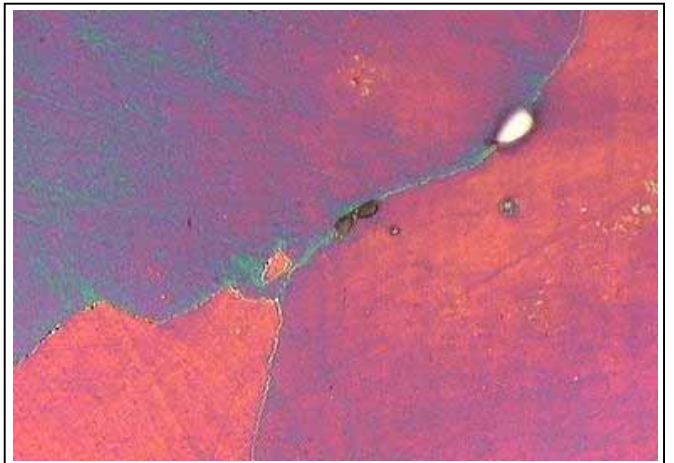
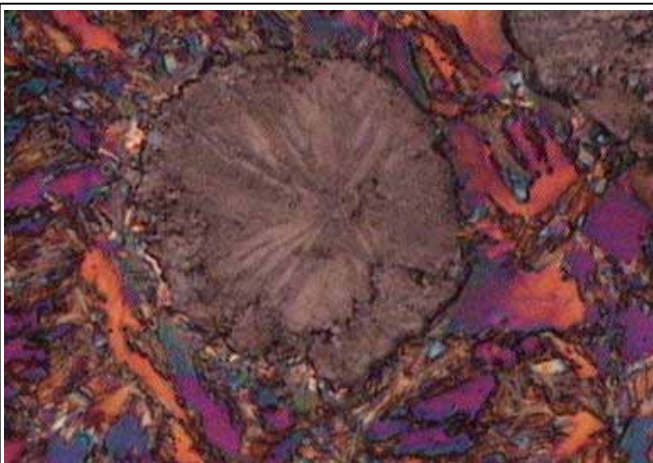
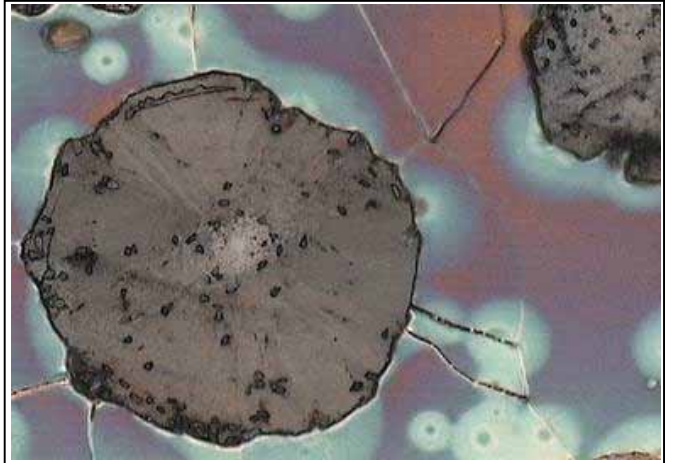
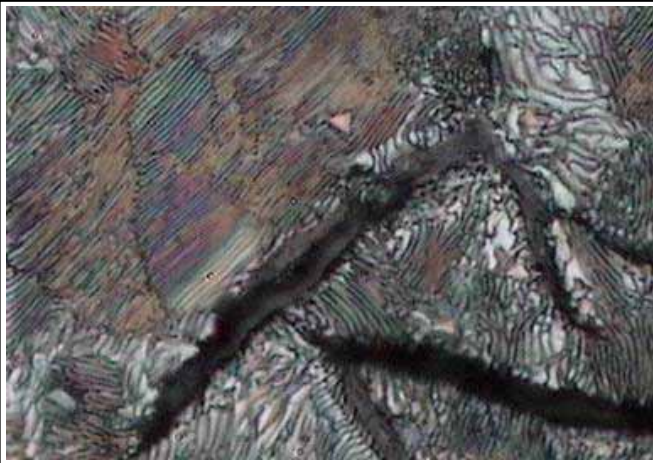
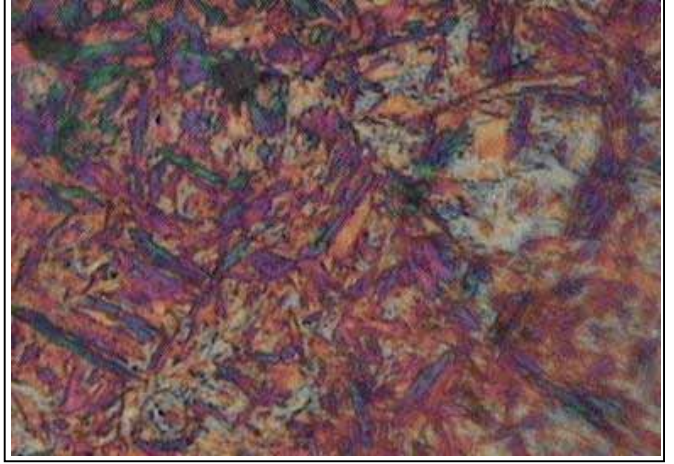
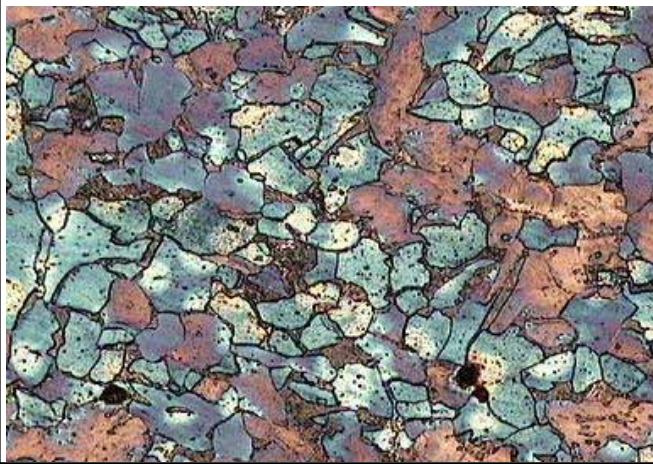


