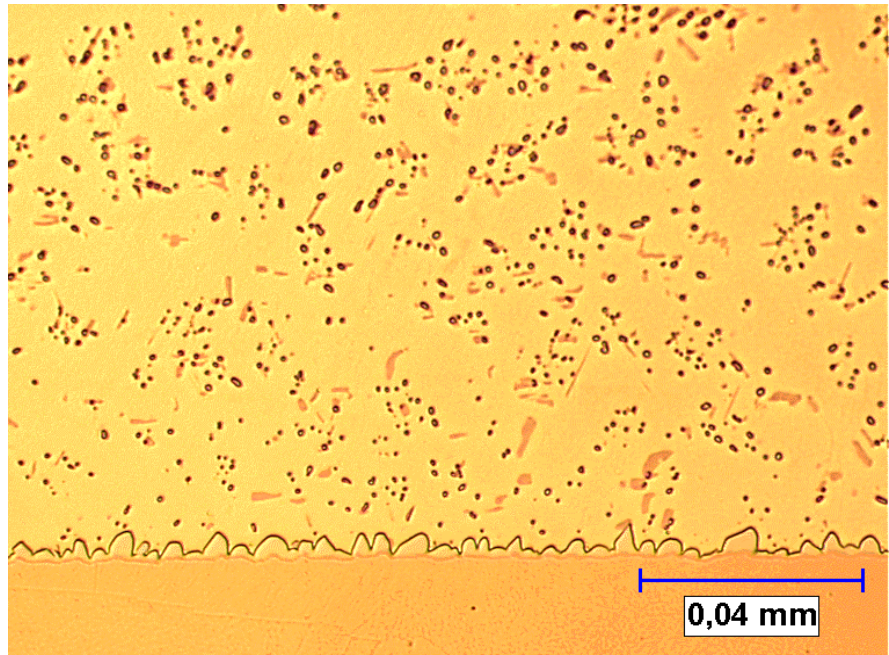


SnBi10/Cu couple
230°C; 5 min
E: mag. 200×
PL

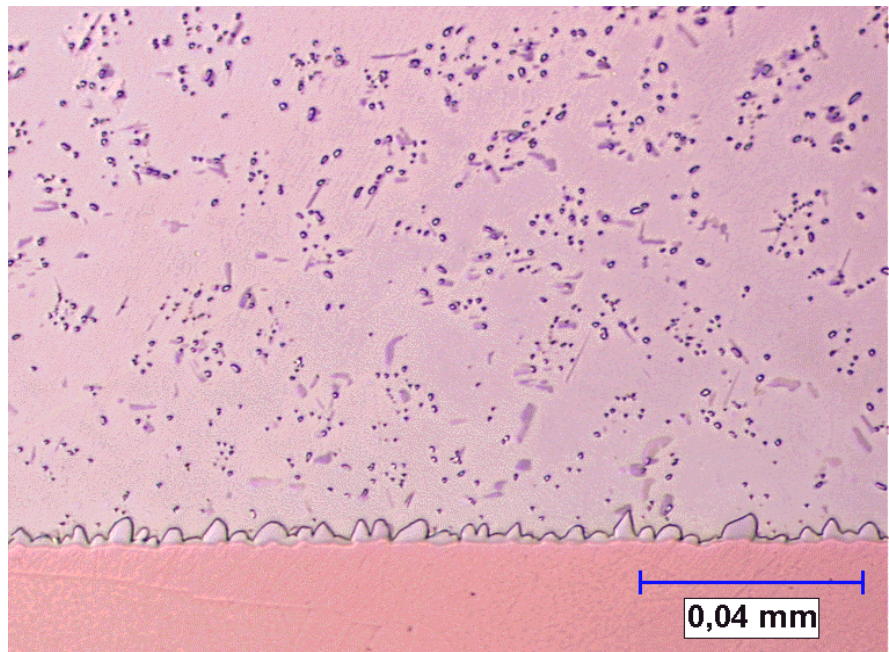


SnBi10/Cu couple
230°C; 5 min
E: mag. 200×
PC

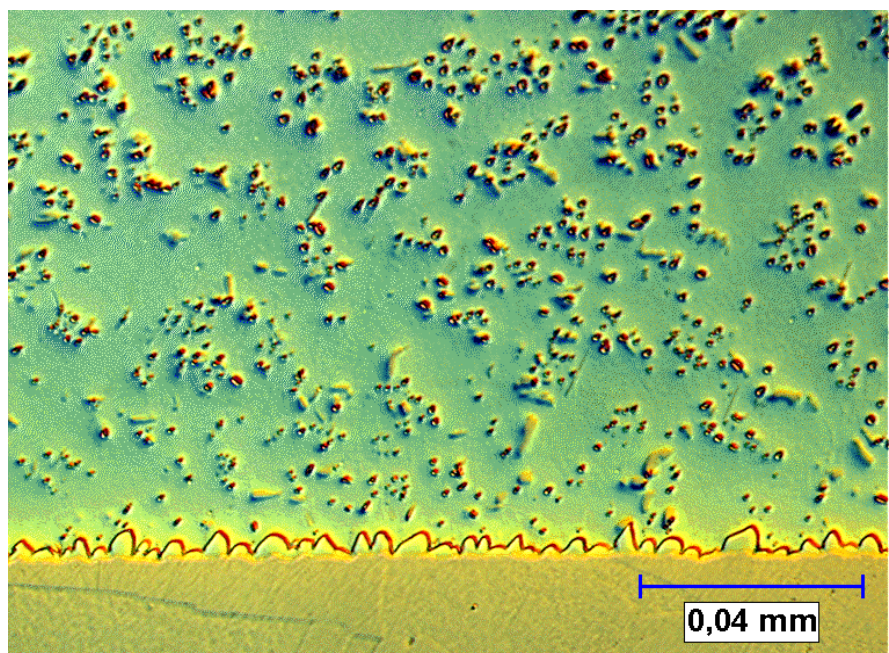
SnBi10/Cu couple
230°C; 5 min
E: mag. 500×
CL

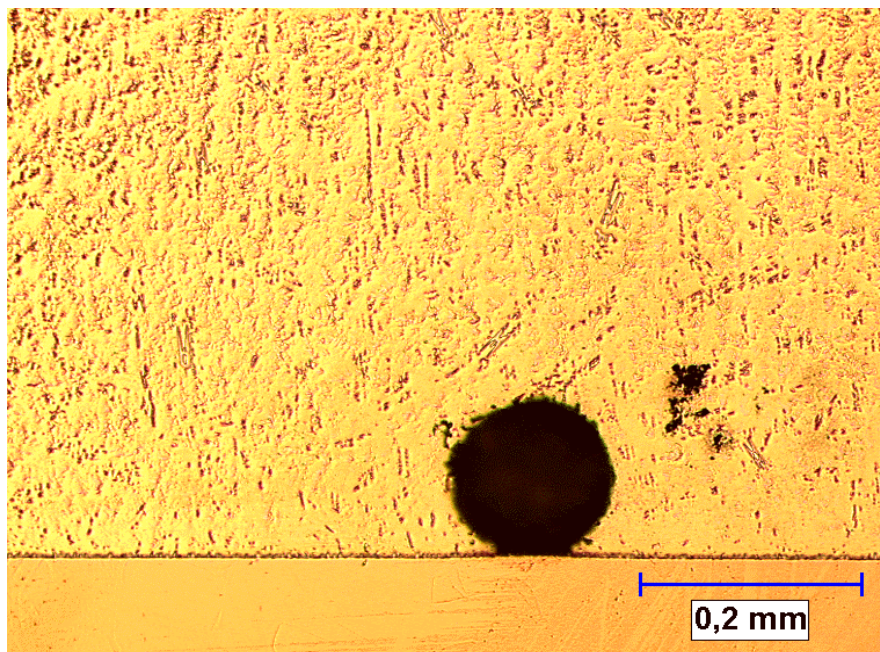


SnBi10/Cu couple
230°C; 5 min
E: mag. 500×
PL

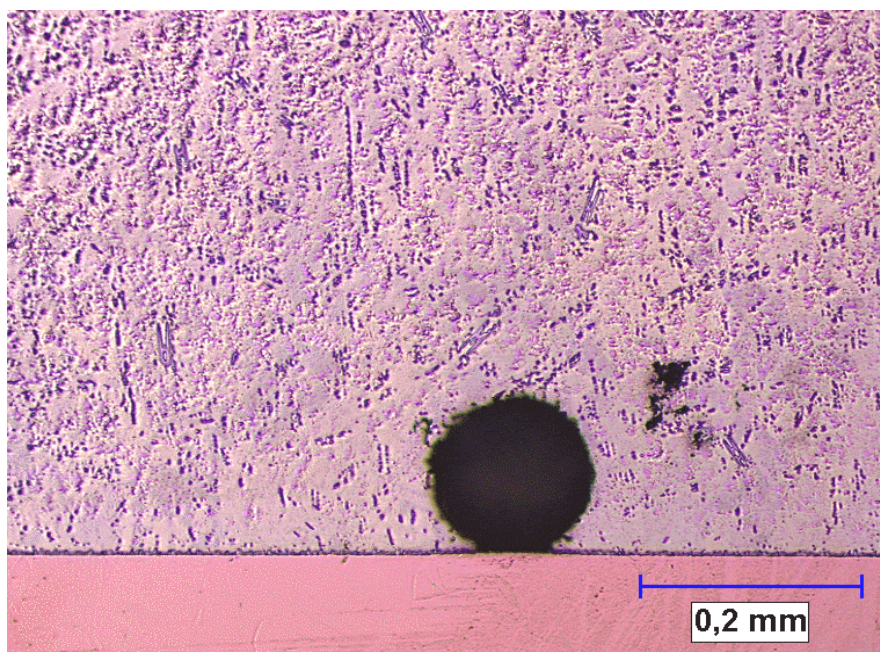


SnBi10/Cu couple
230°C; 5 min
E: mag. 500×
PC

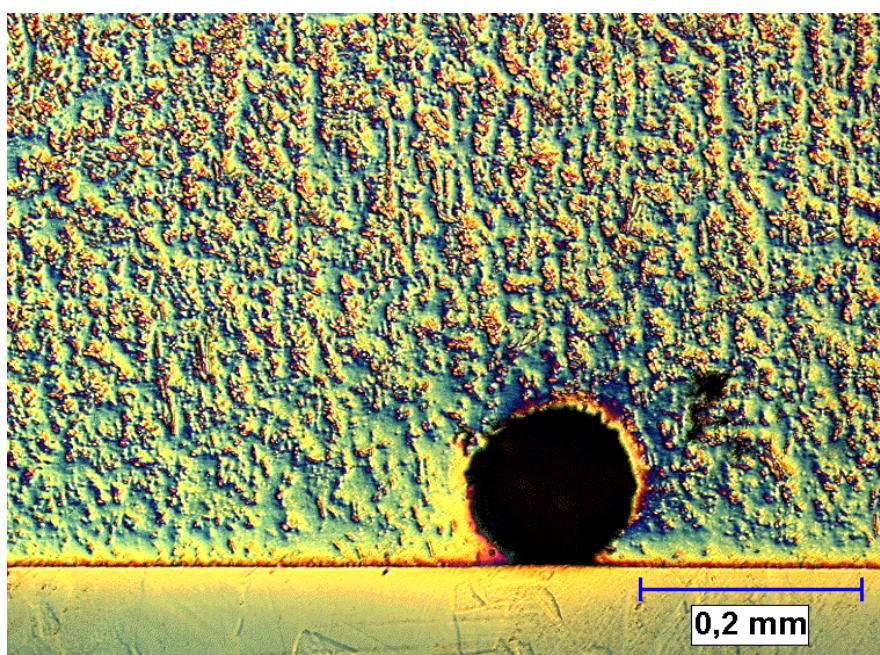




SnBi15/Cu couple
230°C; 5 min
E: mag. 100×
CL

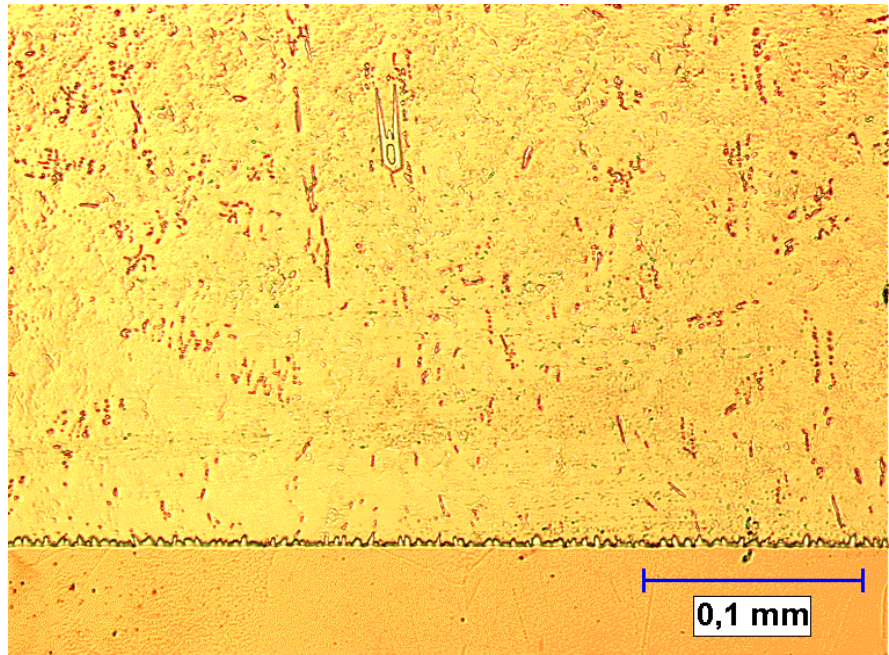


SnBi15/Cu couple
230°C; 5 min
E: mag. 100×
PL

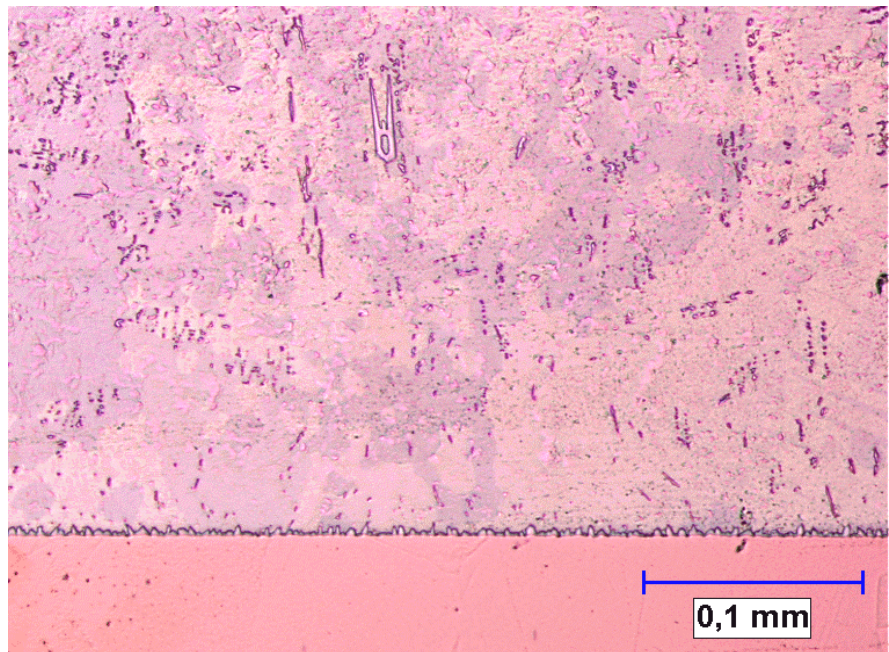


SnBi15/Cu couple
230°C; 5 min
E: mag. 100×
PC

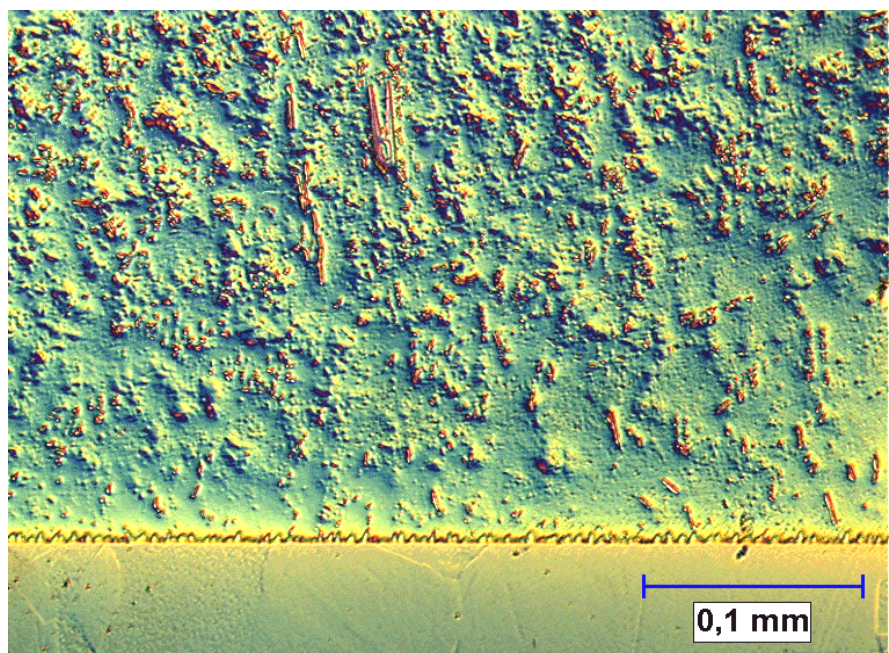
SnBi15/Cu couple
230°C; 5 min
E: mag. 200×
CL

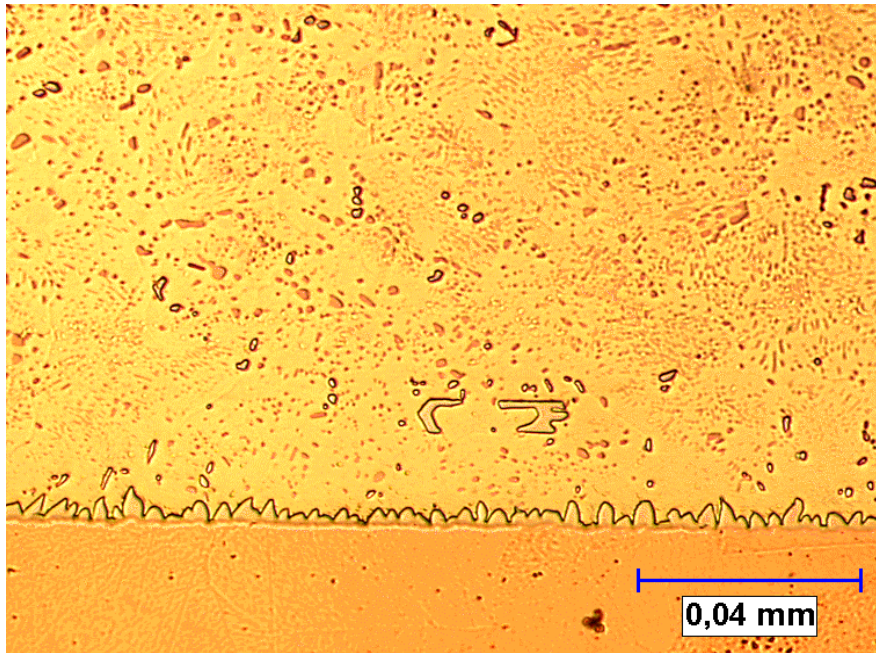


SnBi15/Cu couple
230°C; 5 min
E: mag. 200×
PL

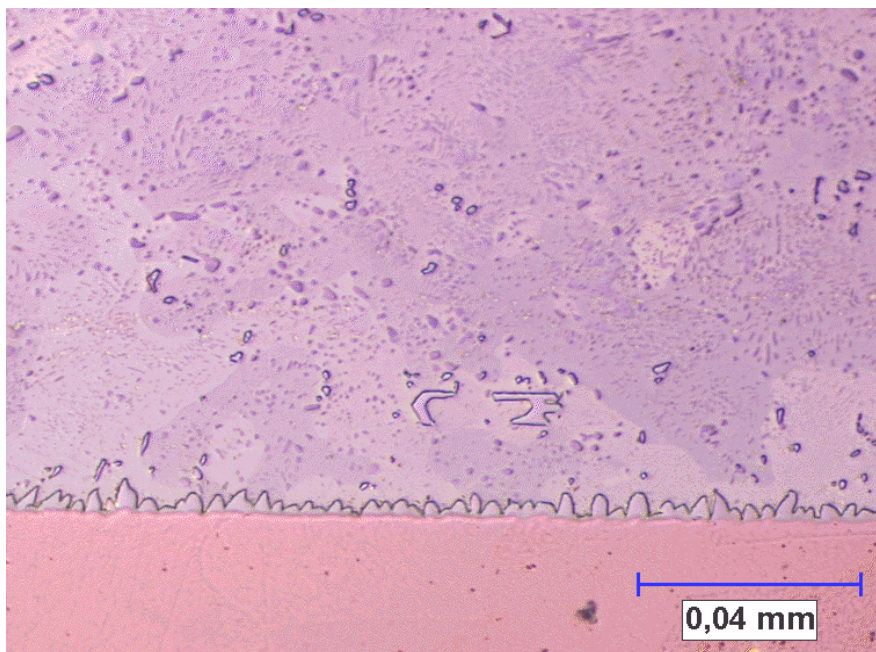


SnBi15/Cu couple
230°C; 5 min
E: mag. 200×
PC

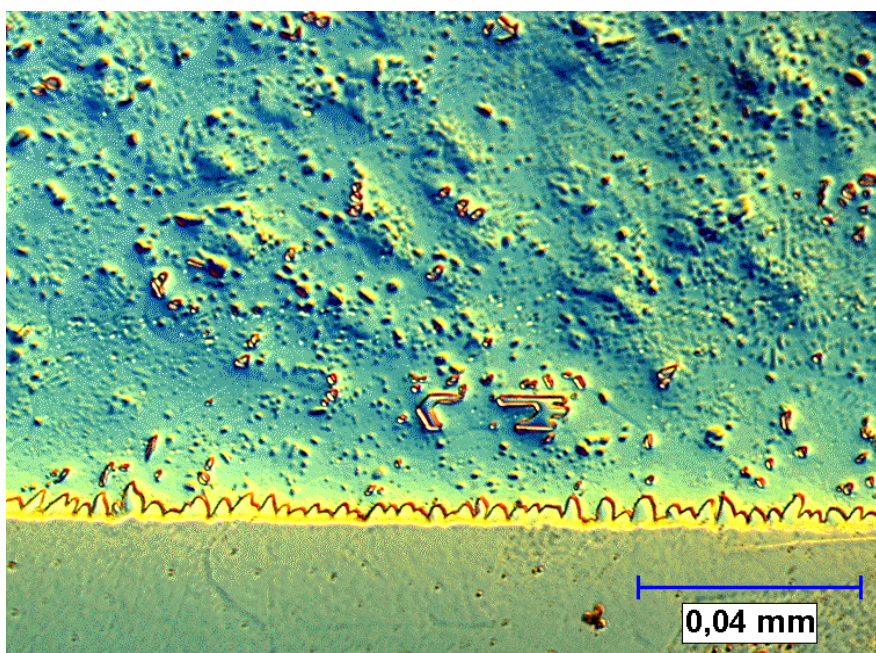




SnBi15/Cu couple
230°C; 5 min
E: mag. 500×
CL

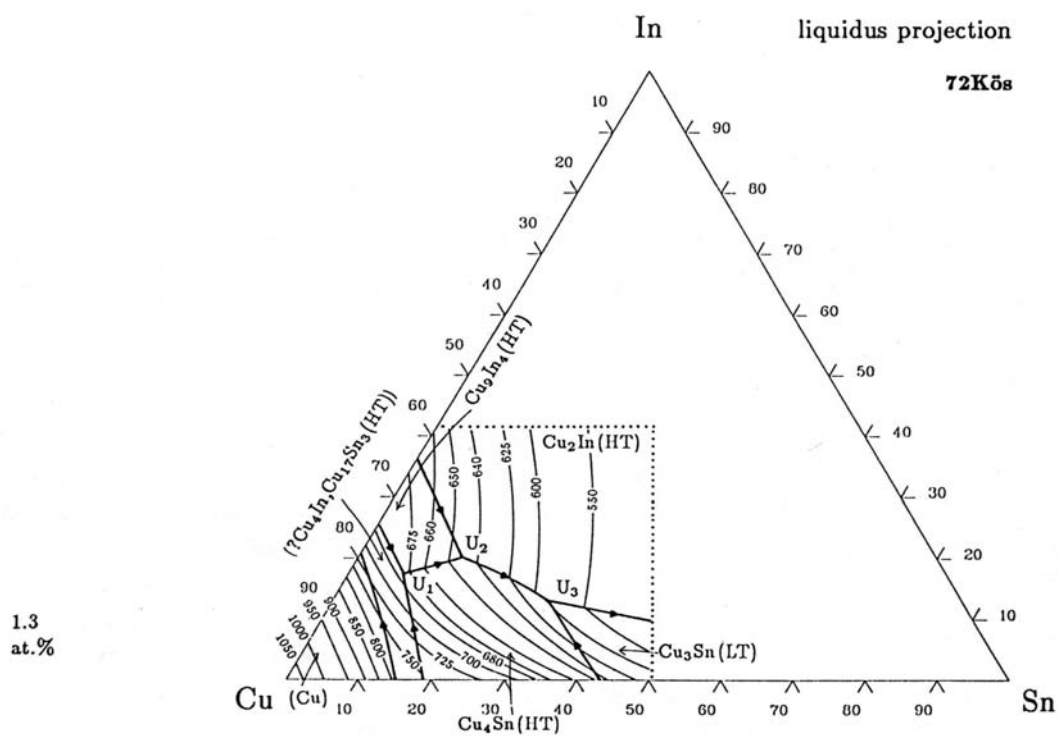
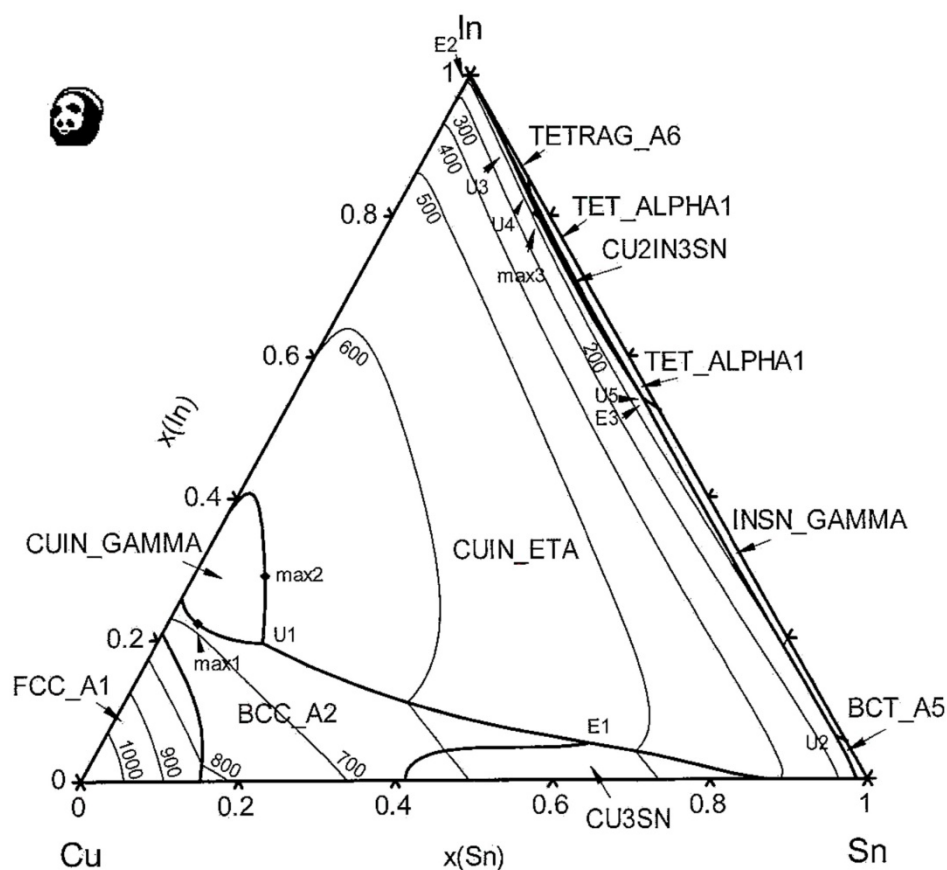


SnBi15/Cu couple
230°C; 5 min
E: mag. 500×
PL



SnBi15/Cu couple
230°C; 5 min
E: mag. 500×
PC

Sn – In – Cu



Reaction Scheme

Cu-In-Sn

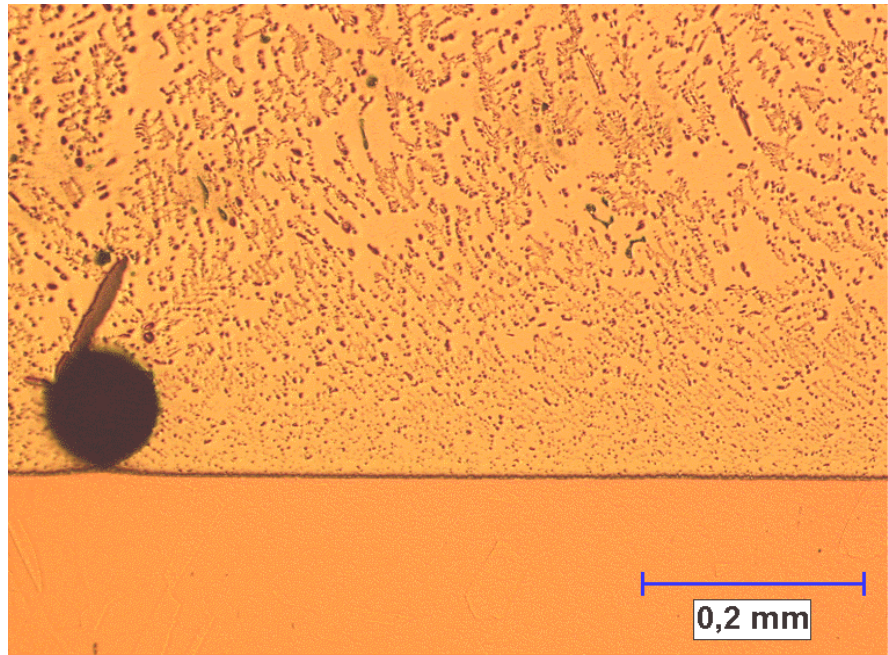
72K5s

- $U_1: L + (?Cu_4In, Cu_{17}Sn_3(HT)) \rightleftharpoons Cu_9In_4(HT) + Cu_4Sn(HT) \quad 676^\circ C$
 $U_2: L + Cu_9In_4(HT) \rightleftharpoons Cu_2In(HT) + Cu_4Sn(HT) \quad 648^\circ C$
 $U_3: L + Cu_4Sn(HT) \rightleftharpoons Cu_2In(HT) + Cu_3Sn(LT) \quad 583^\circ C$

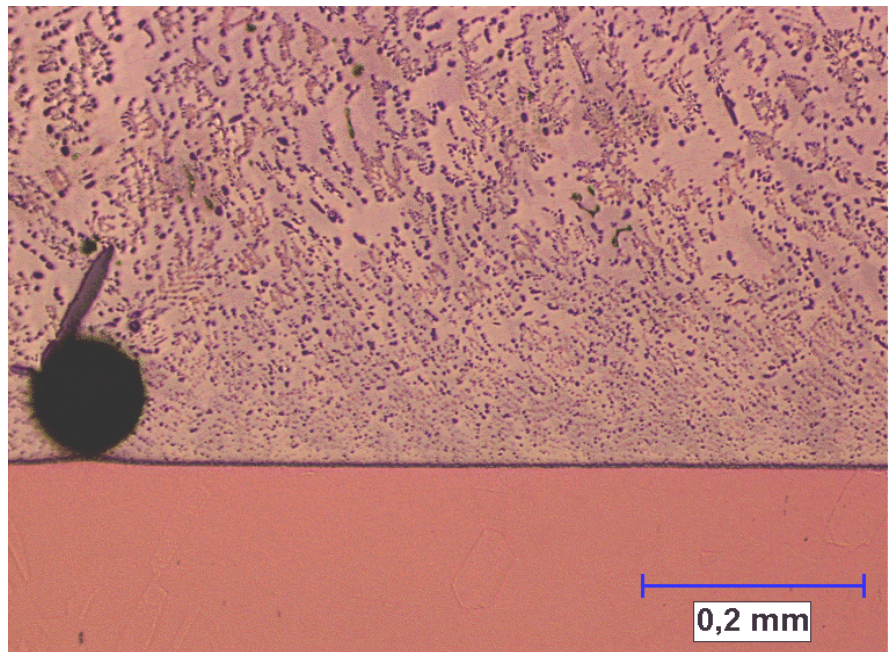
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
SnIn5 / Cu	230°C, 5 min, flux	35°	25
SnIn10 / Cu	230°C, 5 min, flux	37°	24
SnIn15 / Cu	230°C, 5 min, flux	40°	22
SnIn20 / Cu	230°C, 5 min, flux	33°	16

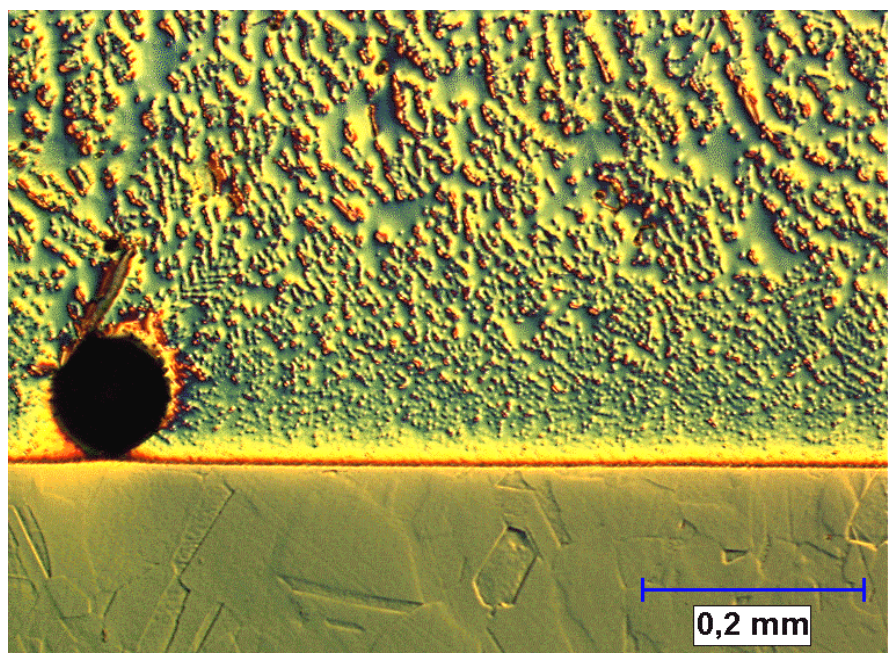
SnIn5/Cu couple
230°C; 5 min
E: mag. 100×
CL

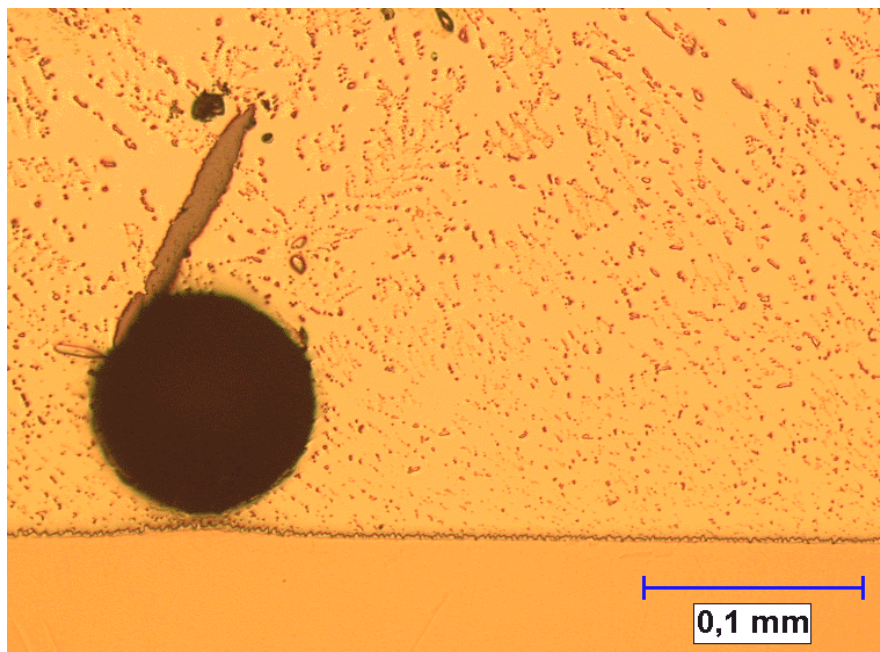


SnIn5/Cu couple
230°C; 5 min
E: mag. 100×
PL

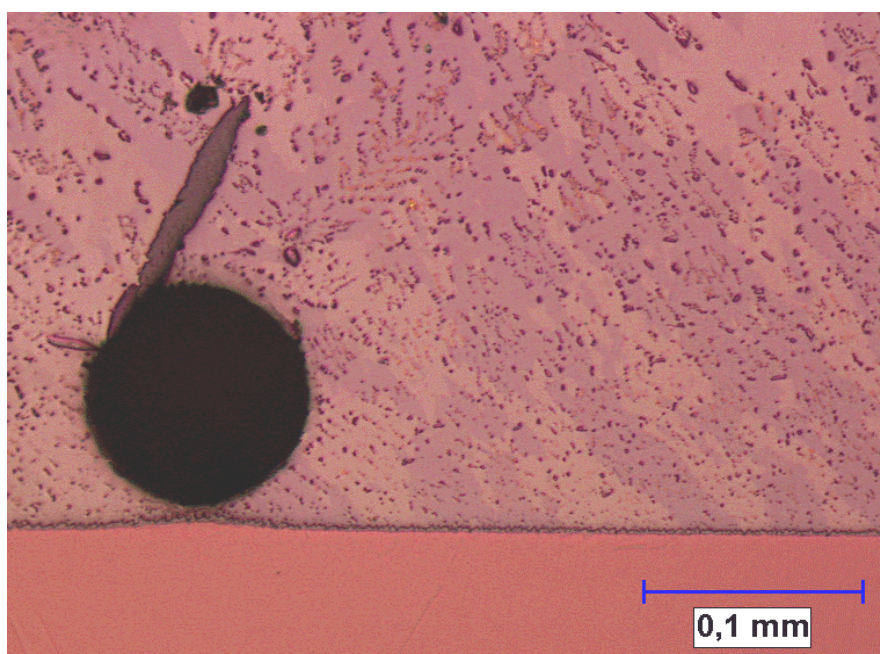


SnIn5/Cu couple
230°C; 5 min
E: mag. 100×
PC

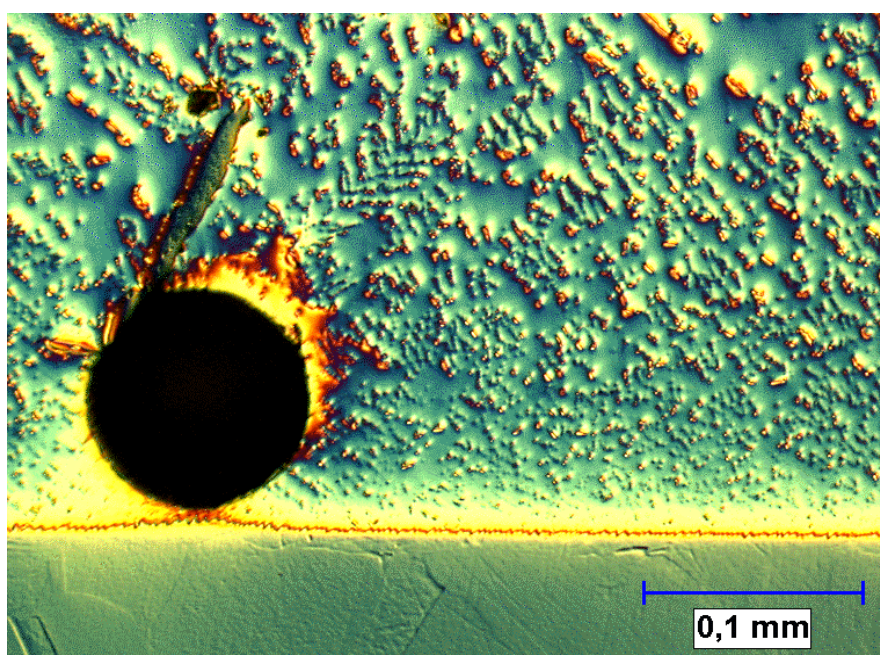




SnIn5/Cu couple
230°C; 5 min
E: mag. 200×
CL

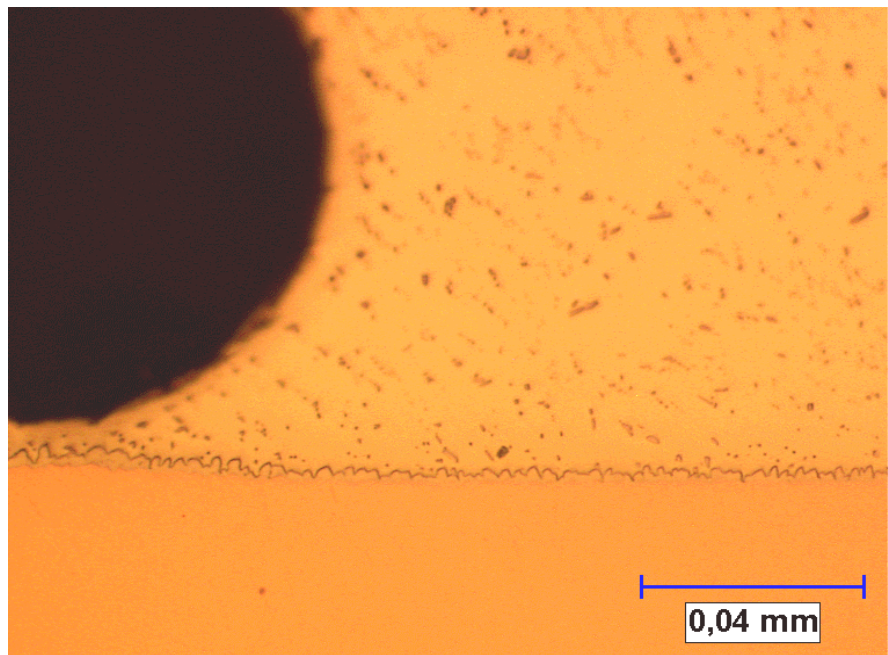


SnIn5/Cu couple
230°C; 5 min
E: mag. 200×
PL

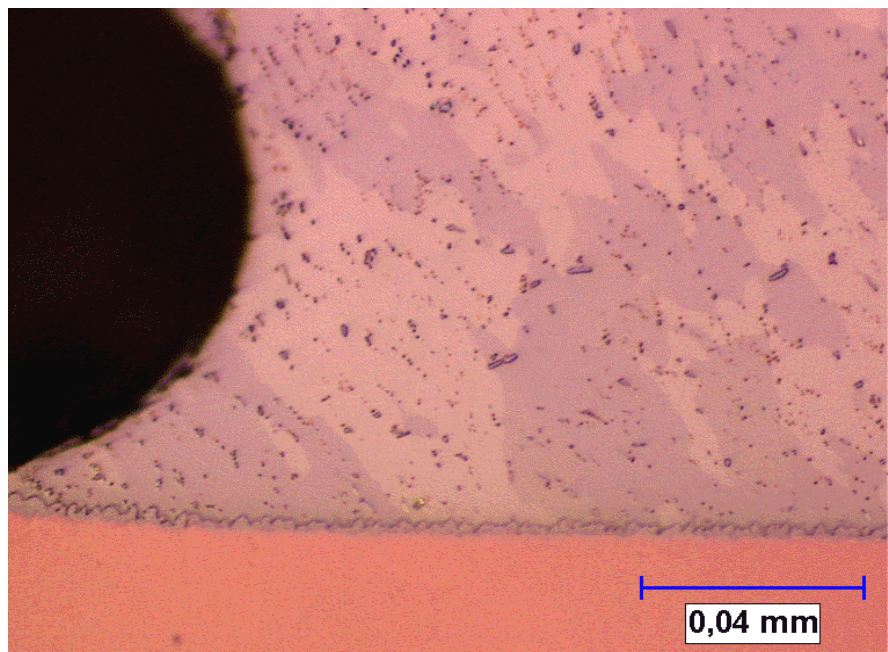


SnIn5/Cu couple
230°C; 5 min
E: mag. 200×
PC

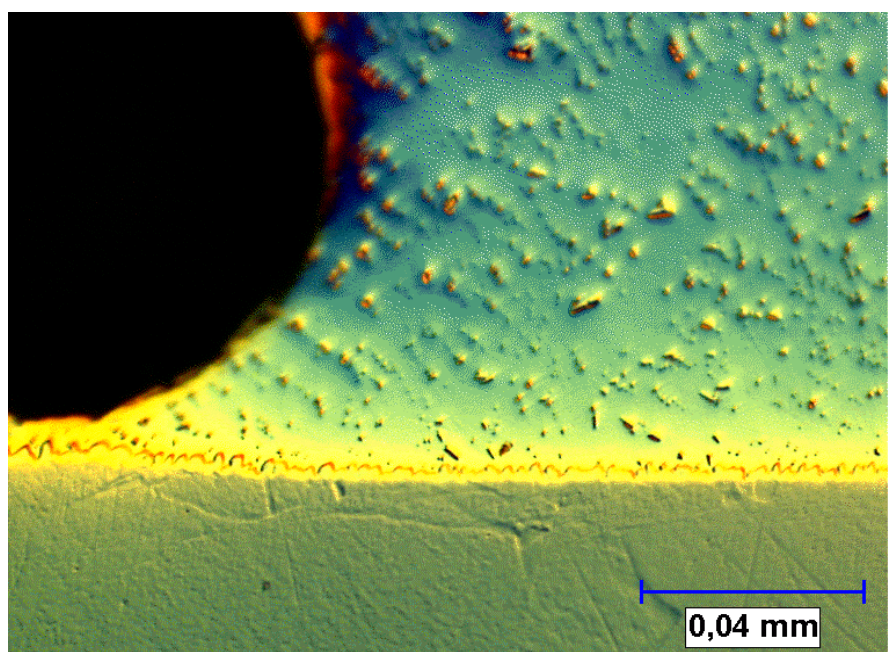
SnIn5/Cu couple
230°C; 5 min
E: mag. 500×
CL