**Metal specimen set
for
Metallurgical Study**



TIS MOTION & CONTROL PTE LTE

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Preface

The microstructures can tell the properties, quality, and the characteristics of metals. Metals with different compositions and different heat treatment condition will be different in microstructures. These set of specimens contains various kinds of ferrous metal in various conditions. These specimens can be used as the reference in studying of Metallurgy, Foundry, Heat Treatment, and Manufacturing Processes, etc.

There are 30 pieces of specimen in this set. Each specimen is prepared, etched, and coated with transparency coating material to protect the specimen surface and to be able to be seen under microscope. without any cleaning process. The specimens were kept in three wooden boxes, 10 pieces each. The data and specimen descriptions and micro-photographs are prepared and combined as a book and supplied together with the specimens.

TIS MOTION & CONTROL PTE LTD

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1. General Background and Introduction

1.1 General Engineering Materials:

Engineering materials can be classified into two classes, **Metal** and **Non-metal**.

A **Metal**: an element that has several metallic properties as the followings:

1. Shiny appearance.
2. Give sonorous tone when struck.
3. Good conduction of heat and electricity.
4. High malleability(can be rolled or pressed into shape).
5. High ductility(can be drawn into wire).
6. With possible emission of electrons when heated(thermionic effect) or when the surface is struck by light(photoelectric effect).
7. Hard and heavy.
8. Not transparent.

All metals have some of these properties. Some metals have every one of these properties. There are about 70 elements are classified as metals: e.g. Fe, Cr, Ni, Mg, Al, Cu etc.

A **Non-metal**: an element with certain physical and chemical properties opposite to those of metals. Non-metals accept electron to form negatively charged ions.

There are about 20 elements are classified as metals: e.g. S, P, C, Si and F etc.

The **metals** can be divided into two classes: **Non-ferrous metals** and **Ferrous metals** which are also divided into many sub-classes as shown in Fig.1.

The **Non-metals** are **Polymers** and **Ceramic** are out of the scope of this book.

All specimens mentioned in this book are Ferrous metals and picked up from **Carbon steels**, **Low alloy steels**, **Cast irons**, **Tool steels**, and **Cast steels**.

1.2. Steel Making

Carbon steels, Low alloy steels, and Tool steels are made as shown in Fig.2. Cast irons and Cast steels are made as shown in Fig.3.