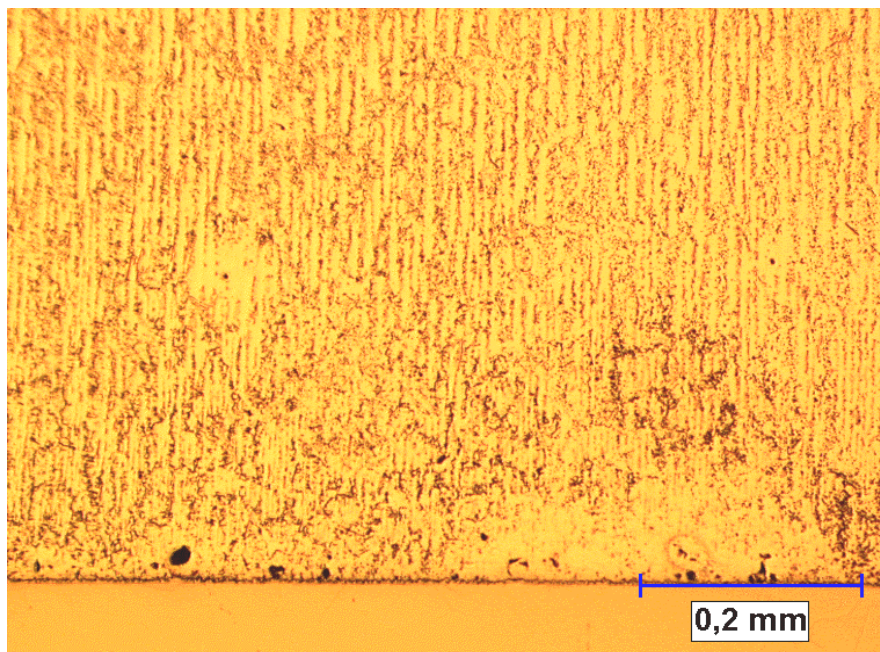


SnIn5/Cu couple
230°C; 5 min
E: mag. 500×
PL

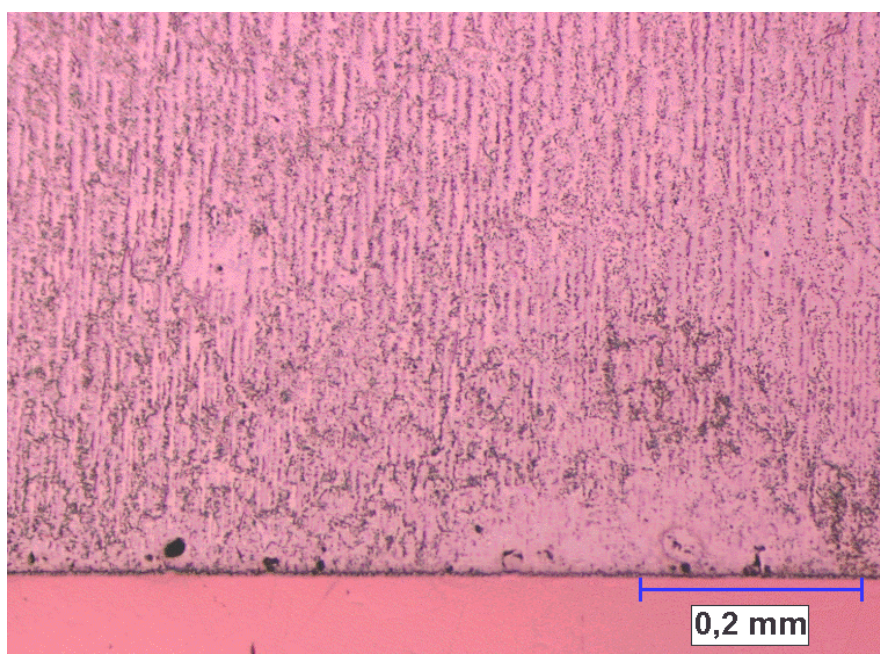


SnIn5/Cu couple
230°C; 5 min
E: mag. 500×
PC

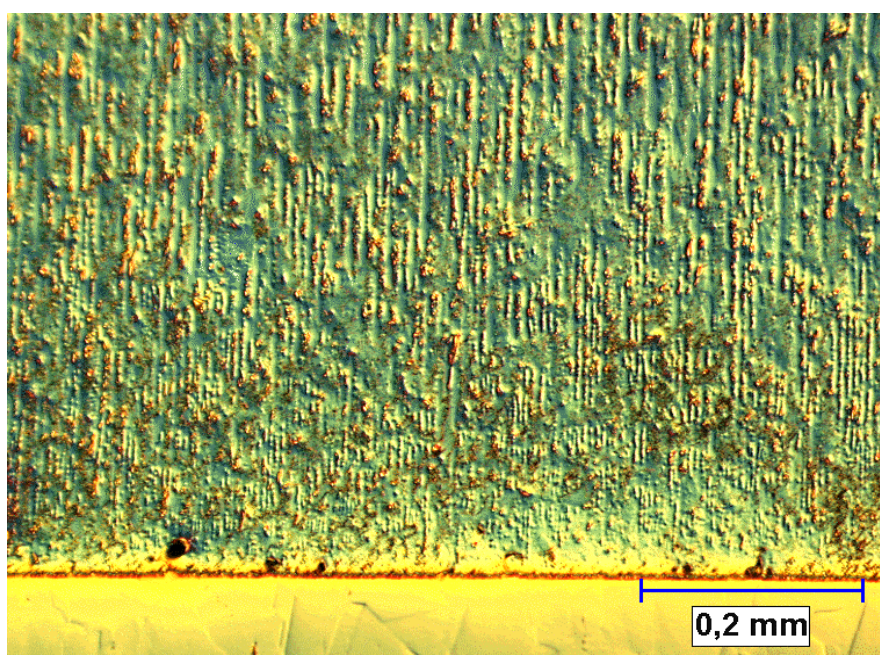




SnIn10/Cu couple
230°C; 5 min
E: mag. 100×
CL

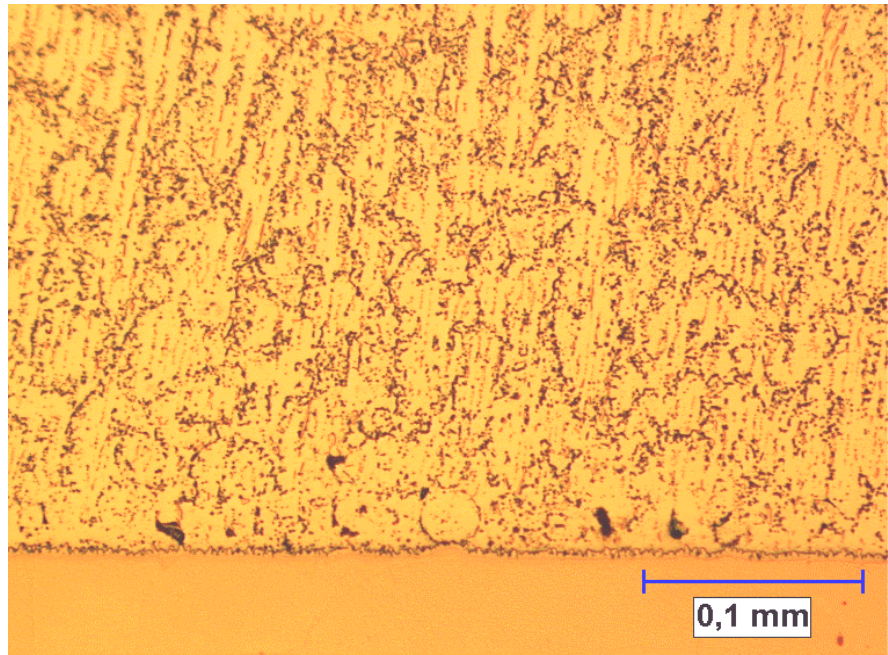


SnIn10/Cu couple
230°C; 5 min
E: mag. 100×
PL

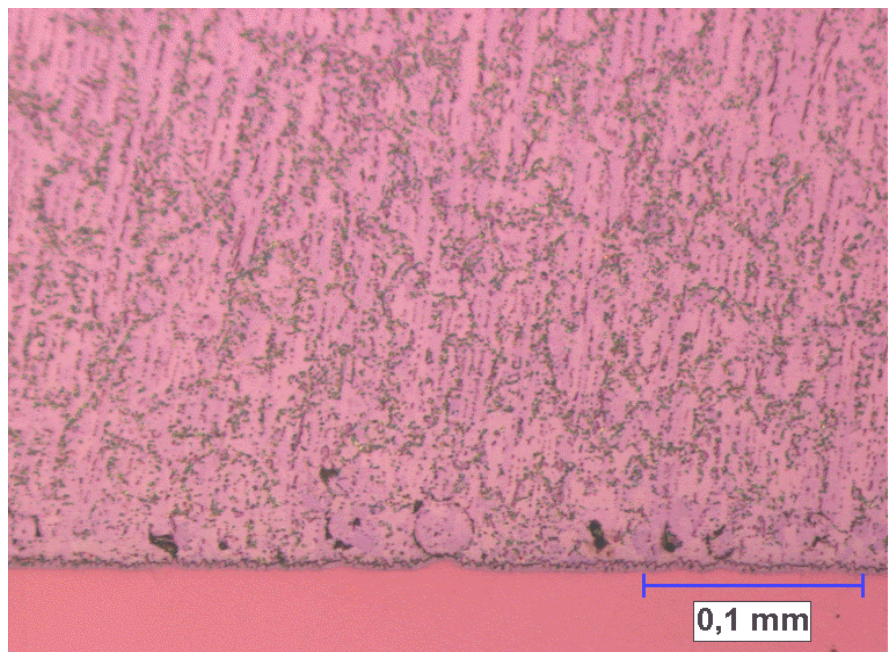


SnIn10/Cu couple
230°C; 5 min
E: mag. 100×
PC

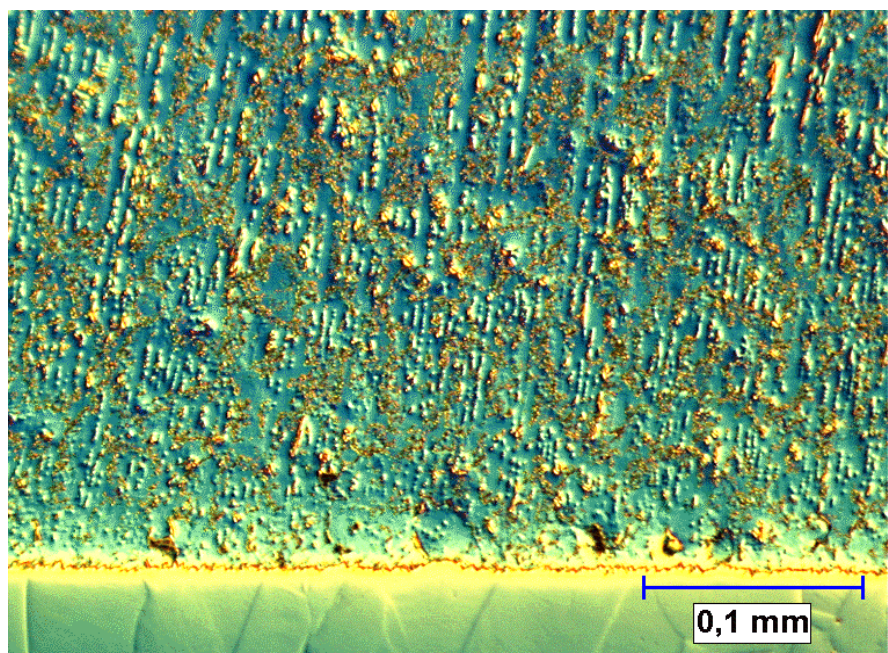
SnIn10/Cu couple
230°C; 5 min
E: mag. 200×
CL

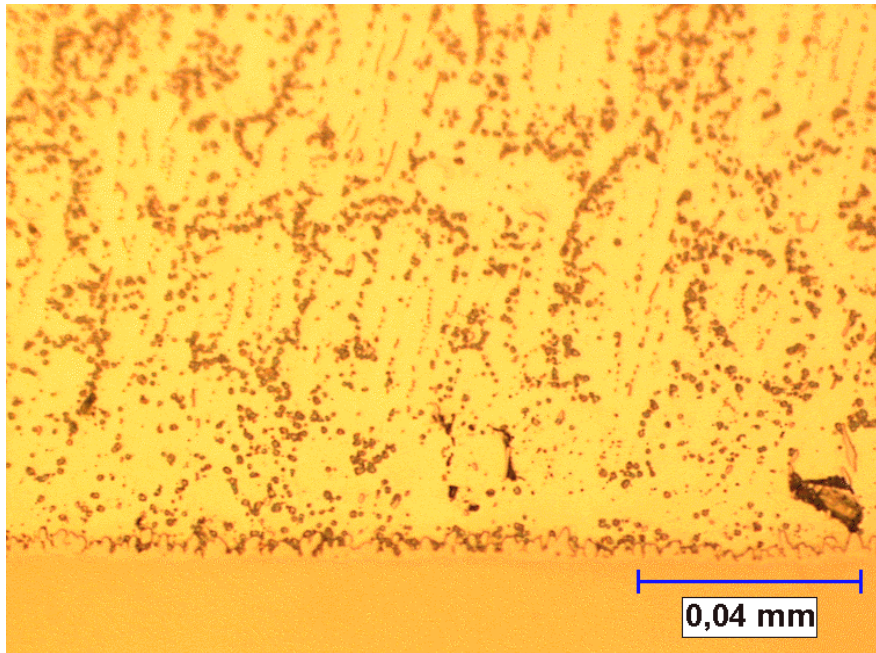


SnIn10/Cu couple
230°C; 5 min
E: mag. 200×
PL

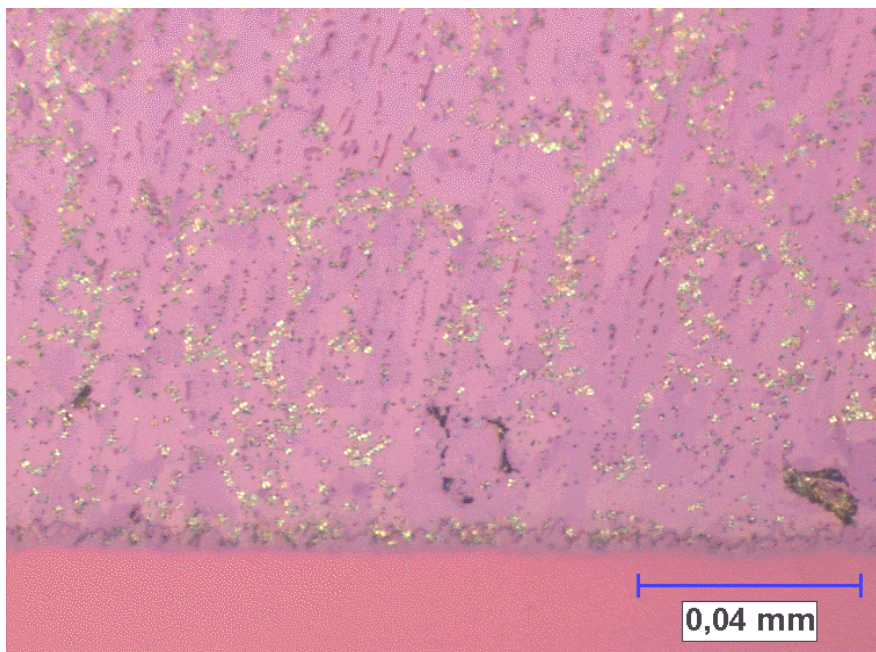


SnIn10/Cu couple
230°C; 5 min
E: mag. 200×
PC

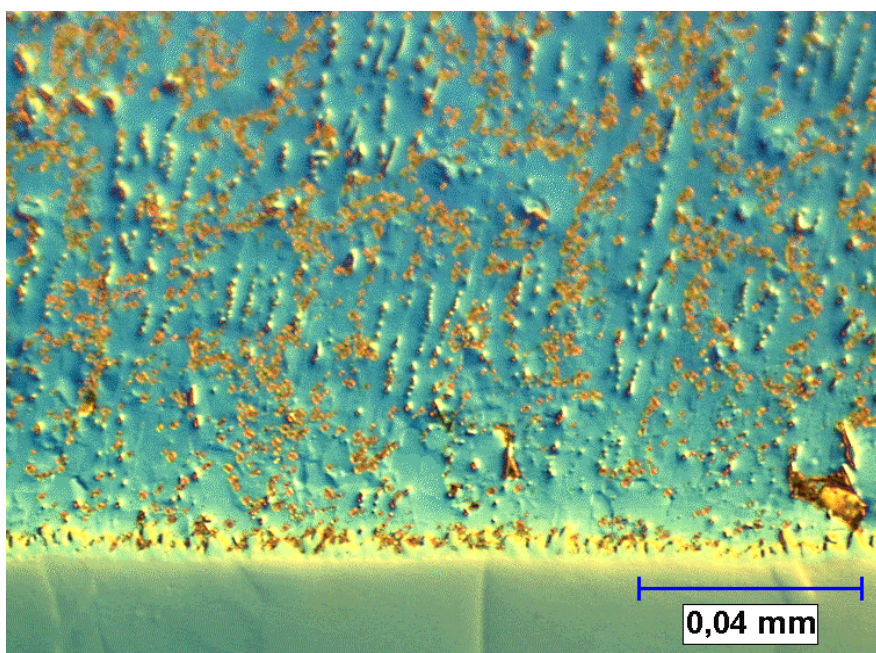




SnIn10/Cu couple
230°C; 5 min
E: mag. 500×
CL

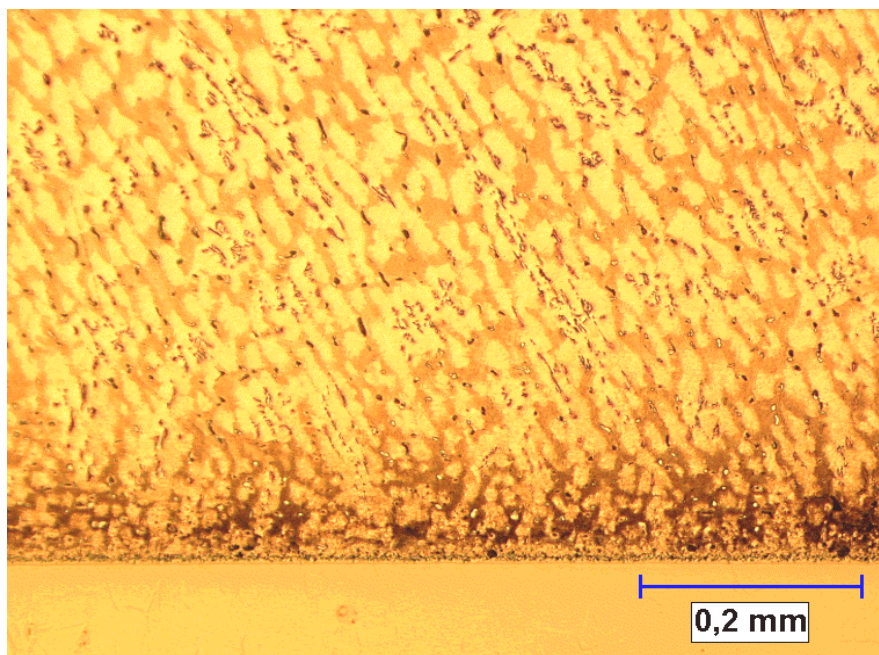


SnIn10/Cu couple
230°C; 5 min
E: mag. 500×
PL

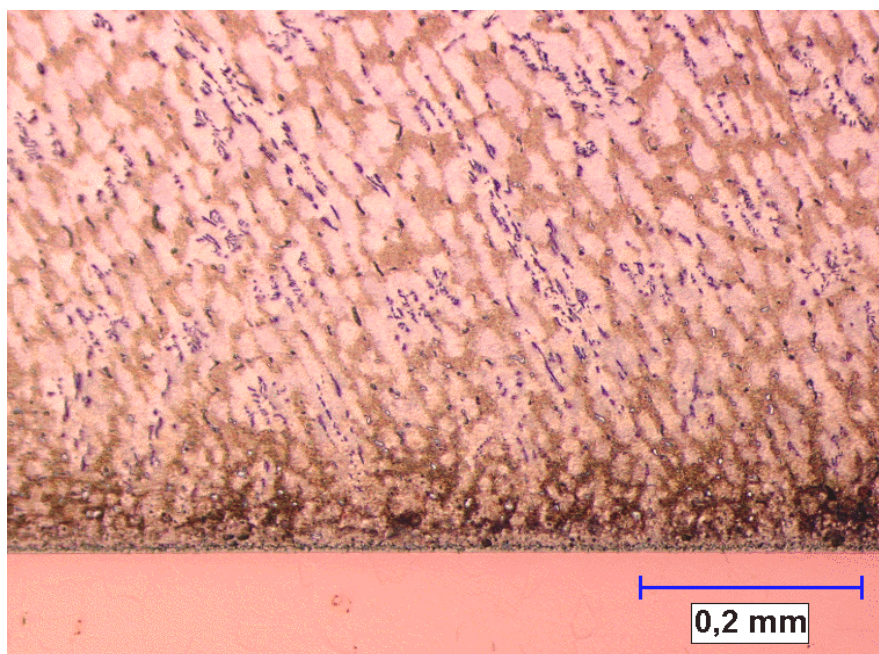


SnIn10/Cu couple
230°C; 5 min
E: mag. 500×
PC

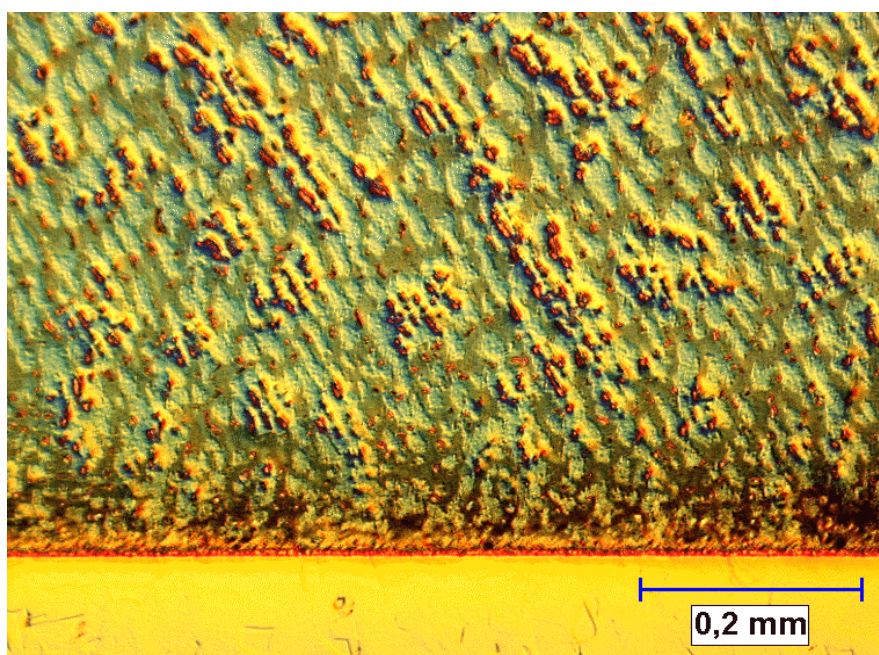
SnIn15/Cu couple
230°C; 5 min
E: mag. 100×
CL

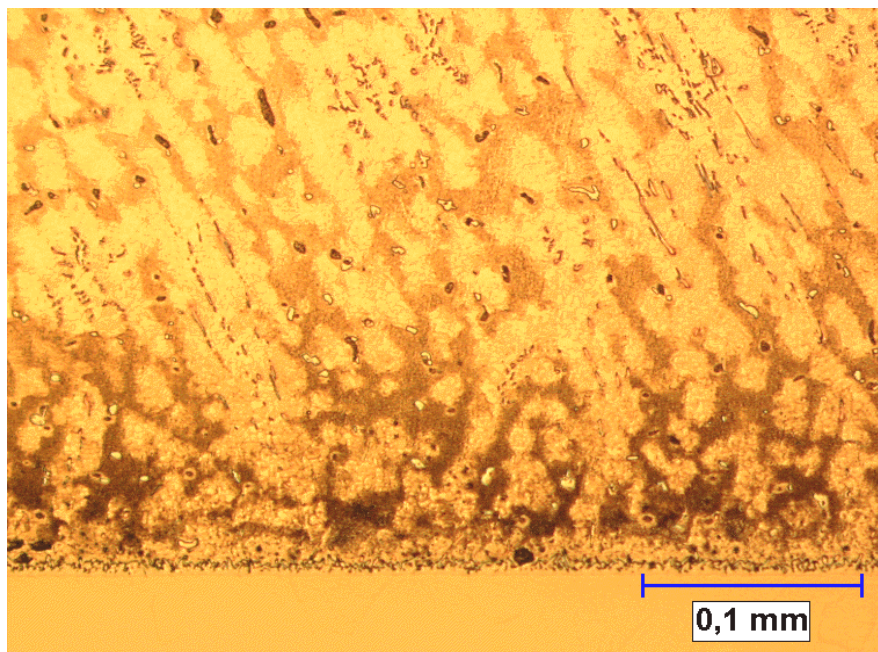


SnIn15/Cu couple
230°C; 5 min
E: mag. 100×
PL

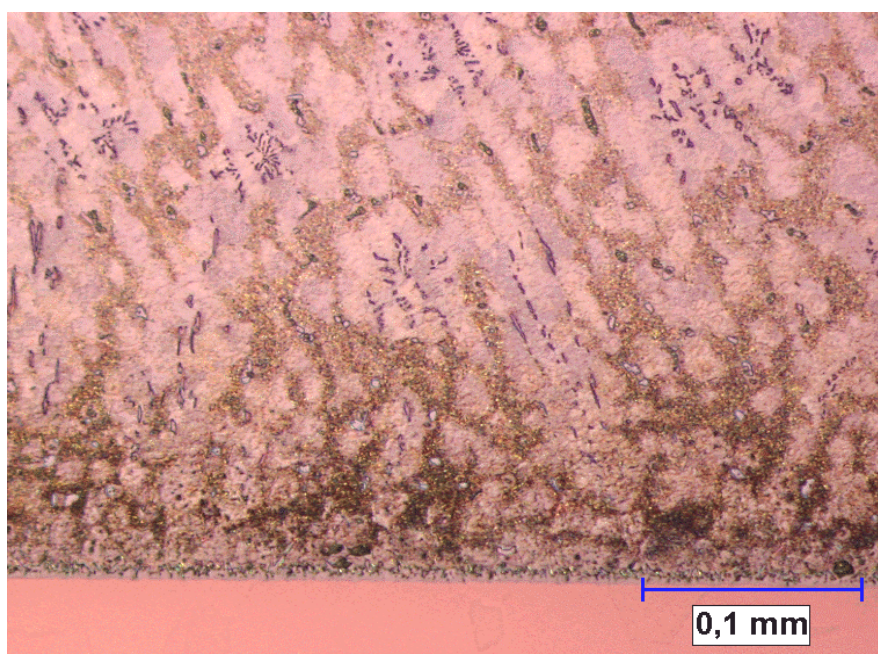


SnIn15/Cu couple
230°C; 5 min
E: mag. 100×
PC

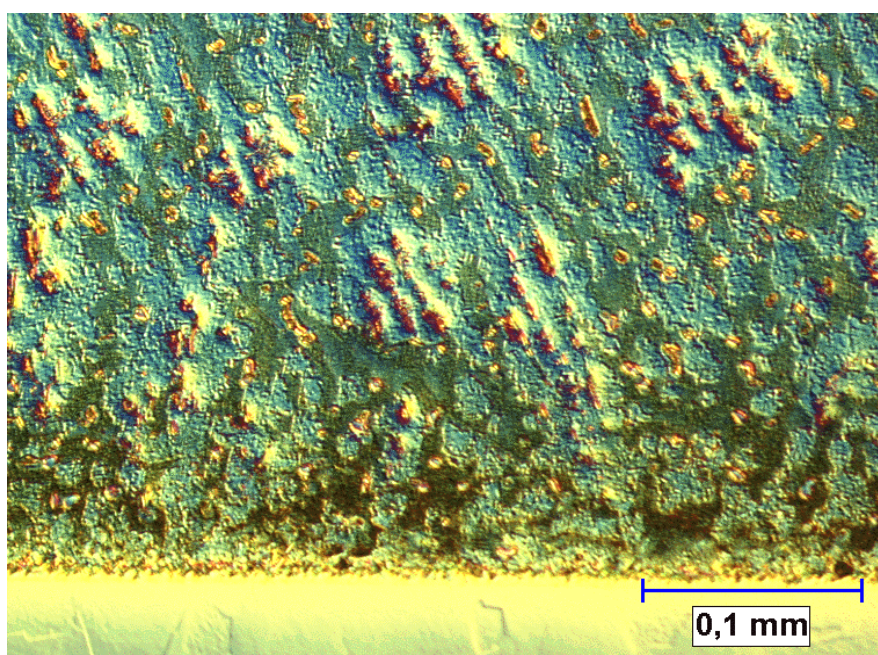




SnIn15/Cu couple
230°C; 5 min
E: mag. 200×
CL

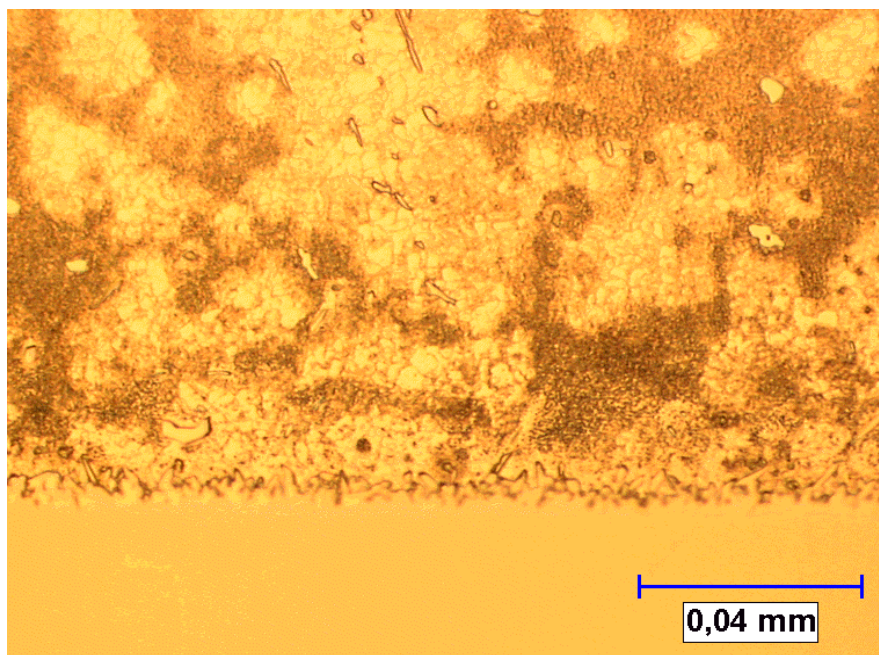


SnIn15/Cu couple
230°C; 5 min
E: mag. 200×
PL

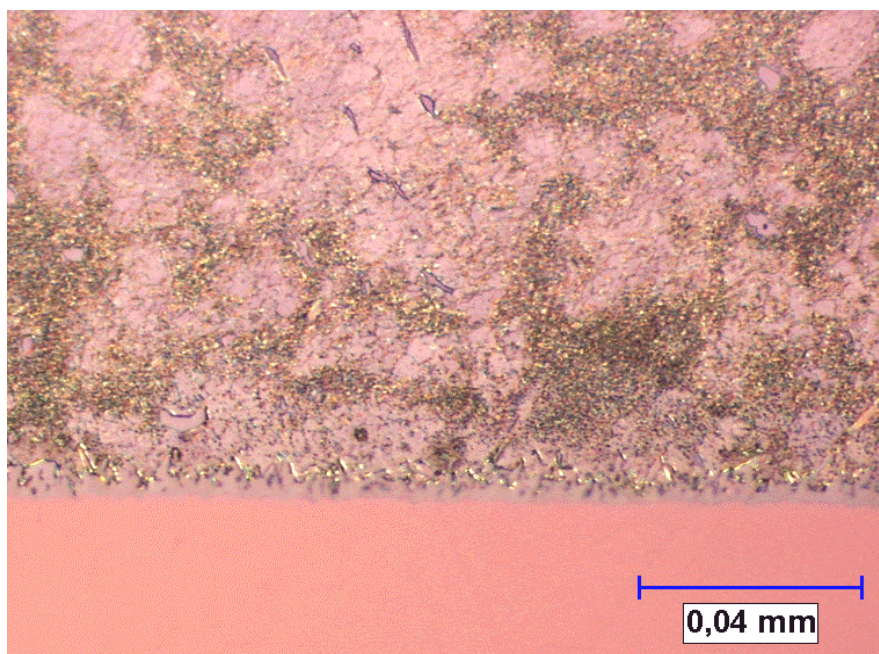


SnIn15/Cu couple
230°C; 5 min
E: mag. 200×
PC

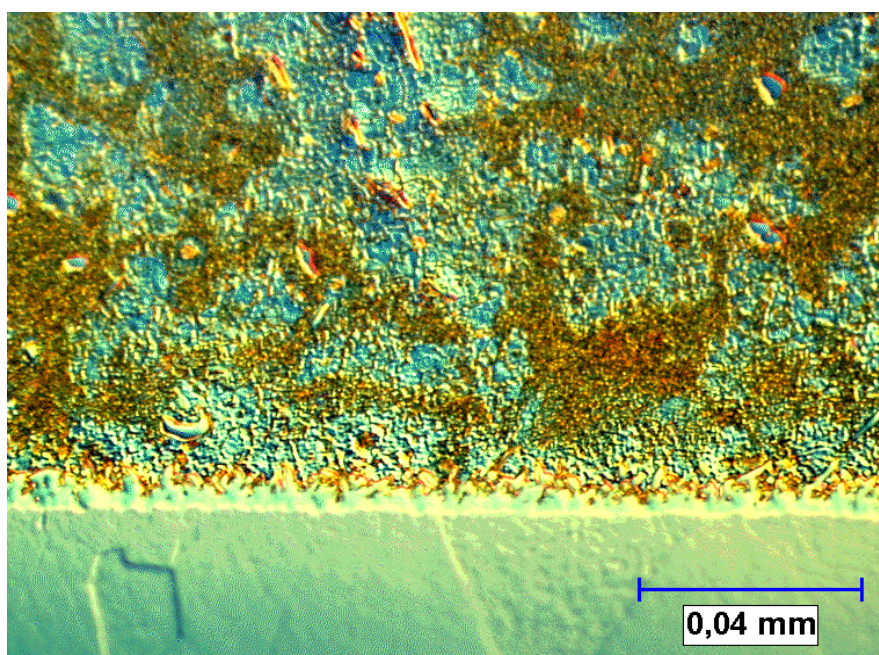
SnIn15/Cu couple
230°C; 5 min
E: mag. 500×
CL

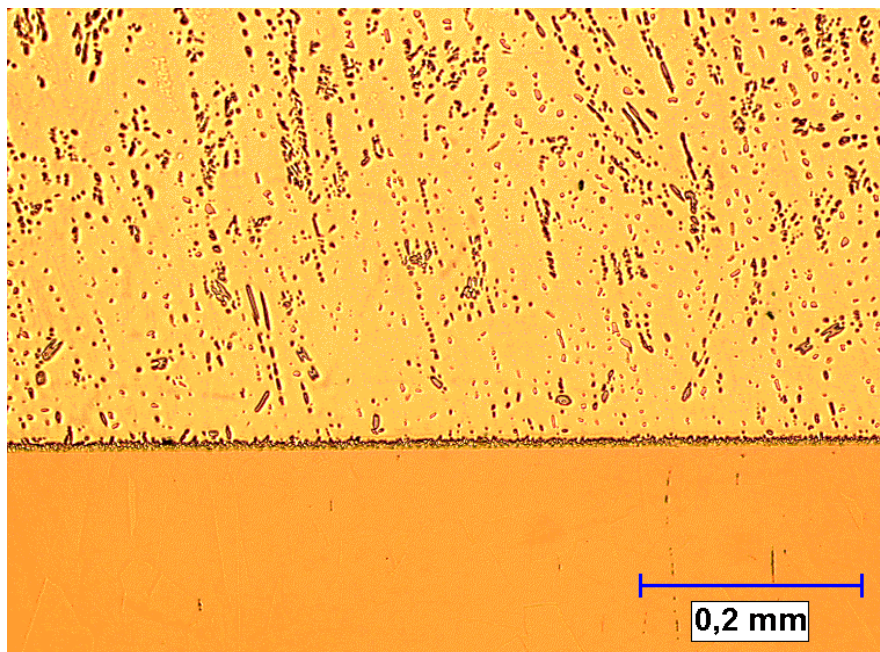


SnIn15/Cu couple
230°C; 5 min
E: mag. 500×
PL

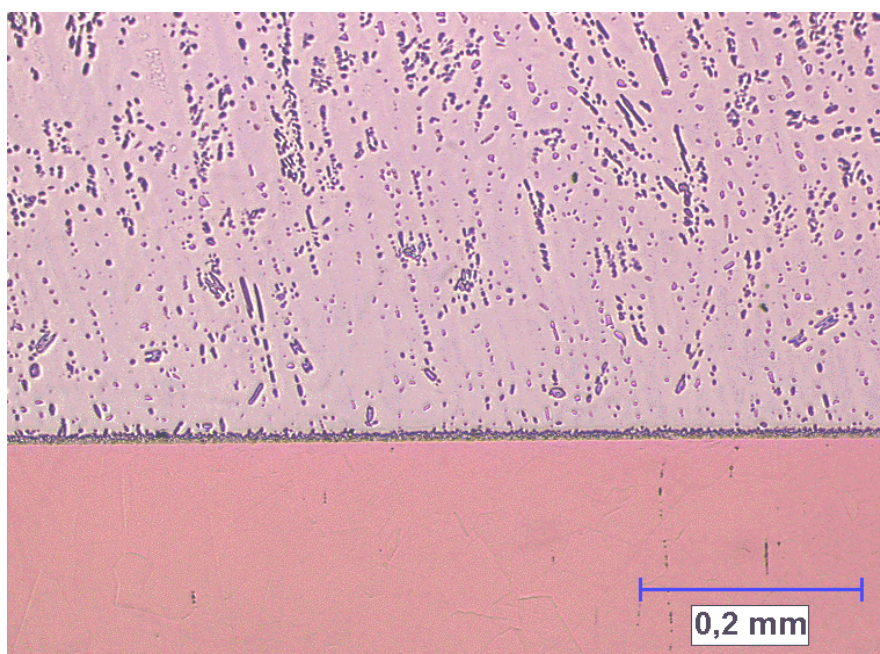


SnIn15/Cu couple
230°C; 5 min
E: mag. 500×
PC

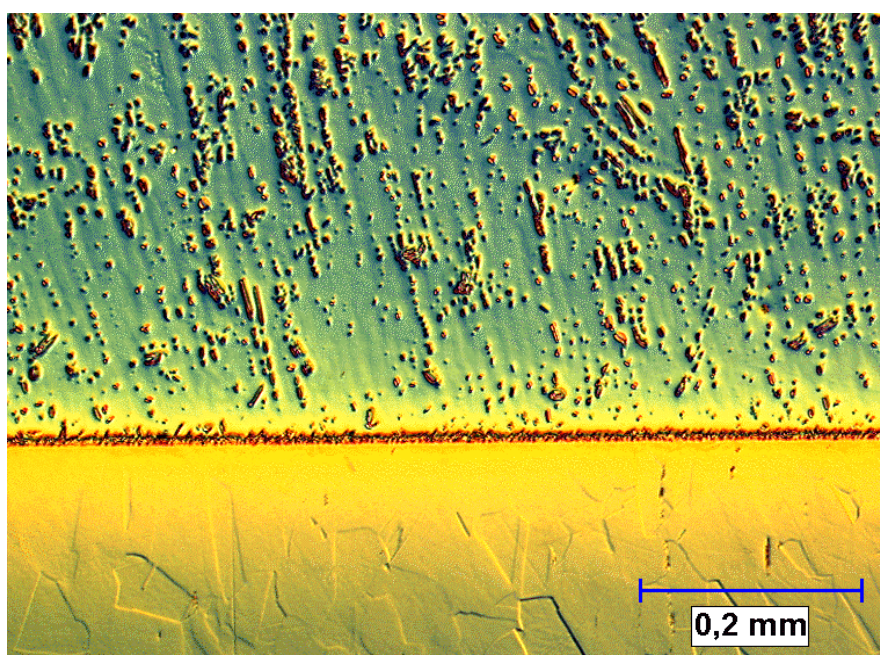




SnIn20/Cu couple
230°C; 5 min
E: mag. 100×
CL

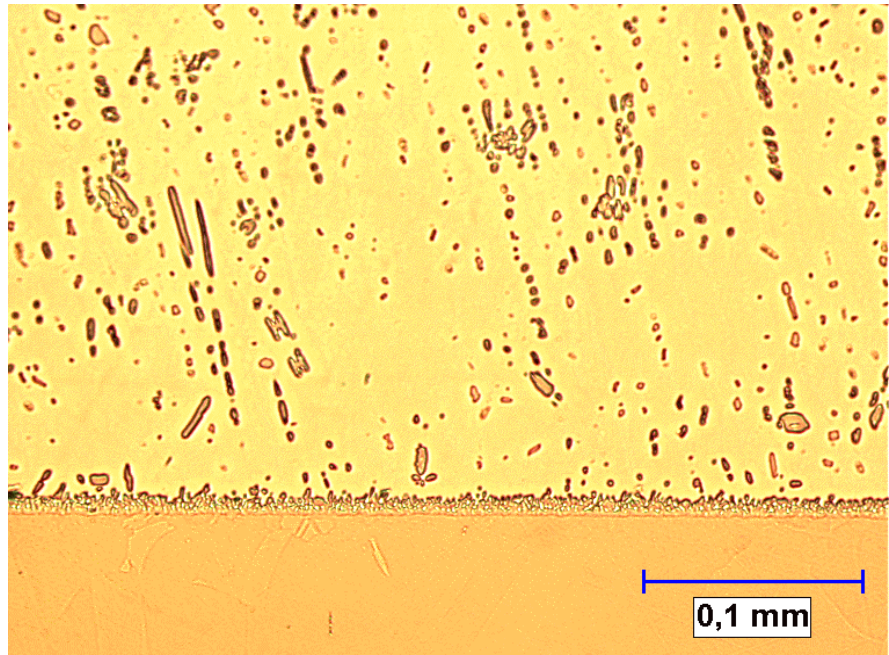


SnIn20/Cu couple
230°C; 5 min
E: mag. 100×
PL

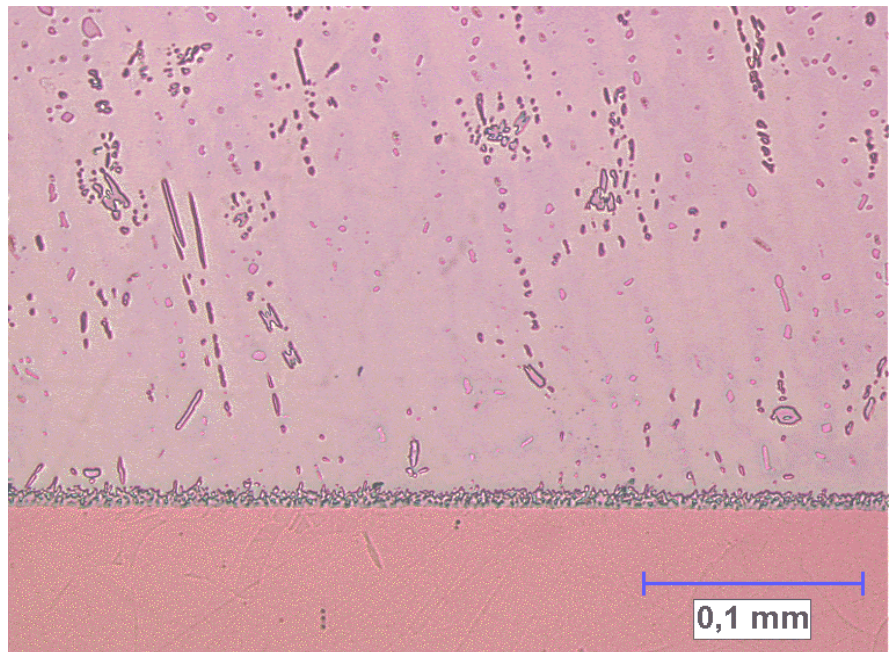


SnIn20/Cu couple
230°C; 5 min
E: mag. 100×
PC

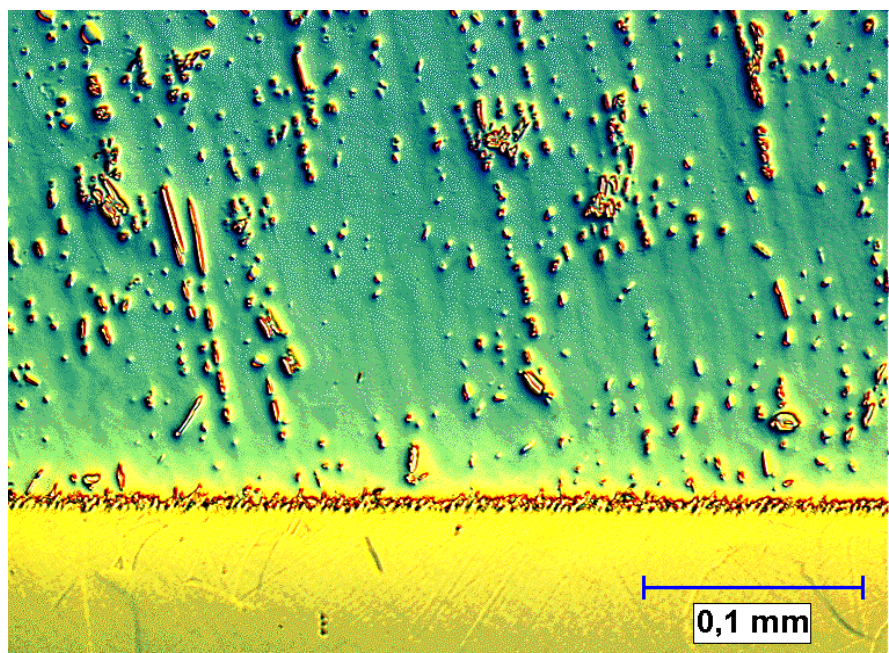
SnIn20/Cu couple
230°C; 5 min
E: mag. 200×
CL

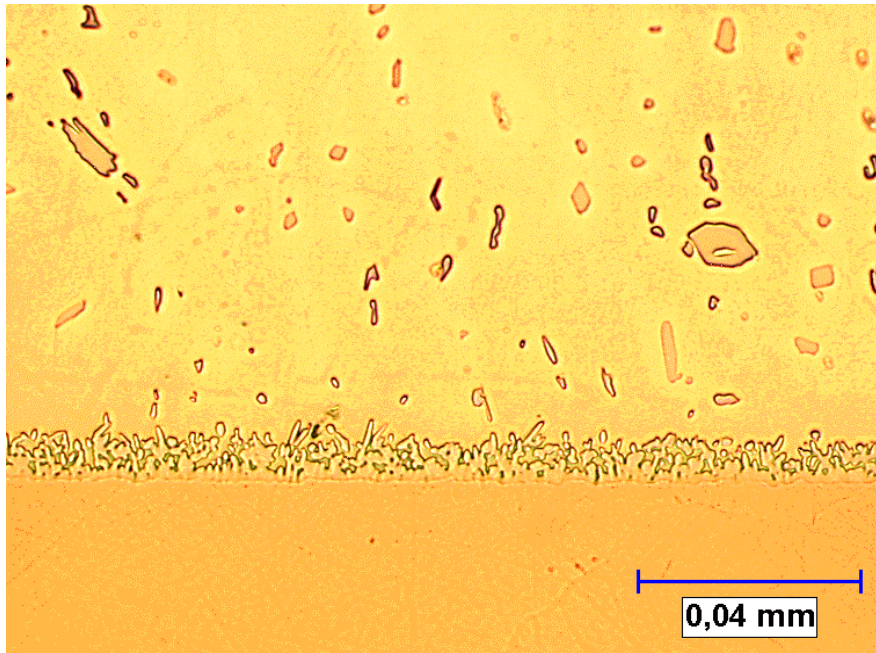


SnIn20/Cu couple
230°C; 5 min
E: mag. 200×
PL

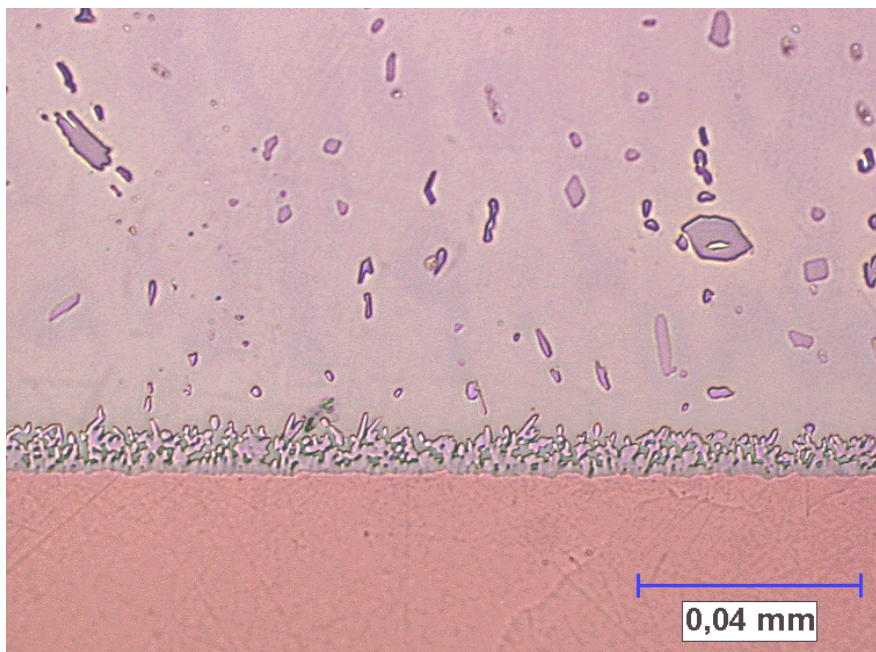


SnIn20/Cu couple
230°C; 5 min
E: mag. 200×
PC

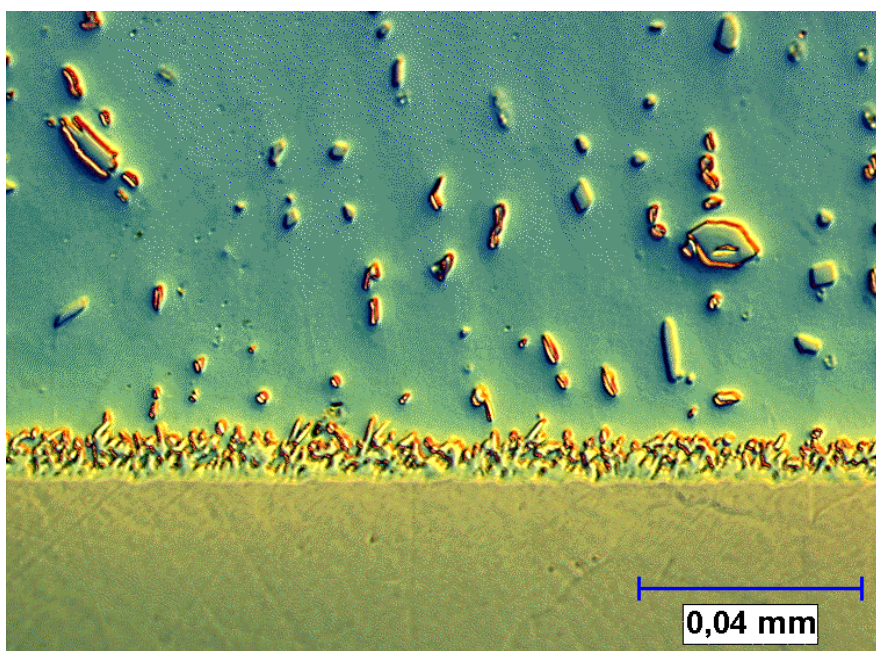




SnIn20/Cu couple
230°C; 5 min
E: mag. 500×
CL

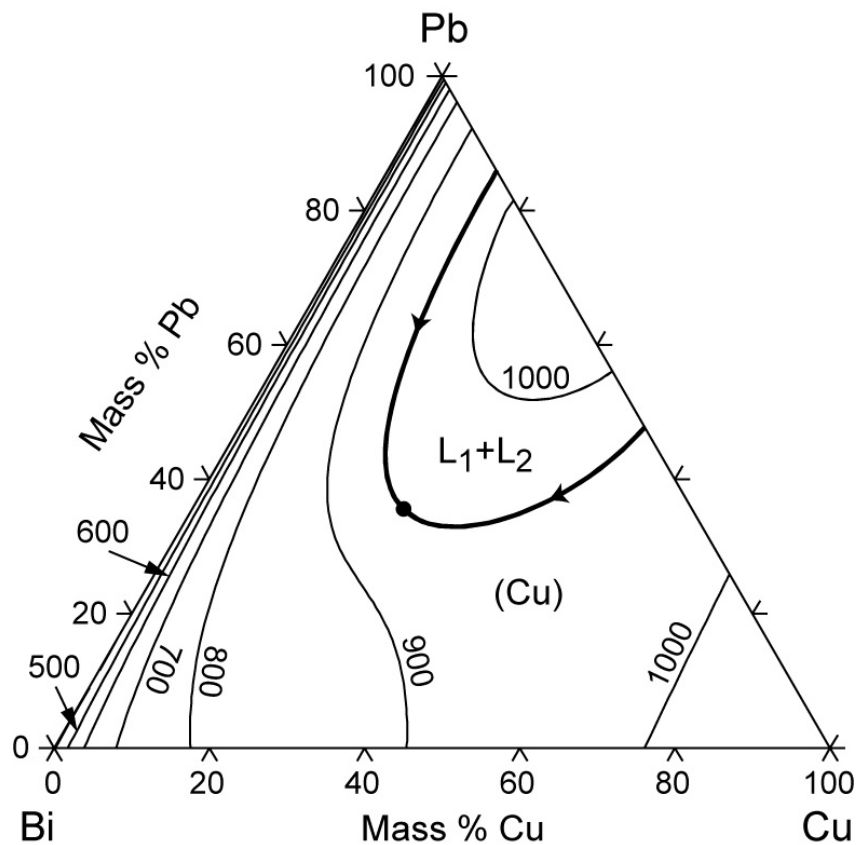


SnIn20/Cu couple
230°C; 5 min
E: mag. 500×
PL

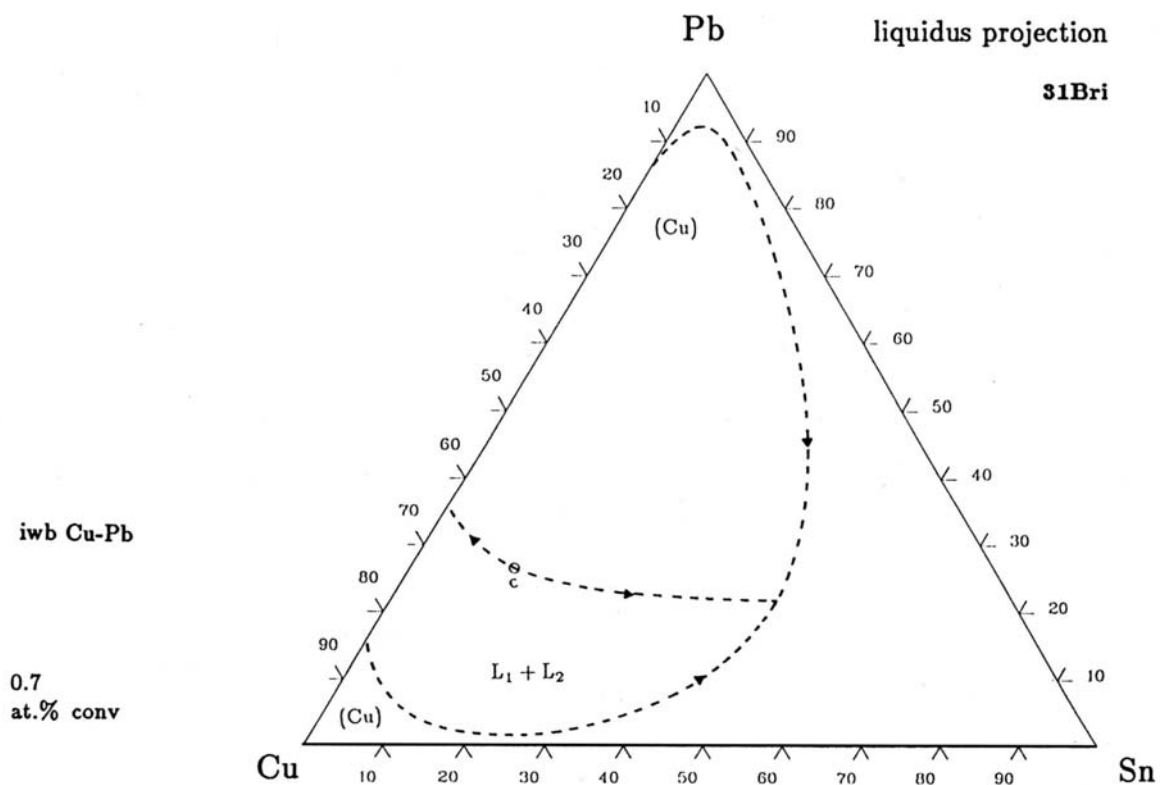


SnIn20/Cu couple
230°C; 5 min
E: mag. 500×
PC

Sn – Pb – Cu



Experimental Phase Diagram (data from <http://www.metallurgy.nist.gov/phase/solder/bicupb-l.jpg>)