1.3. Specimen Selection

The specimen were cut from the specified round bars and flat bars of Carbon steels, Low alloy steels, and Tool steels and heat treated according to the specified processes.

The specimen of Cast iron(gray cast iron, nodular iron, and Bainitic Ductile Iron)were casted by using induction furnace and sand mold, then heat treated according to the specified processes.

Specimen No.29,30 are special alloy cast steel, also were casted in the induction furnace with high percentage of Mn addition and good quality control. No.29 is in as cast condition and No.30 is after annealing.

1.4. Specimen preparation

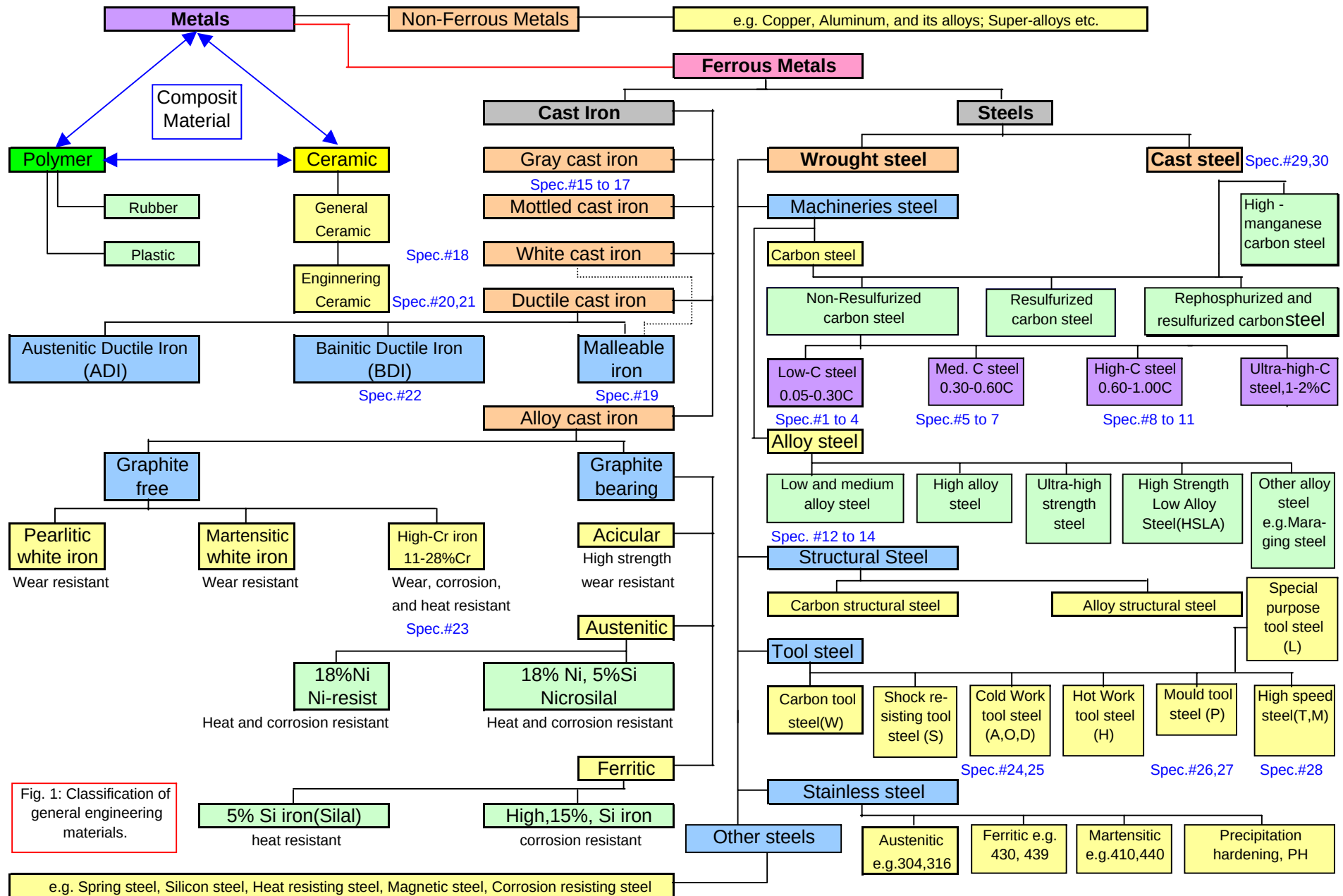
Every specimen was prepared according to the processes shown in Fig.4.