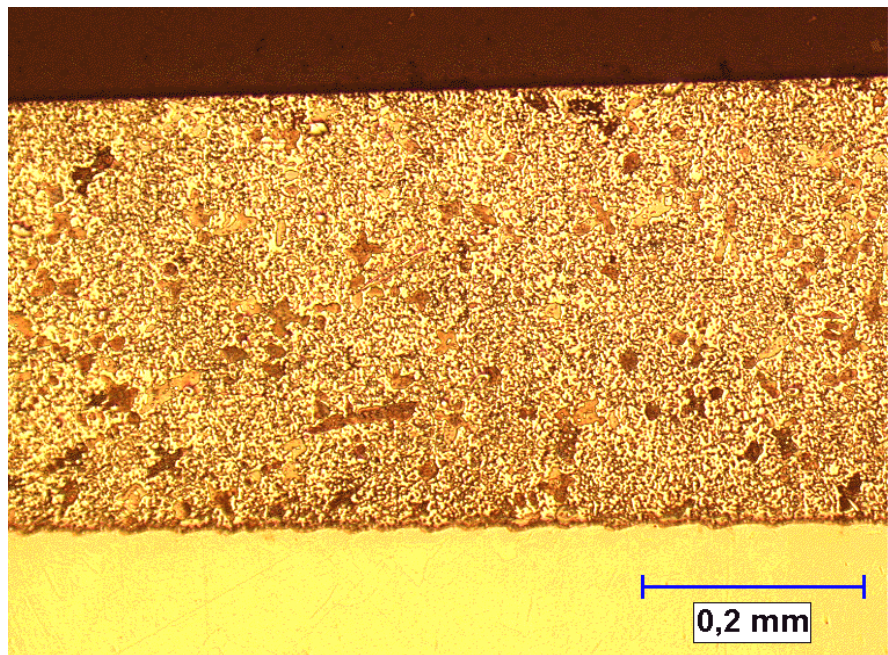


Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•41)

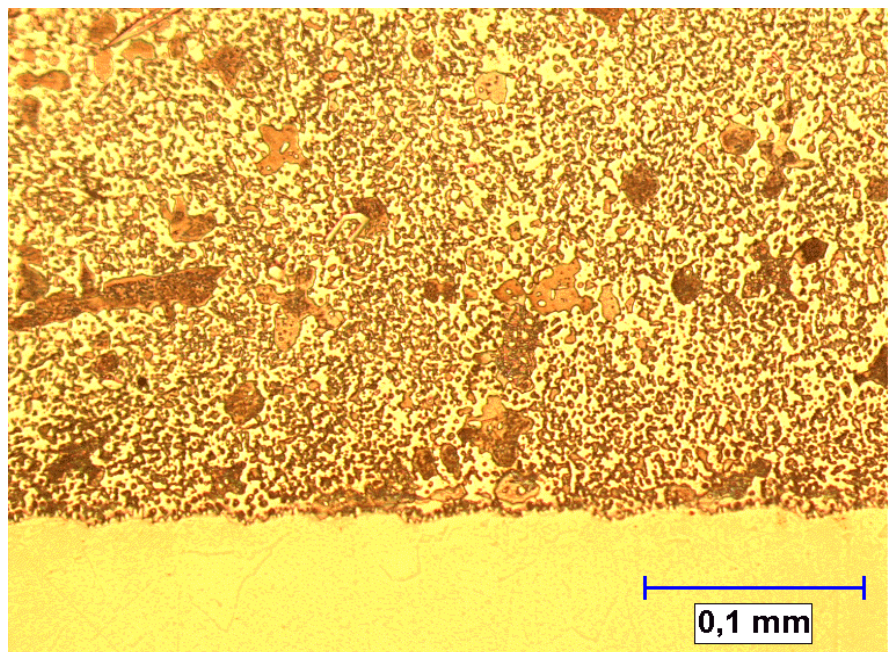
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
SnPb40 / Cu	230°C, 5 min, flux	11°	7
SnPb67 / Cu	230°C, 5 min, flux	16°	9

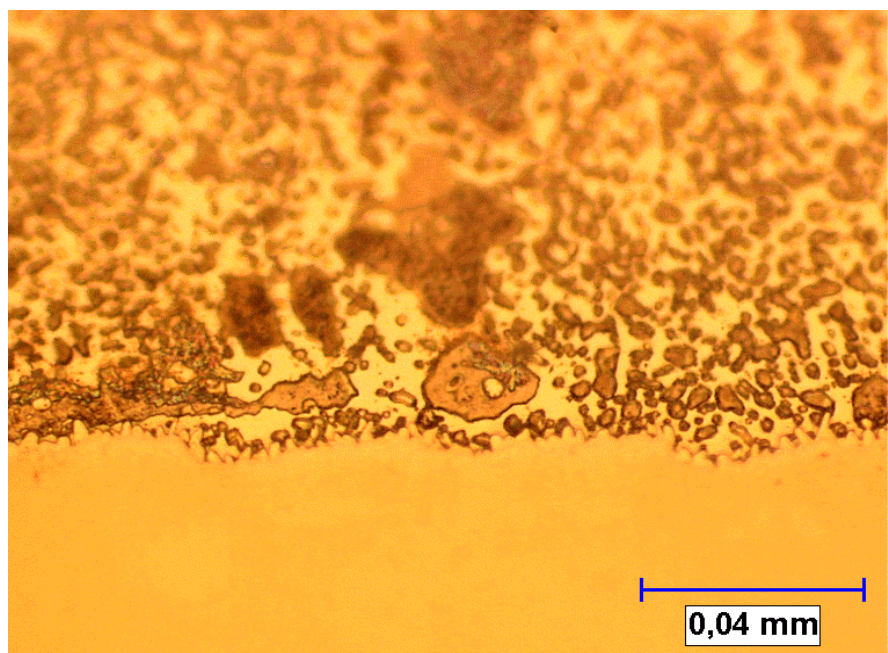
SnPb40/Cu couple
230°C; 5 min
E: mag. 100×
CL

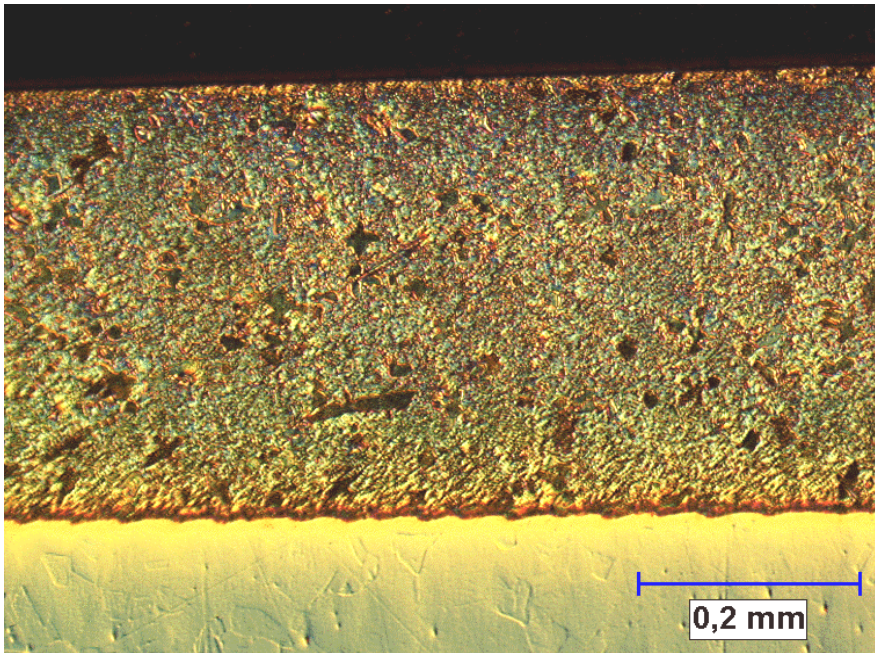


SnPb40/Cu couple
230°C; 5 min
E: mag. 200×
CL

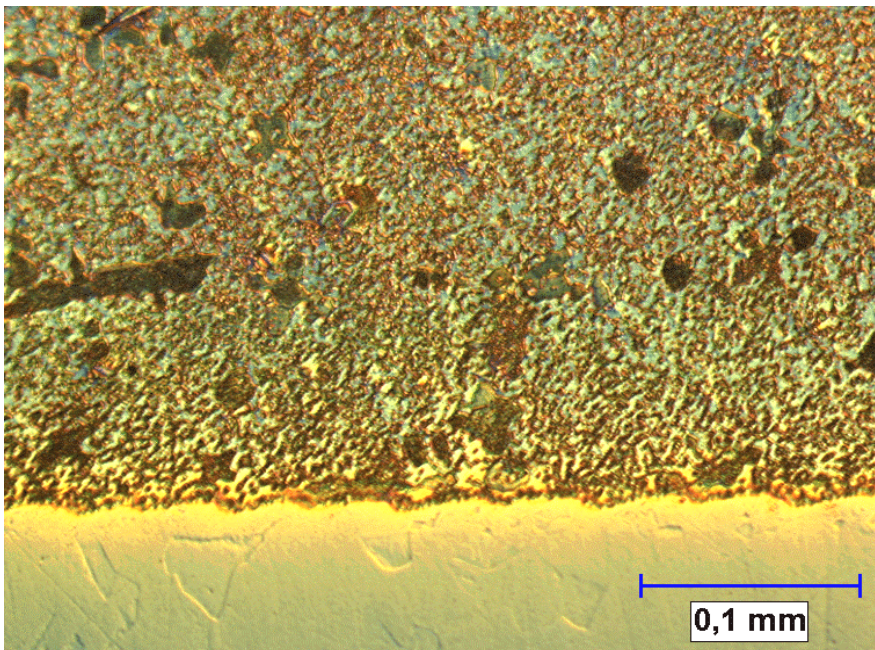


SnPb40/Cu couple
230°C; 5 min
E: mag. 500×
CL

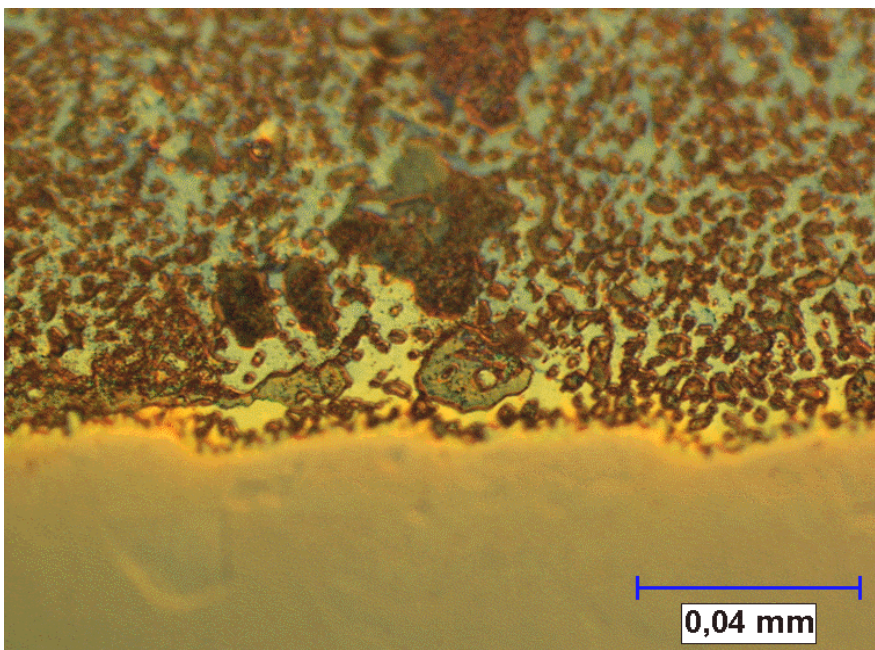




SnPb40/Cu couple
230°C; 5 min
E: mag. 100×
PC

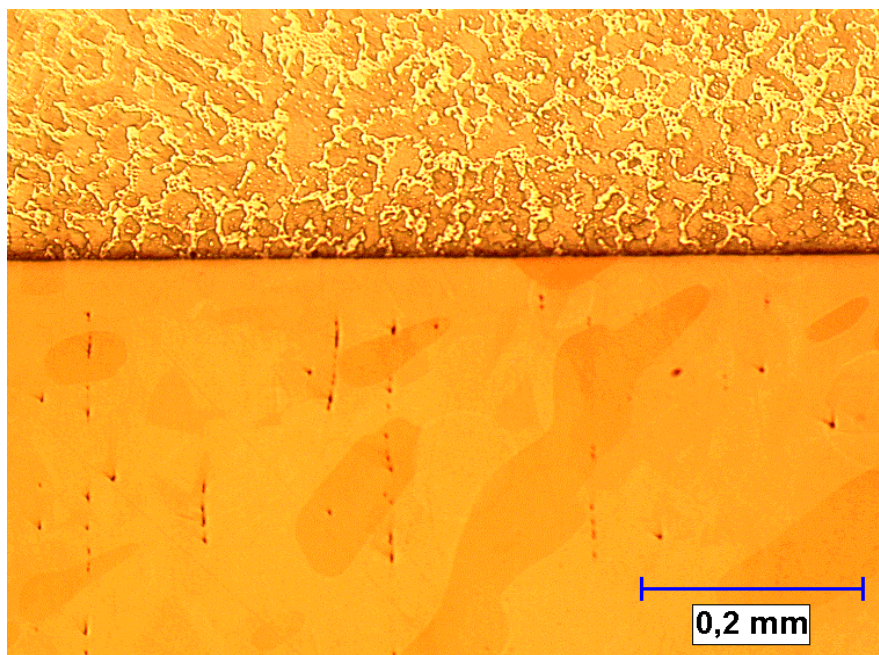


SnPb40/Cu couple
230°C; 5 min
E: mag. 200×
PC

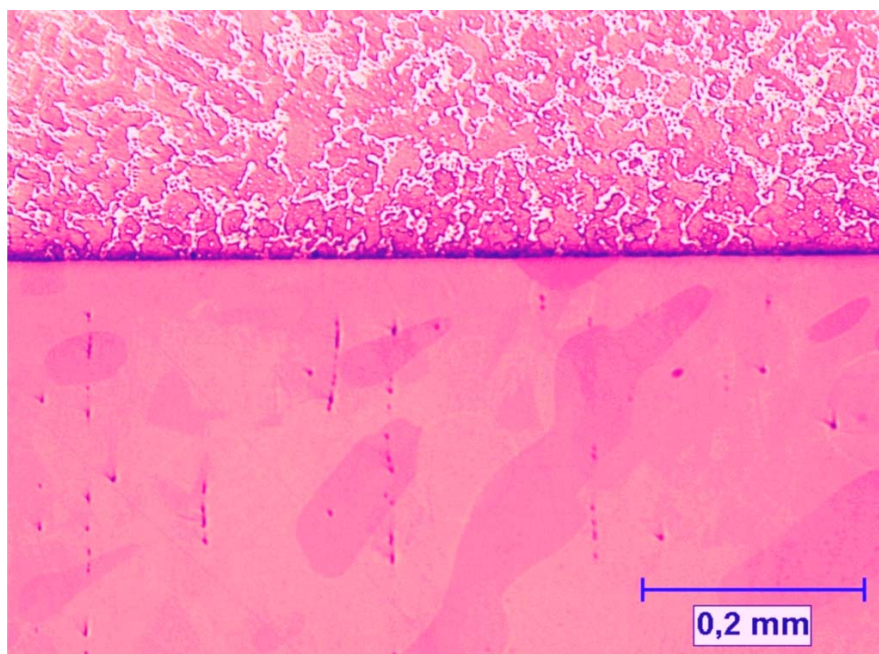


SnPb40/Cu couple
230°C; 5 min
E: mag. 500×
PC

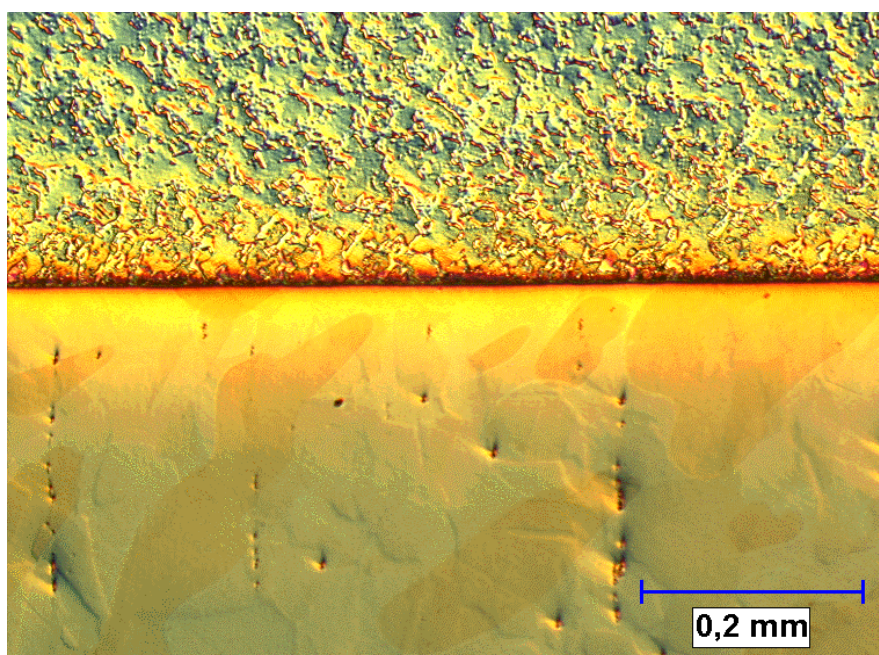
SnPb67/Cu couple
230°C; 5 min
E: mag. 100×
CL

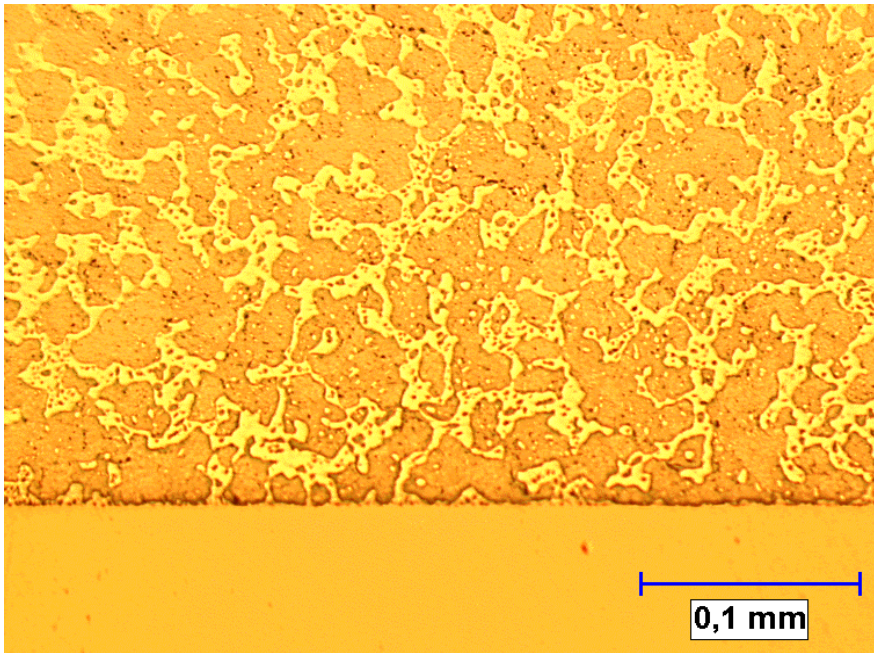


SnPb67/Cu couple
230°C; 5 min
E: mag. 100×
PL

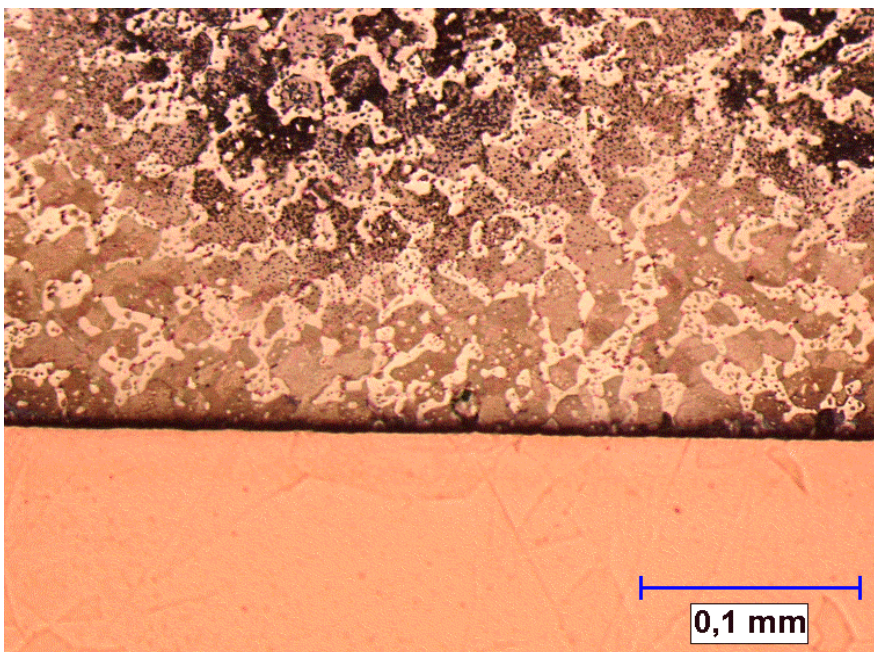


SnPb67/Cu couple
230°C; 5 min
E: mag. 100×
PC

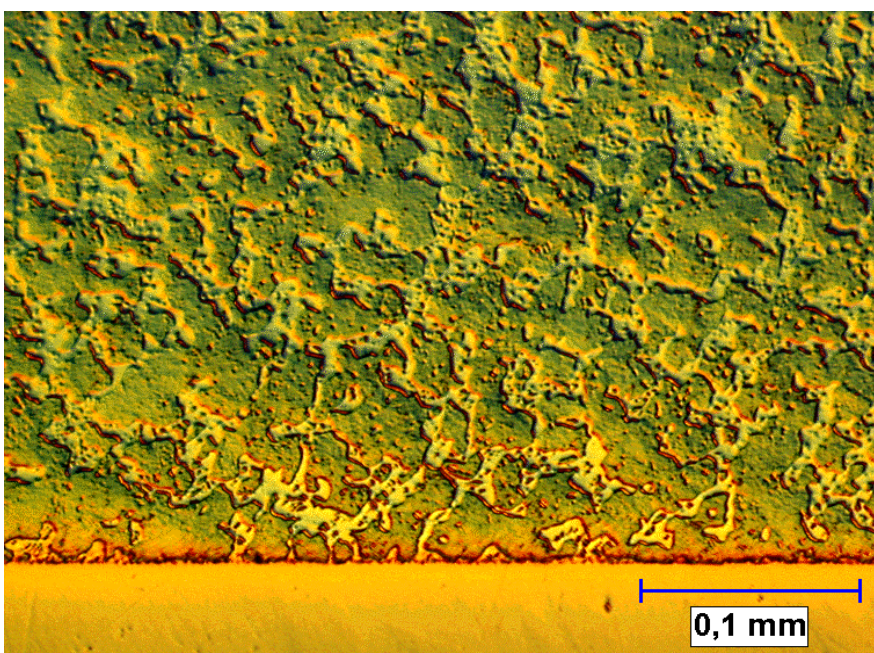




SnPb67/Cu couple
230°C; 5 min
E: mag. 200×
CL

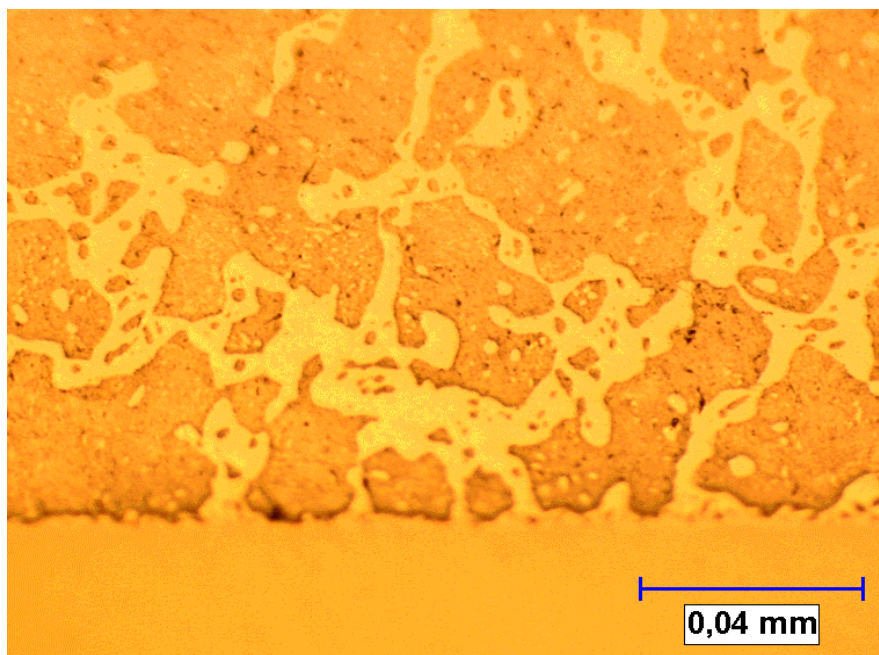


SnPb67/Cu couple
230°C; 5 min
E: mag. 200×
PL

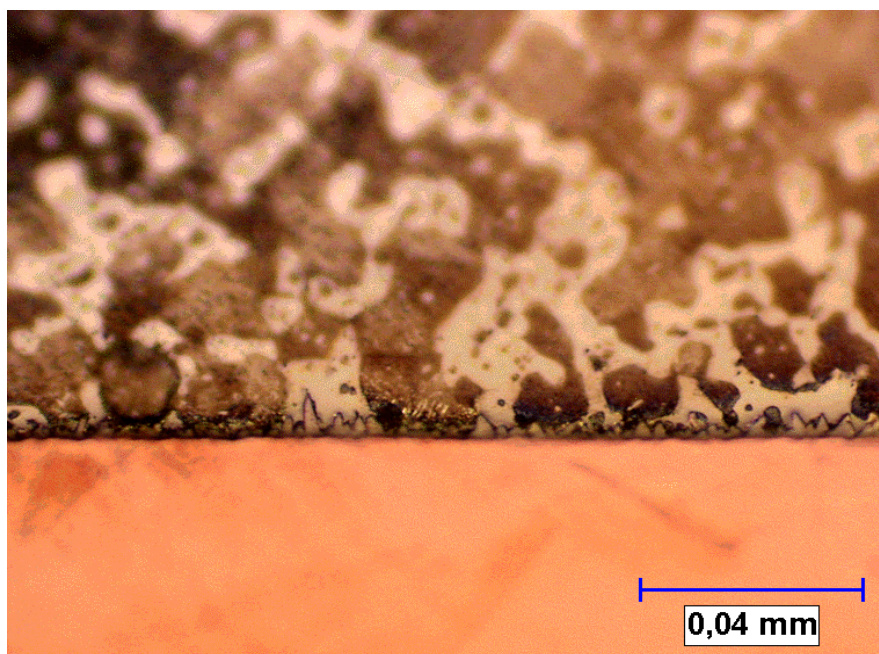


SnPb67/Cu couple
230°C; 5 min
E: mag. 200×
PC

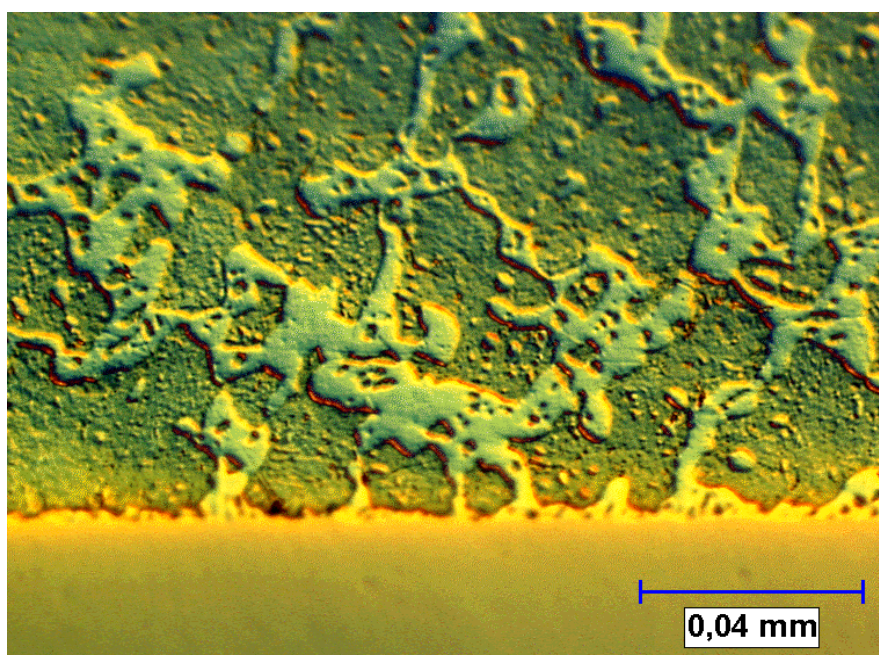
SnPb67/Cu couple
230°C; 5 min
E: mag. 500×
CL



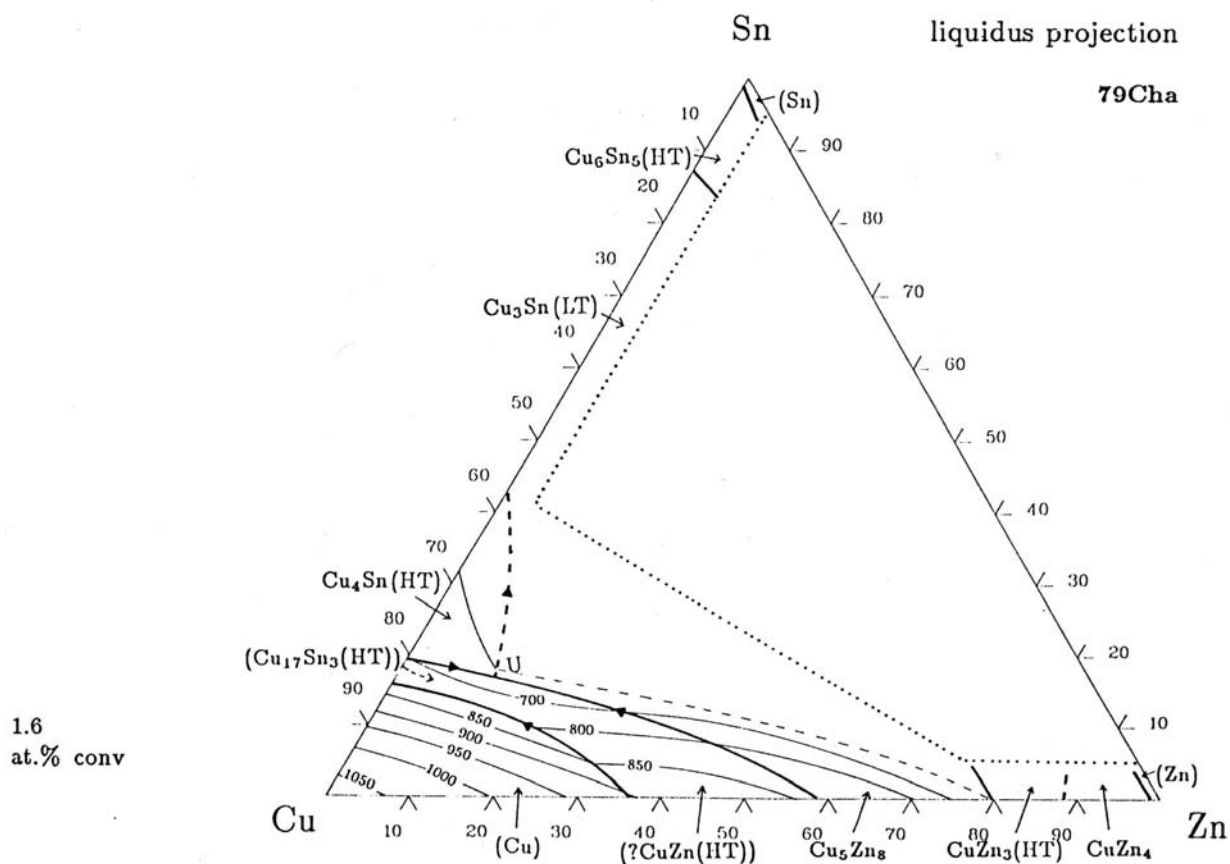
SnPb67/Cu couple
230°C; 5 min
E: mag. 500×
PL



SnPb67/Cu couple
230°C; 5 min
E: mag. 500×
PC



Sn – Zn – Cu

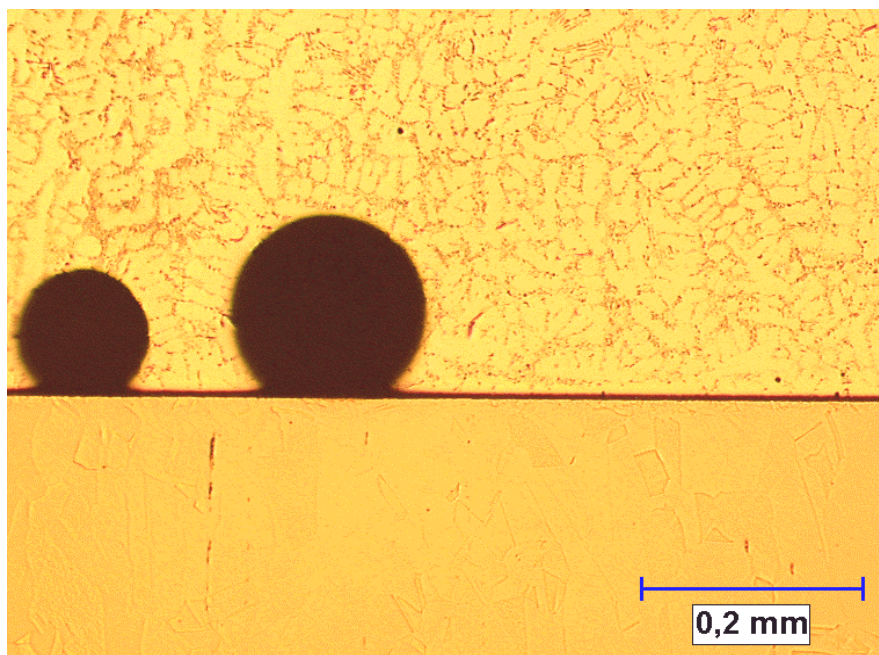


Experimental Phase Diagram (data from ASM Handbook Alloy Phase Diagrams, 1992, vol. 3, p. 2•43)

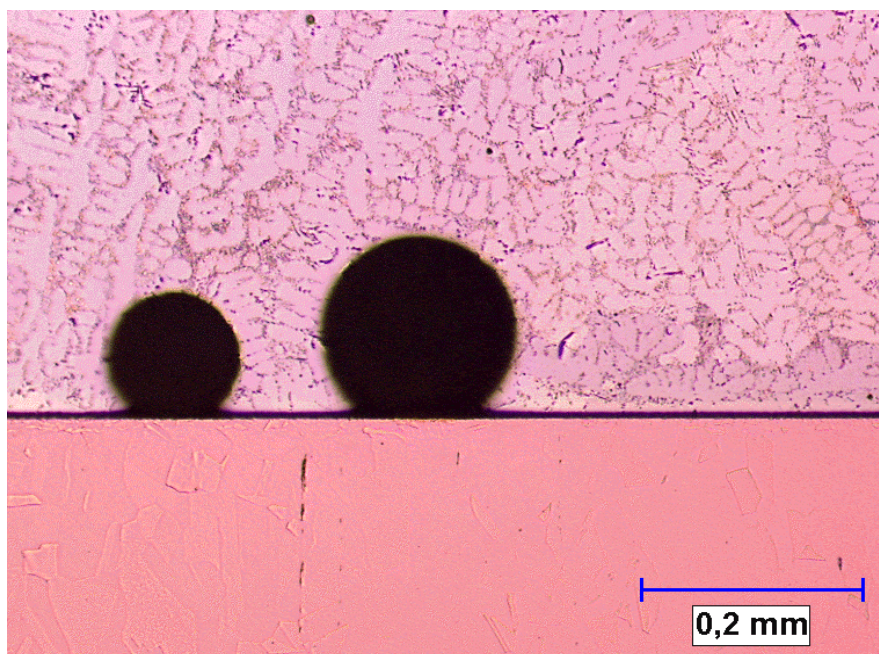
Properties of solder/substrate couples

Couple	Conditions	θ , deg	τ , MPa
SnZn4.5 / Cu	230°C, 5 min, flux	53°	24
SnZn9 / Cu	230°C, 5 min, flux	54°	26
SnZ13.5 / Cu	230°C, 5 min, flux	53°	27

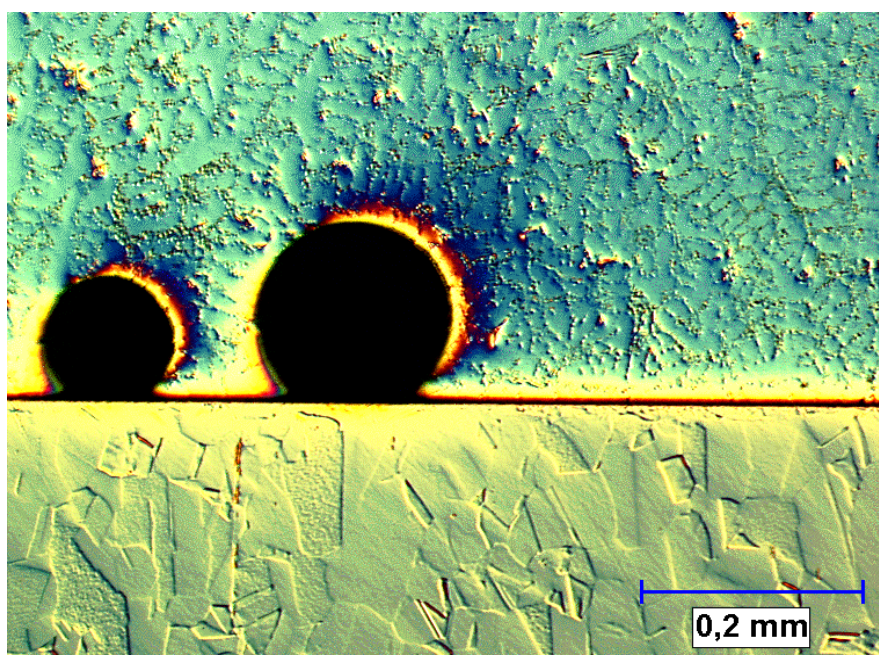
SnZn4.5/Cu couple
230°C; 5 min
E: mag. 100×
CL

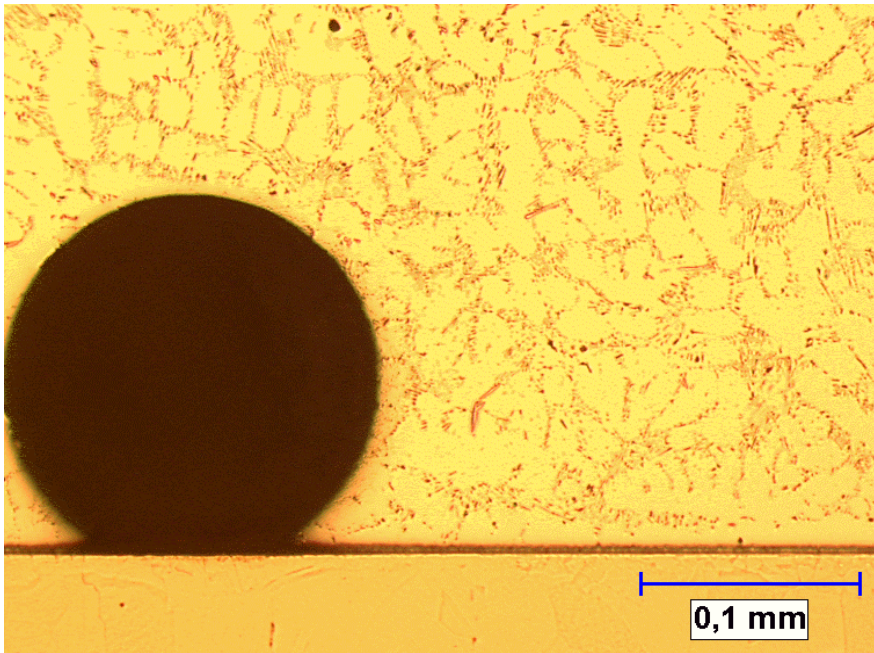


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 100×
PL

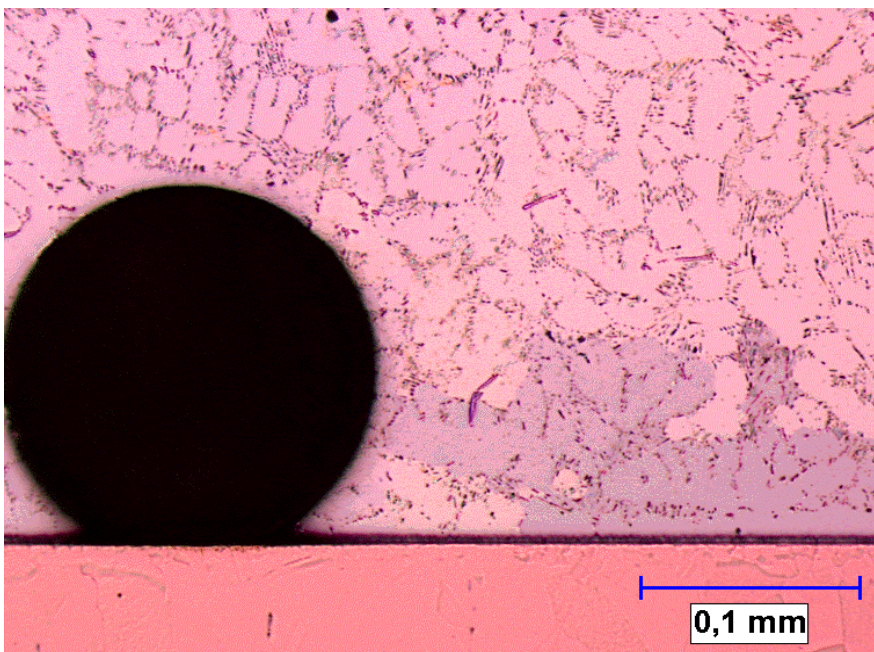


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 100×
PC

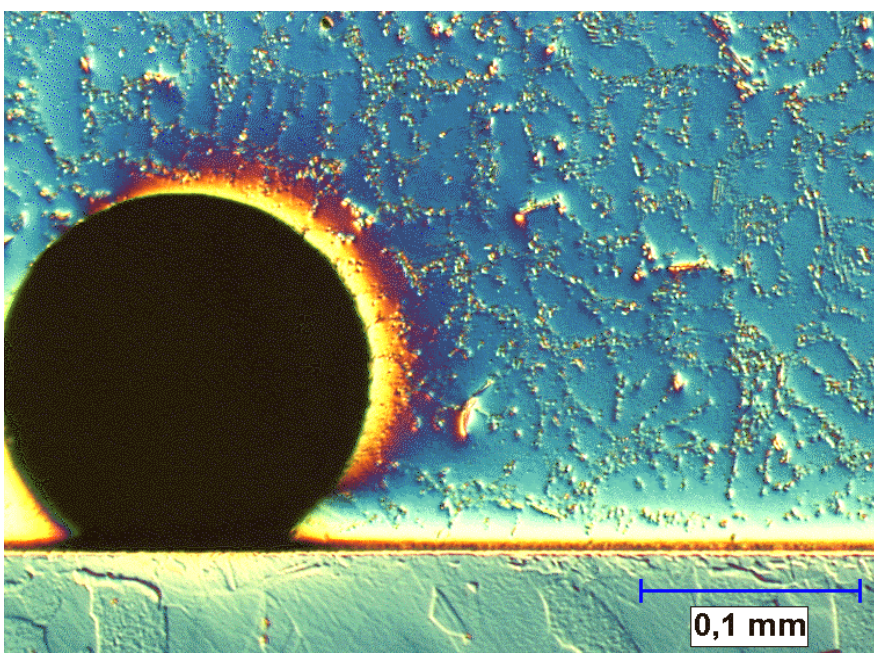




SnZn4.5/Cu couple
230°C; 5 min
E: mag. 200×
CL

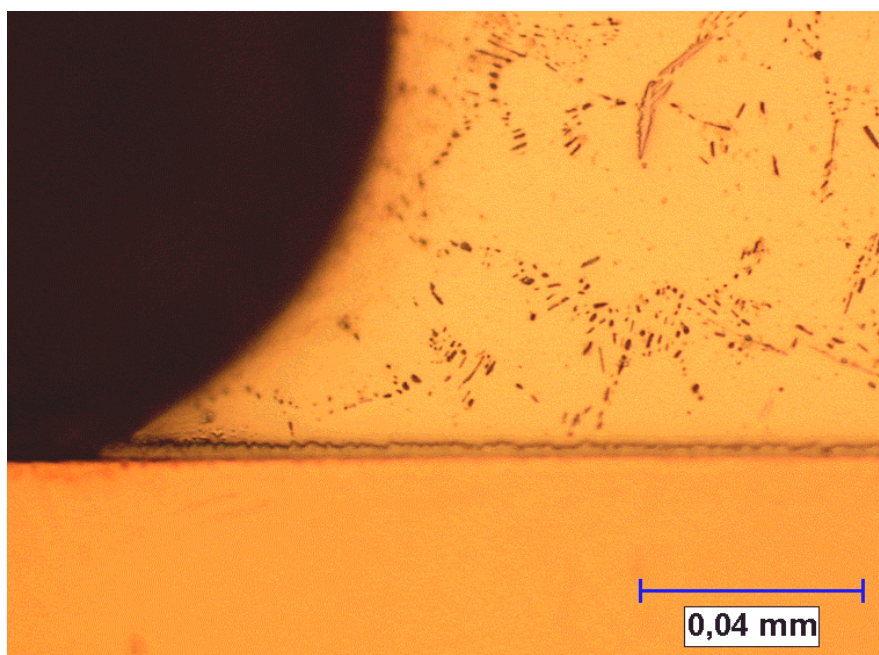


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 200×
PL

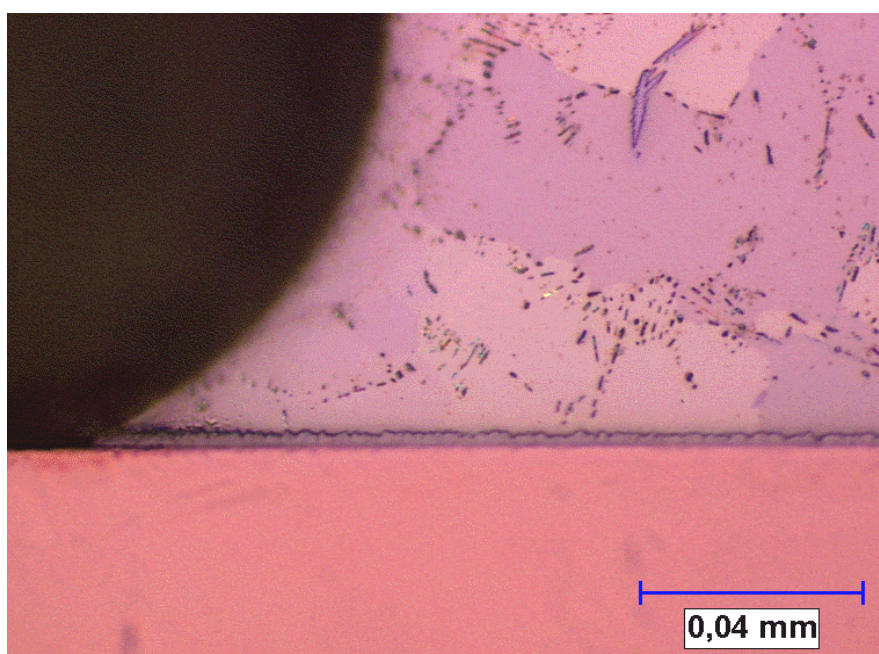


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 200×
PC

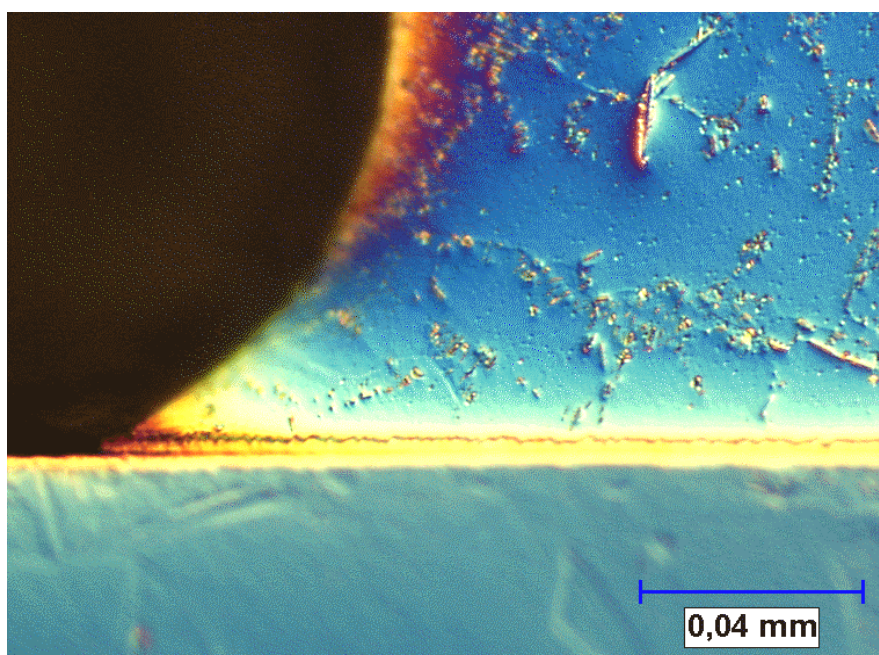
SnZn4.5/Cu couple
230°C; 5 min
E: mag. 500×
CL

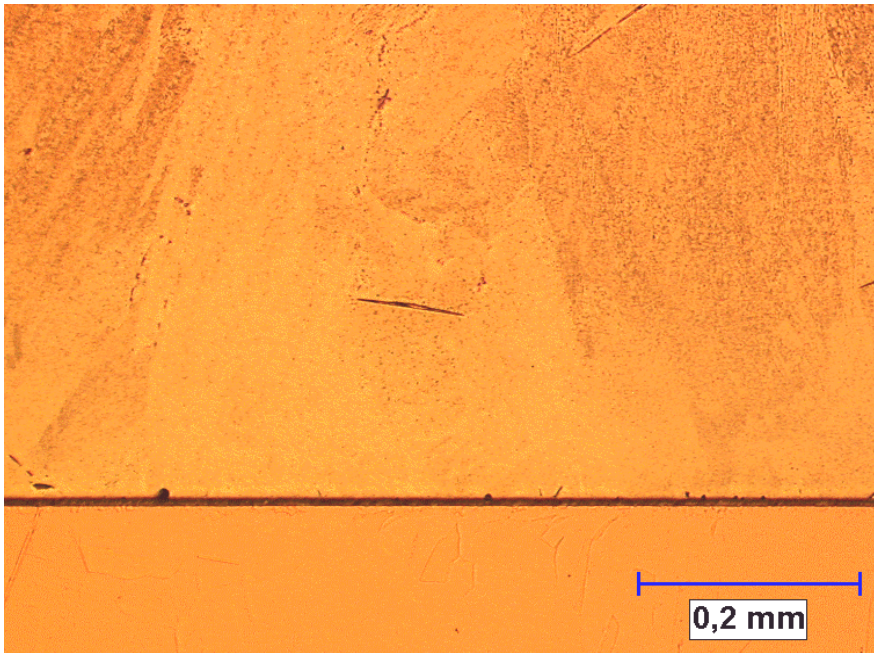


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 500×
PL

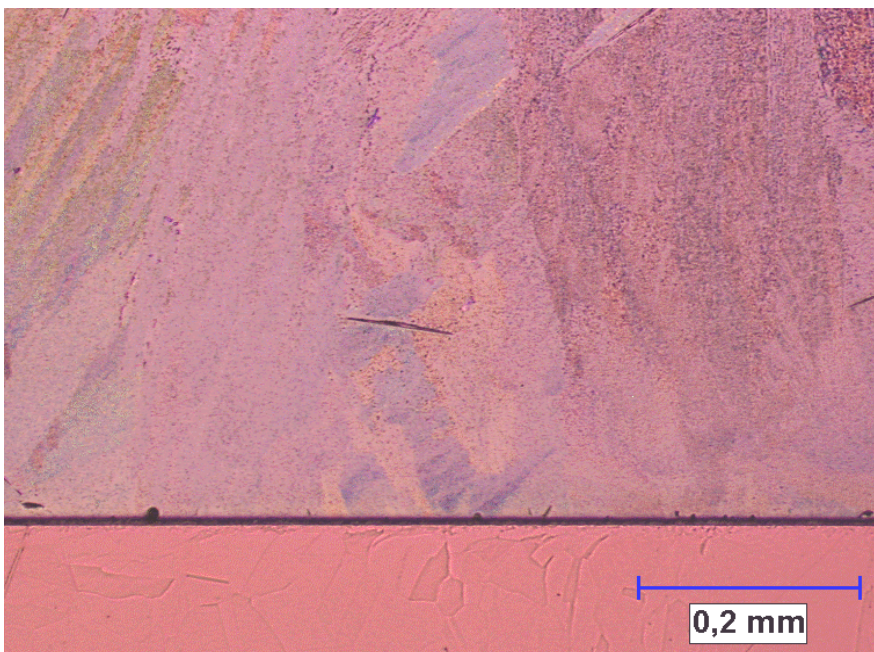


SnZn4.5/Cu couple
230°C; 5 min
E: mag. 500×
PC

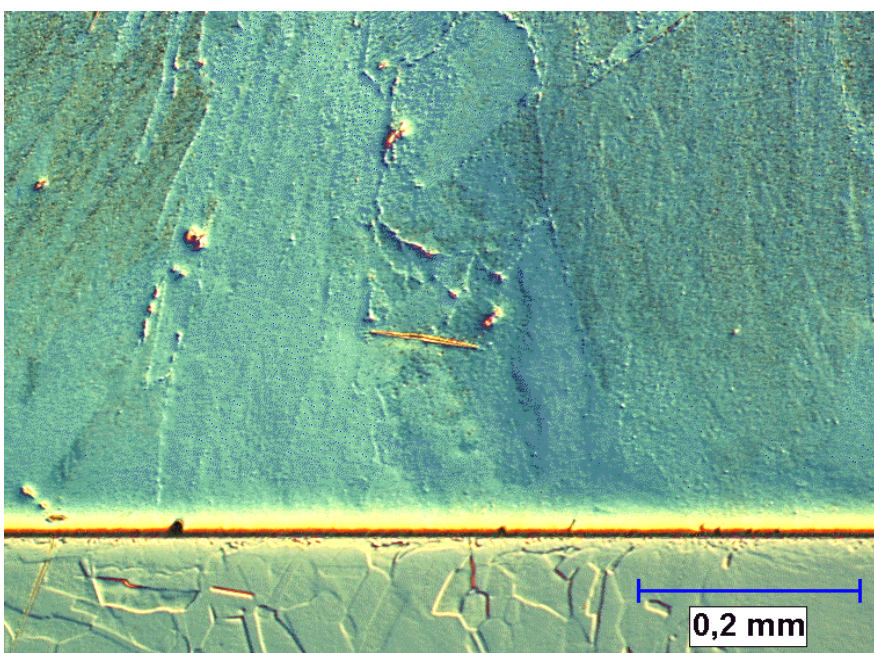




SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
CL

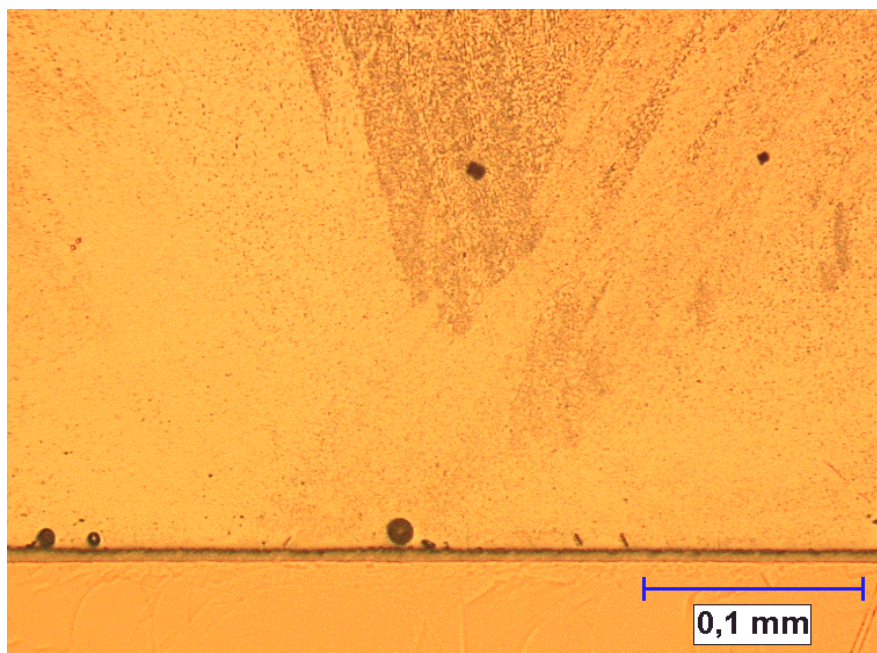


SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
PL

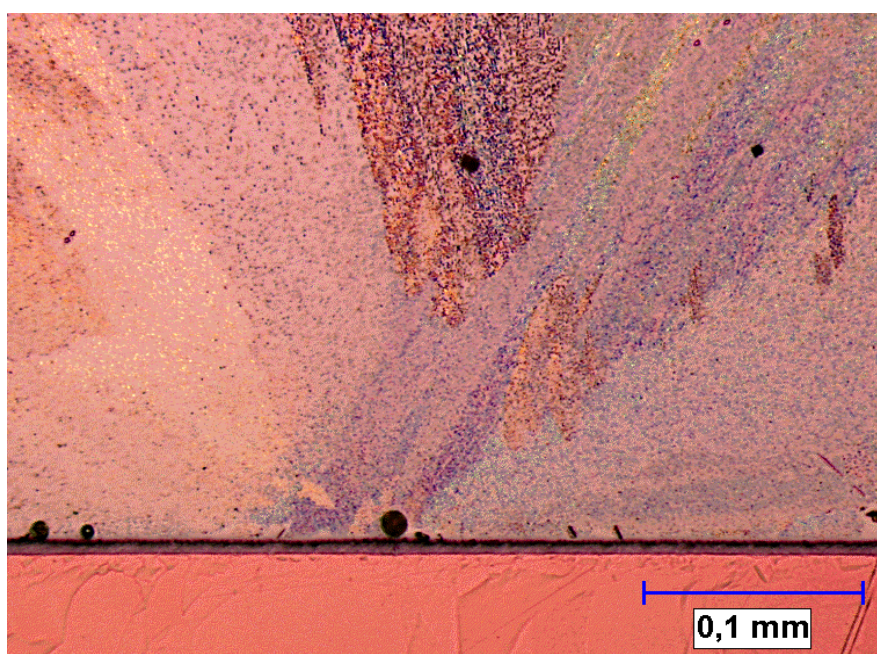


SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
PC

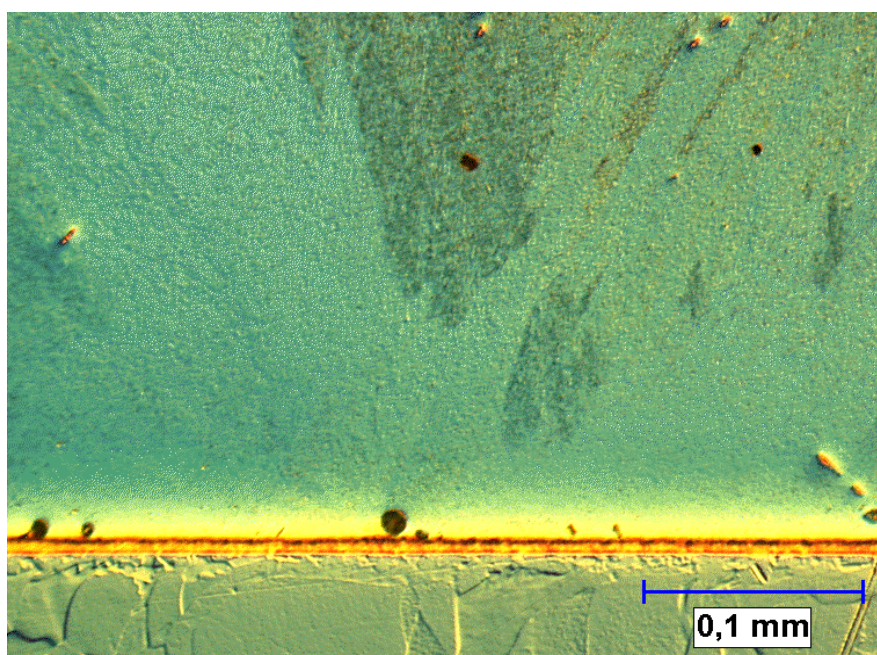
SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
CL

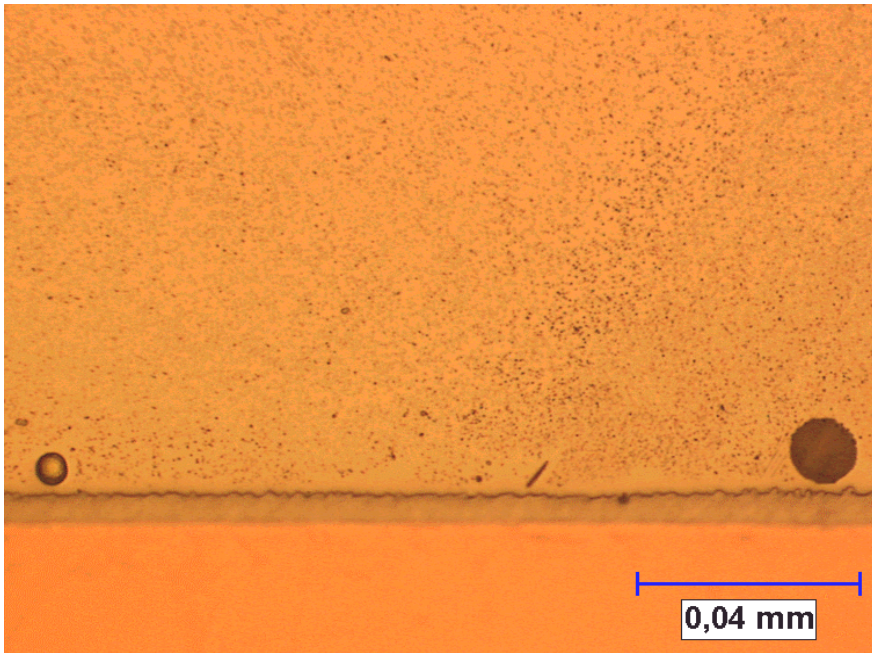


SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
PL

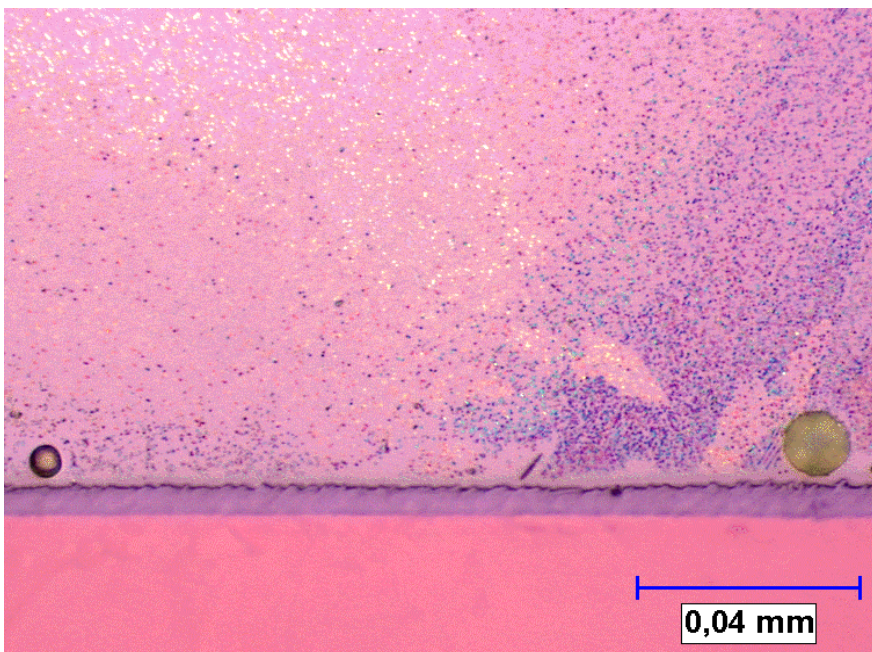


SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
PC

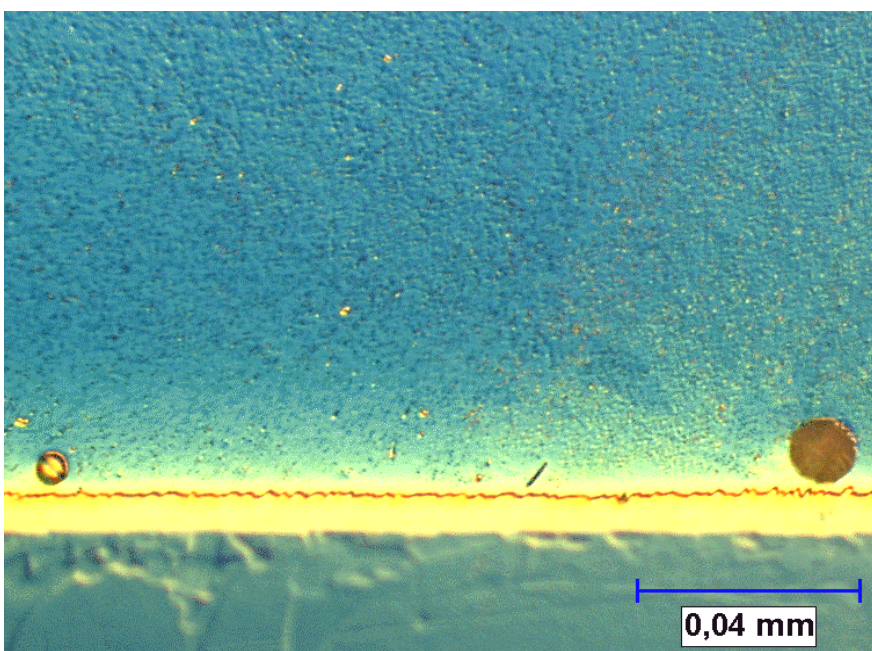




SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
CL

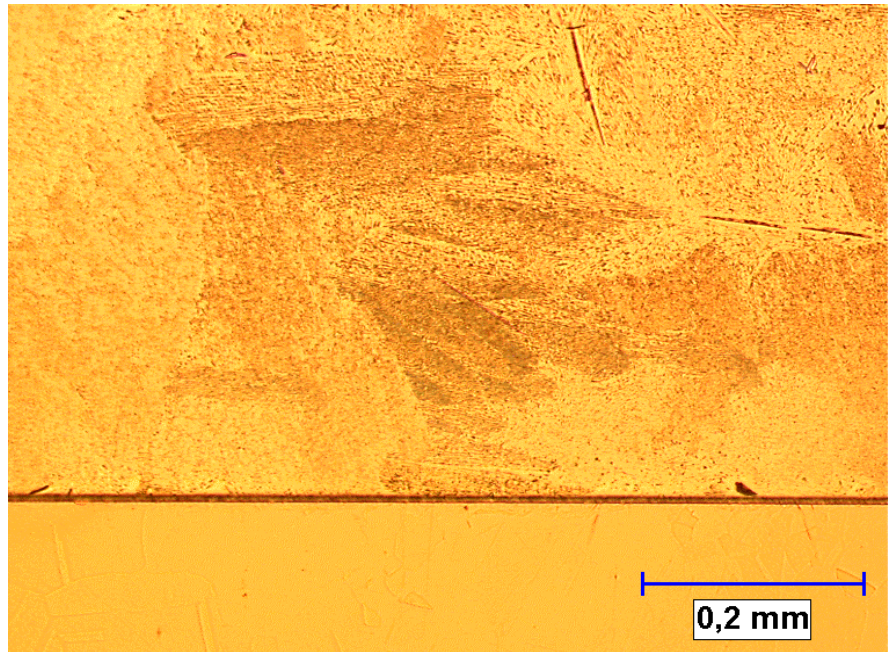


SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
PL

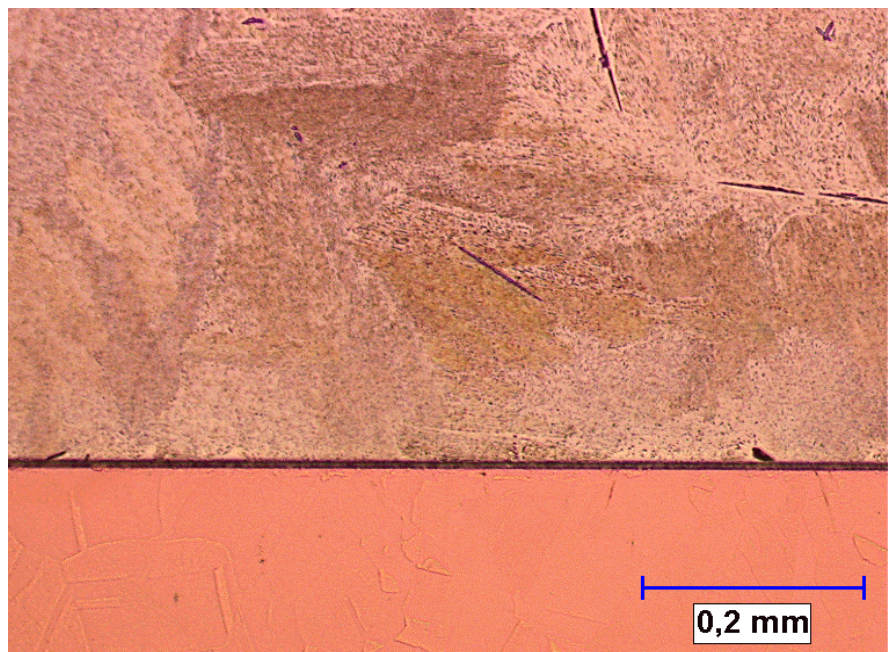


SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
PC

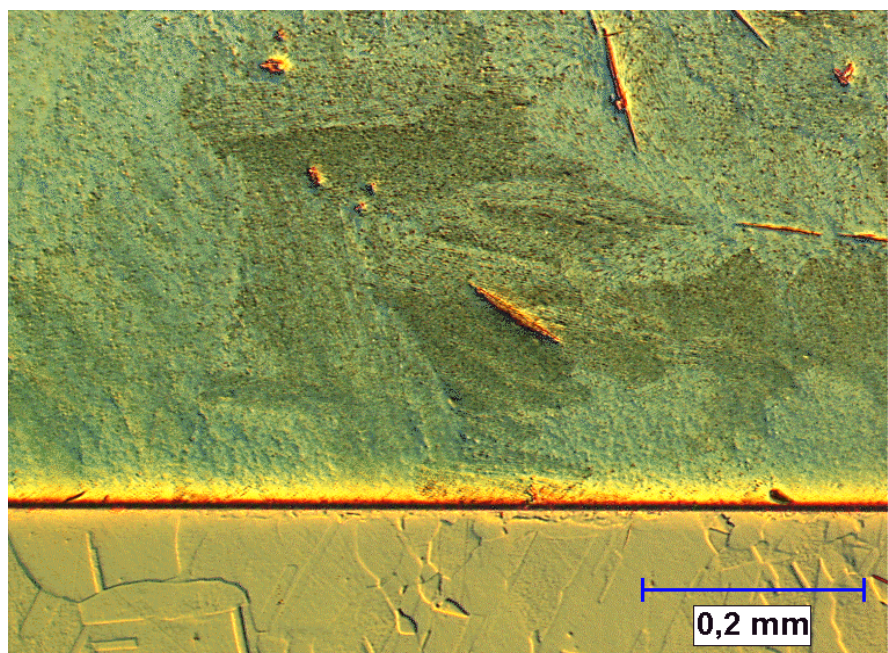
SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
CL

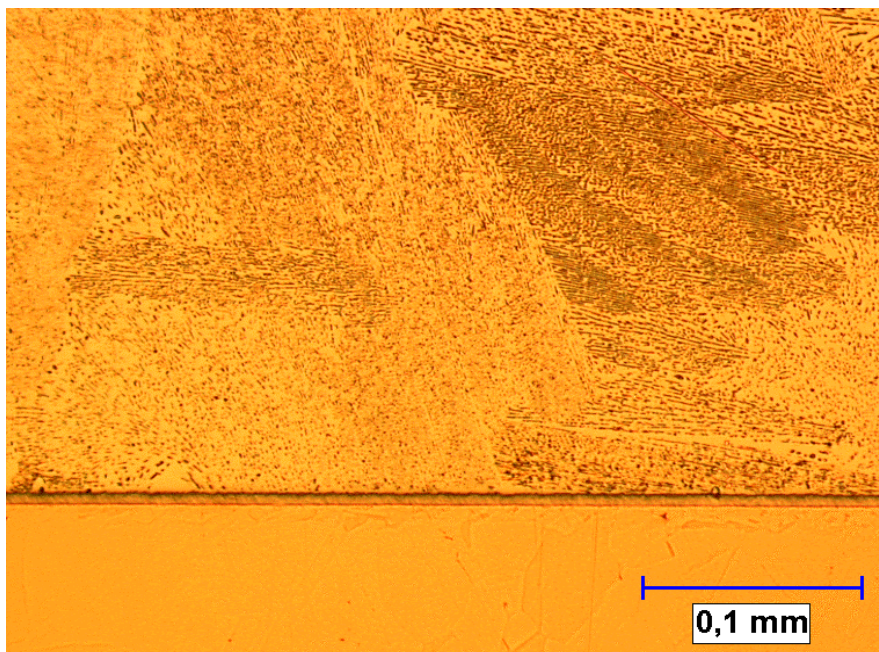


SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
PL

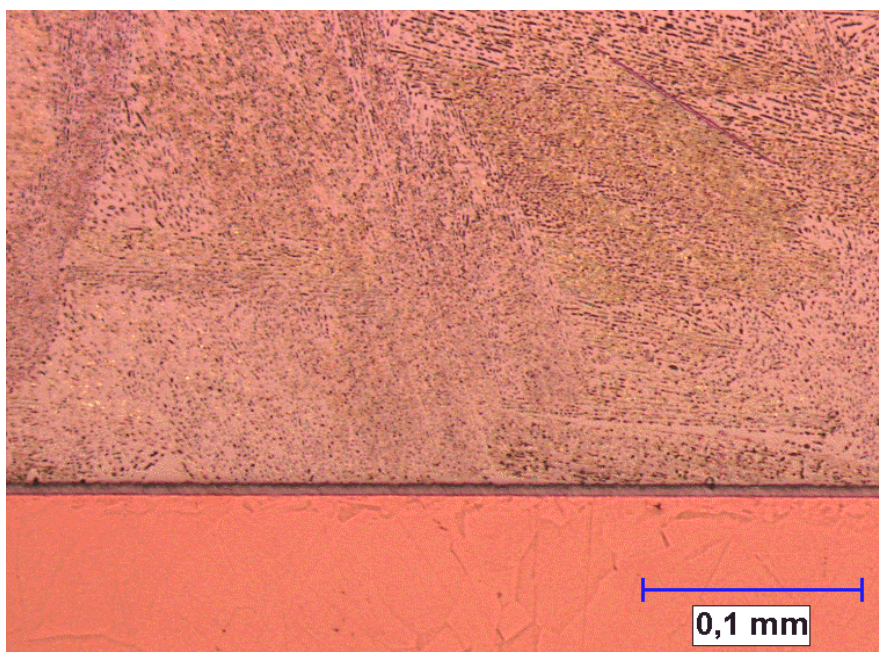


SnZn9/Cu couple
230°C; 5 min
E: mag. 100×
PC

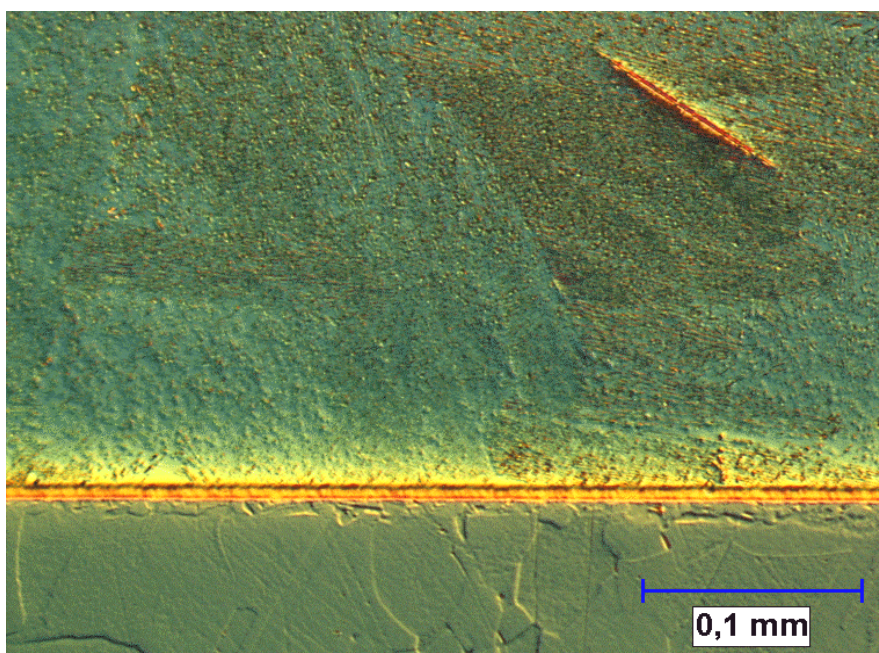




SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
CL

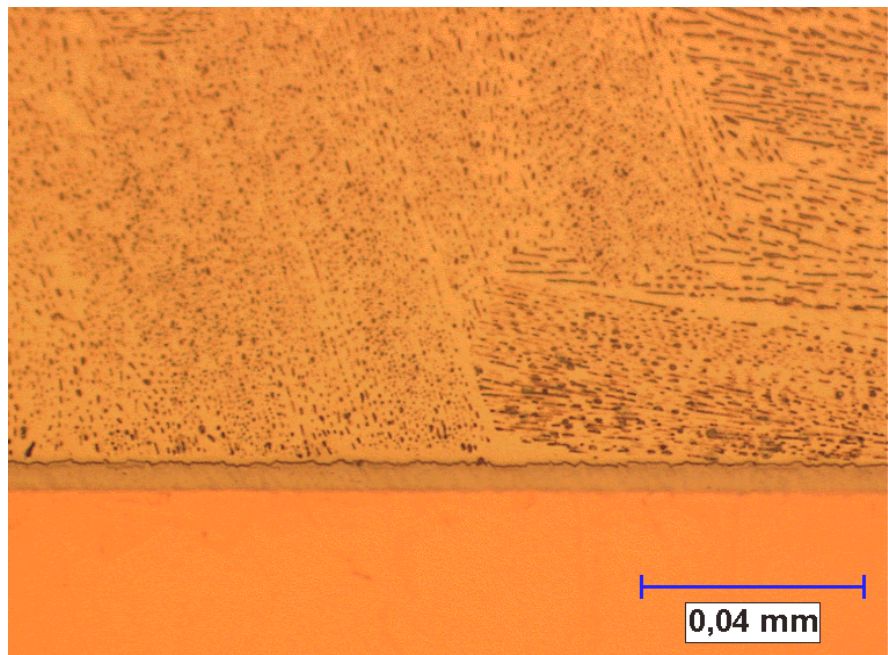


SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
PL

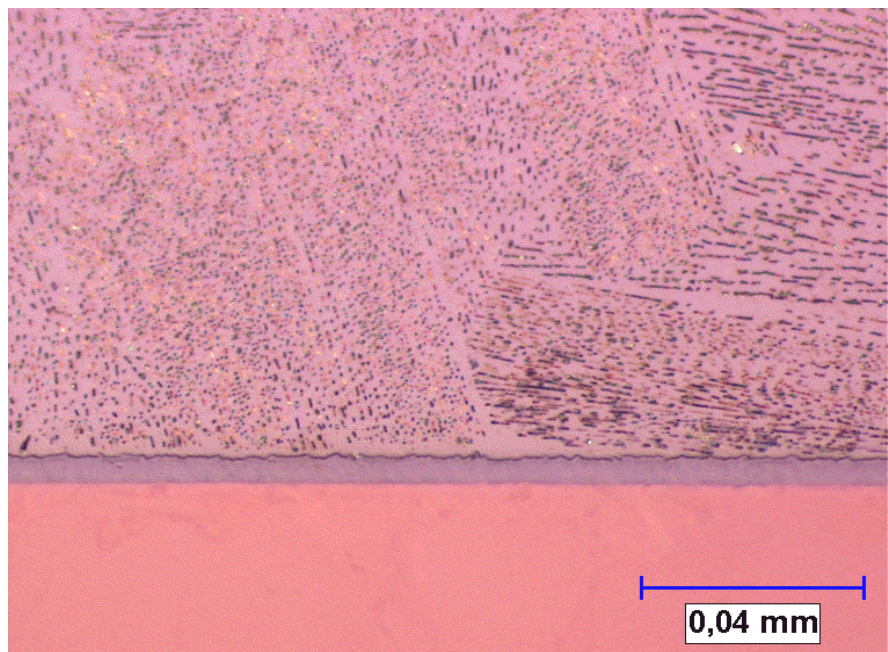


SnZn9/Cu couple
230°C; 5 min
E: mag. 200×
PC

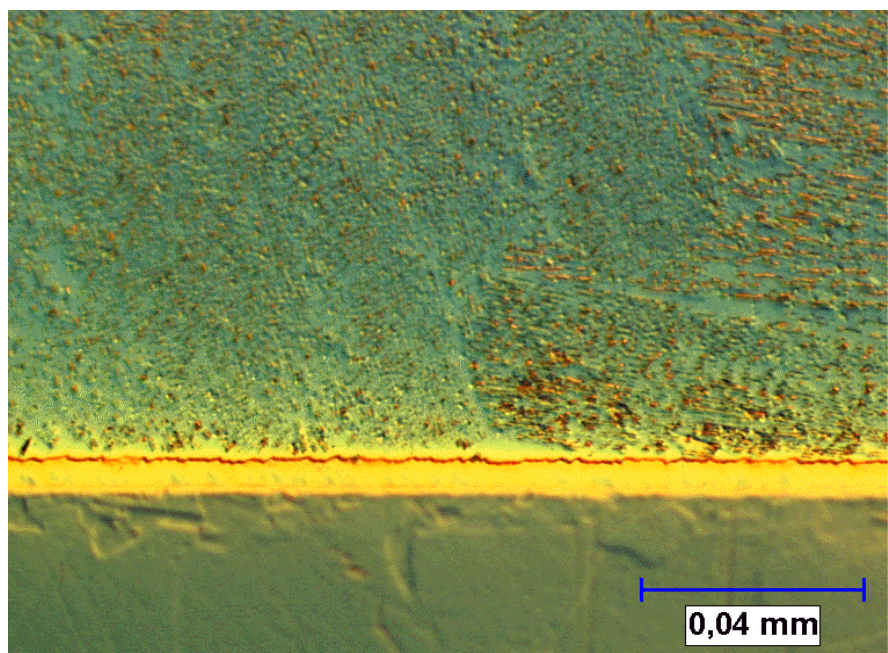
SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
CL

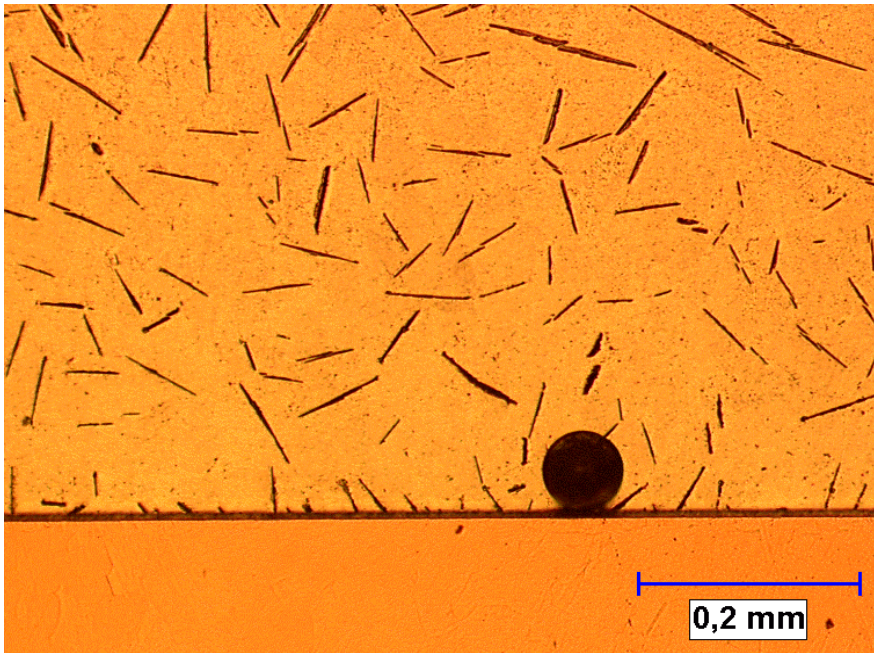


SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
PL

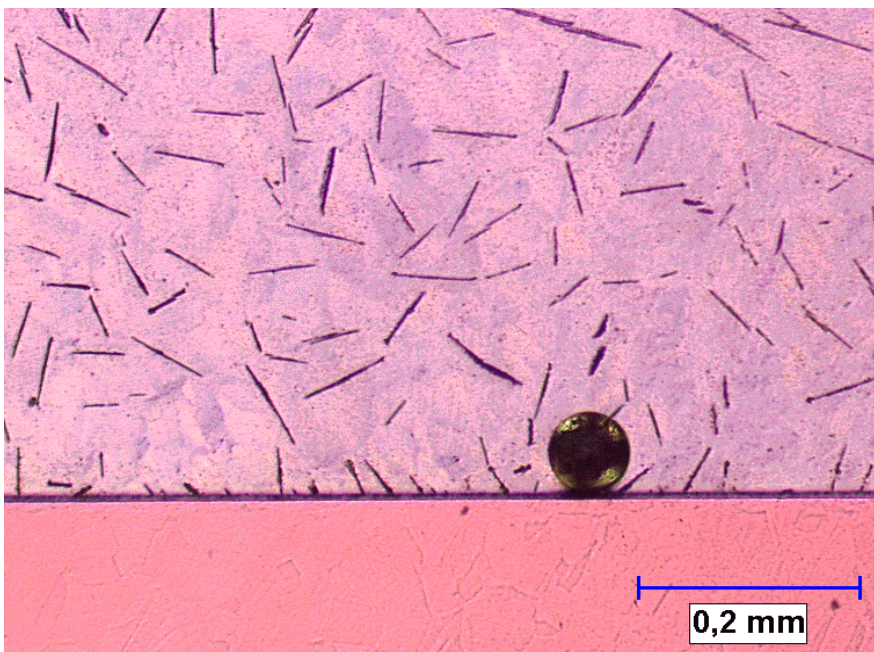


SnZn9/Cu couple
230°C; 5 min
E: mag. 500×
PC

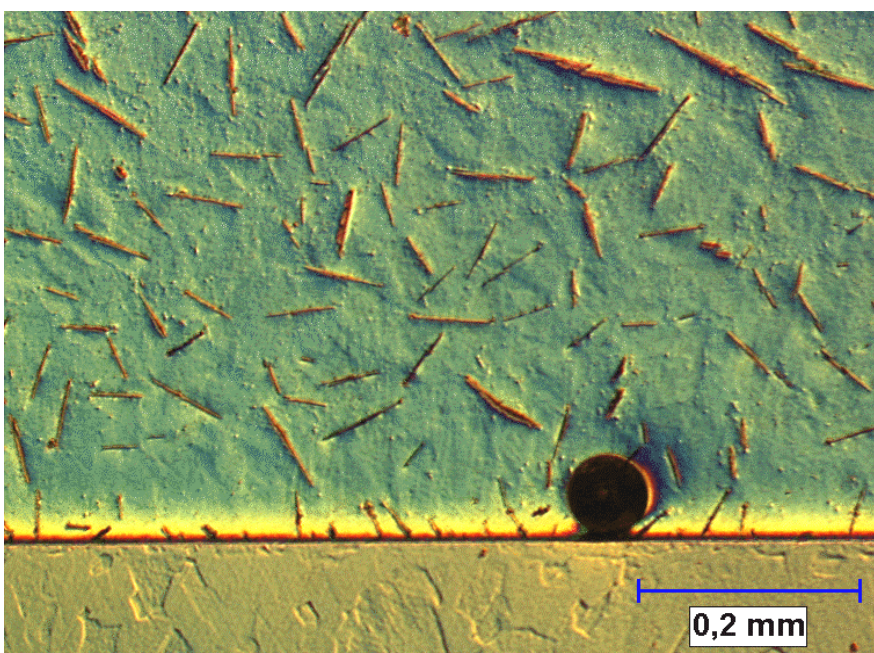




SnZn13.5/Cu couple
230°C; 5 min
E: mag. 100×
CL

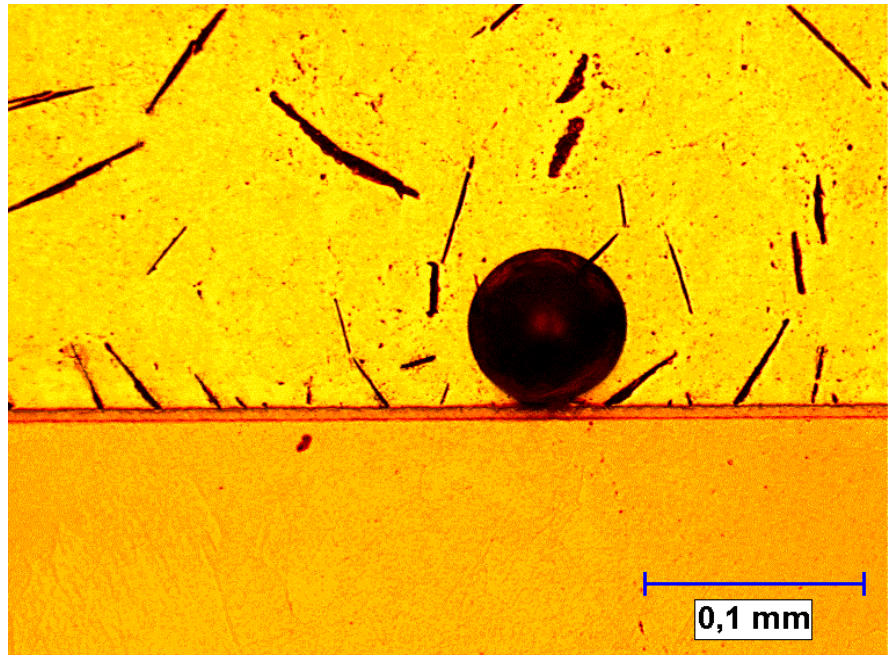


SnZn13.5/Cu couple
230°C; 5 min
E: mag. 100×
PL

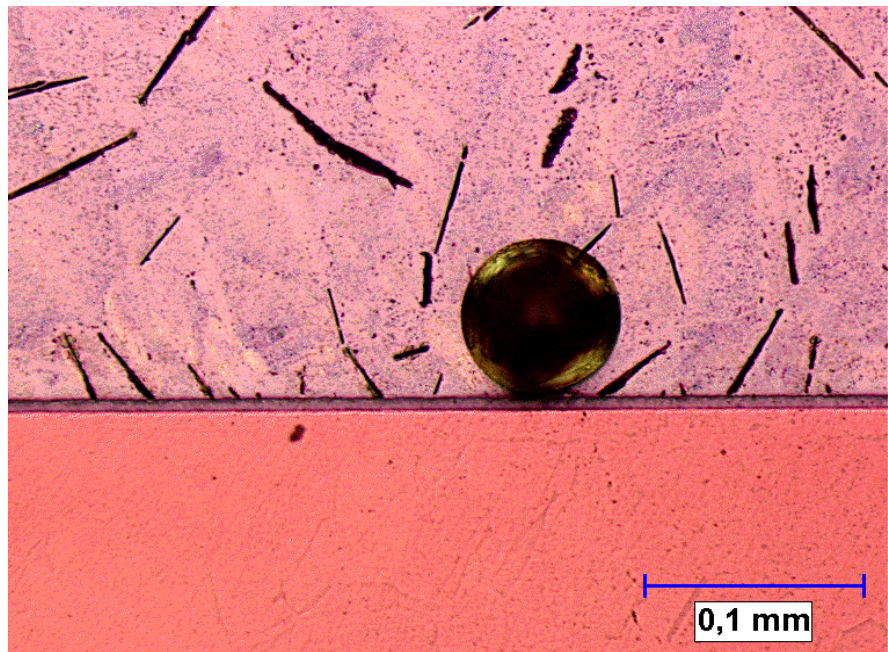


SnZn13.5/Cu couple
230°C; 5 min
E: mag. 100×
PC

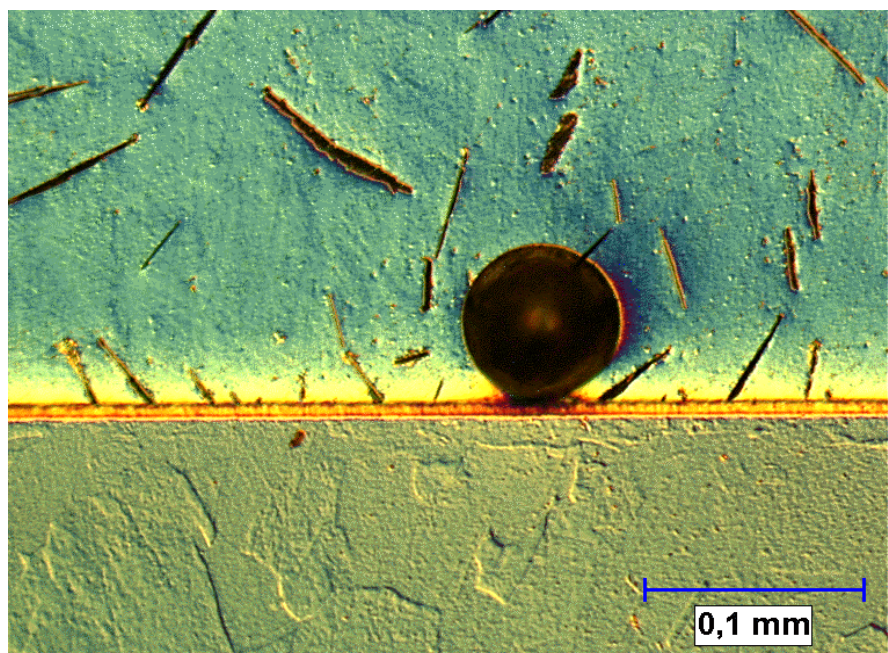
SnZn13.5/Cu couple
230°C; 5 min
E: mag. 200×
CL

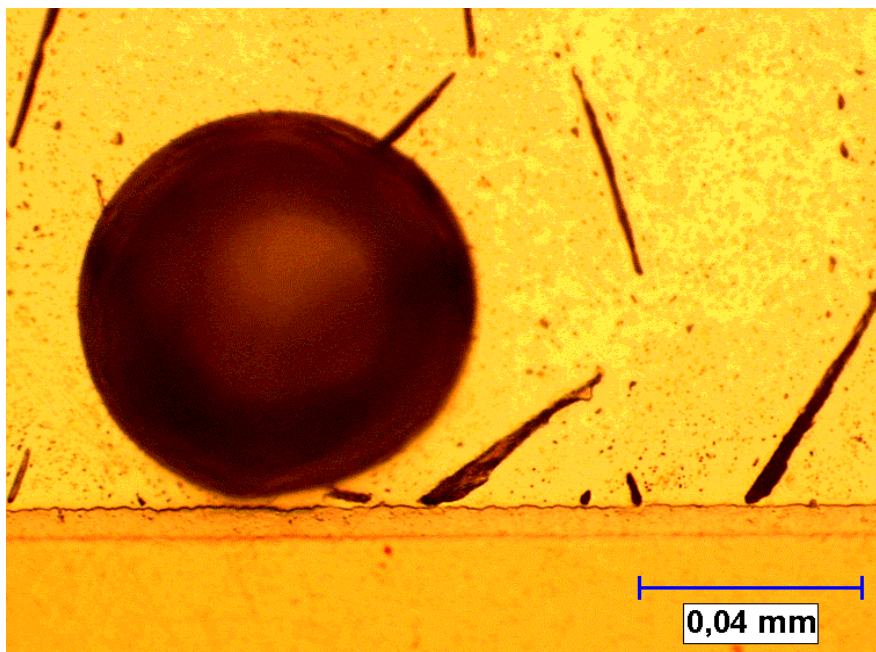


SnZn13.5/Cu couple
230°C; 5 min
E: mag. 200×
PL

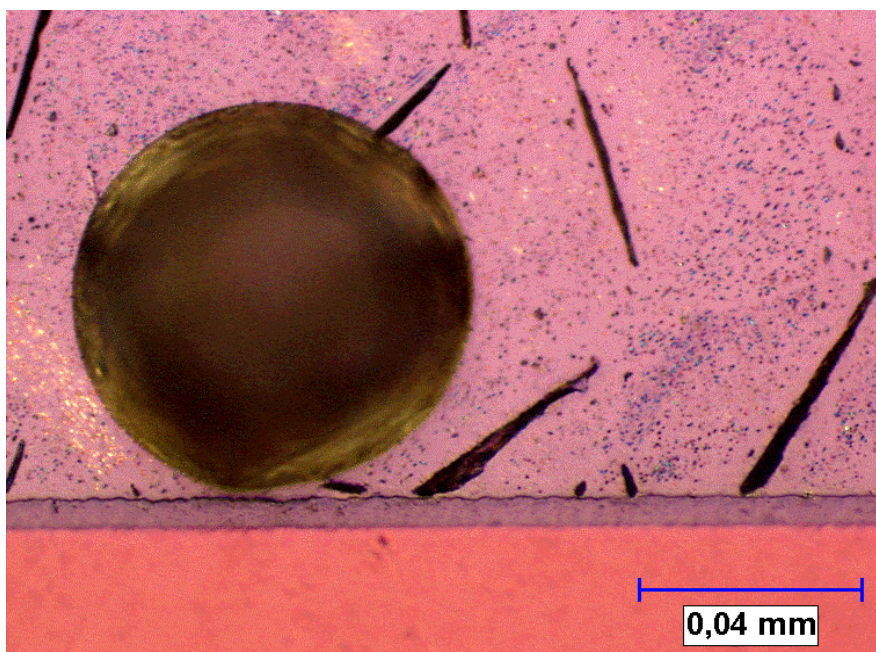


SnZn13.5/Cu couple
230°C; 5 min
E: mag. 200×
PC

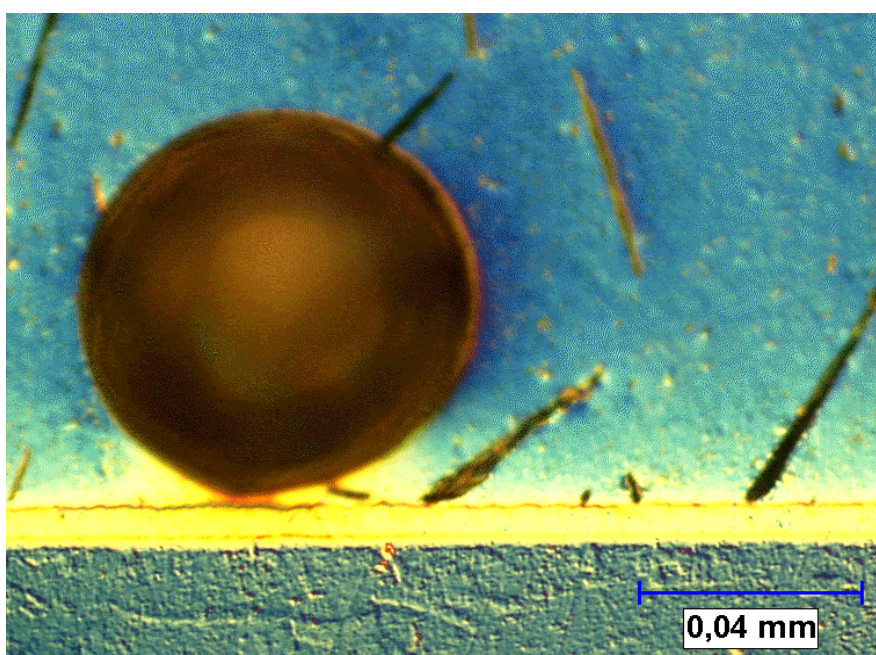




SnZn13.5/Cu couple
230°C; 5 min
E: mag. 500×
CL



SnZn13.5/Cu couple
230°C; 5 min
E: mag. 500×
PL



SnZn13.5/Cu couple
230°C; 5 min
E: mag. 500×
PC