1.5. Heat treatment processes

General heat treatment processes are shown in Fig.5 and the heat treatment processes applied for each specimens is shown in each data sheet for each specimen.

General Engineering Materials

2



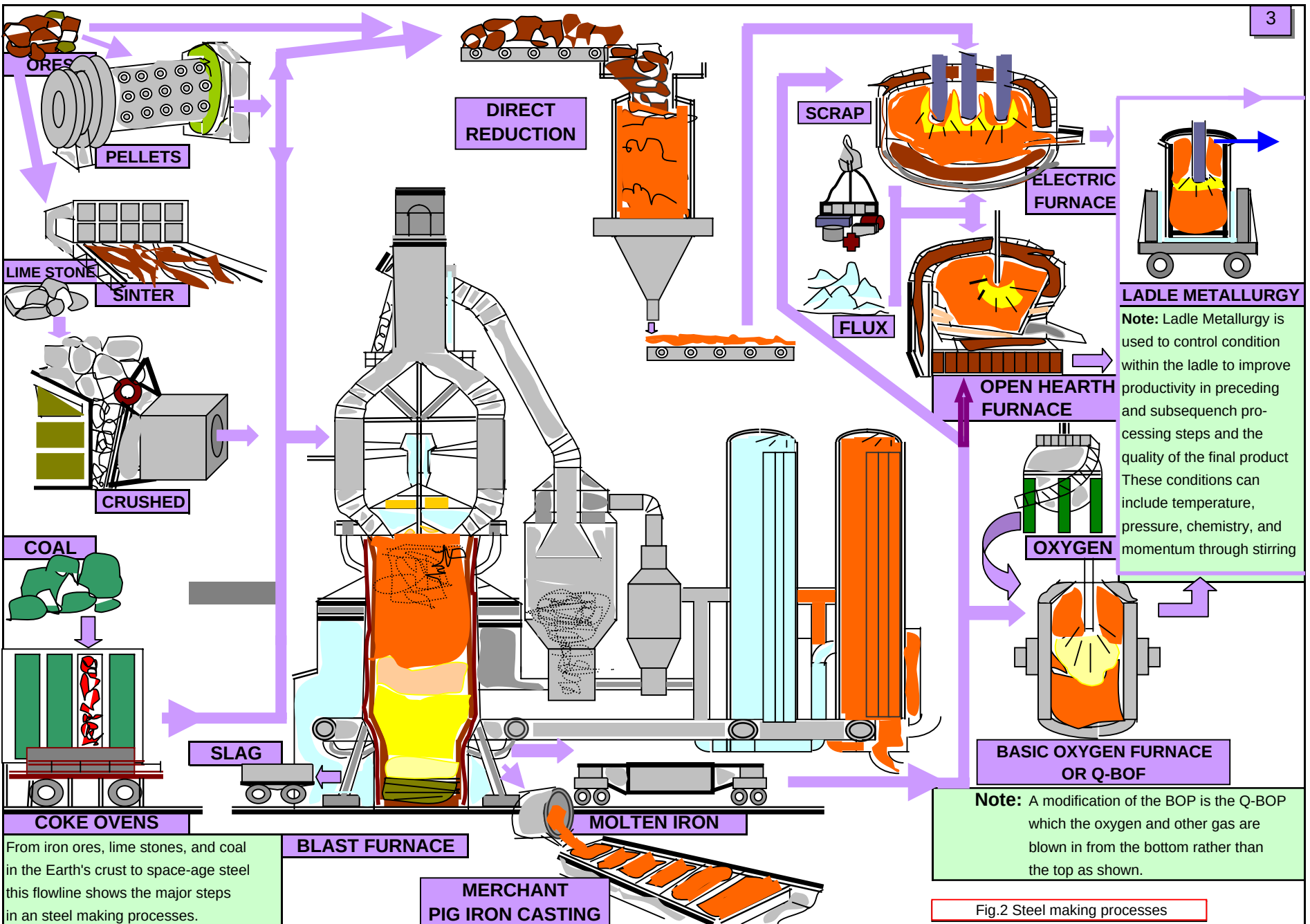


Fig.2 Steel making processes

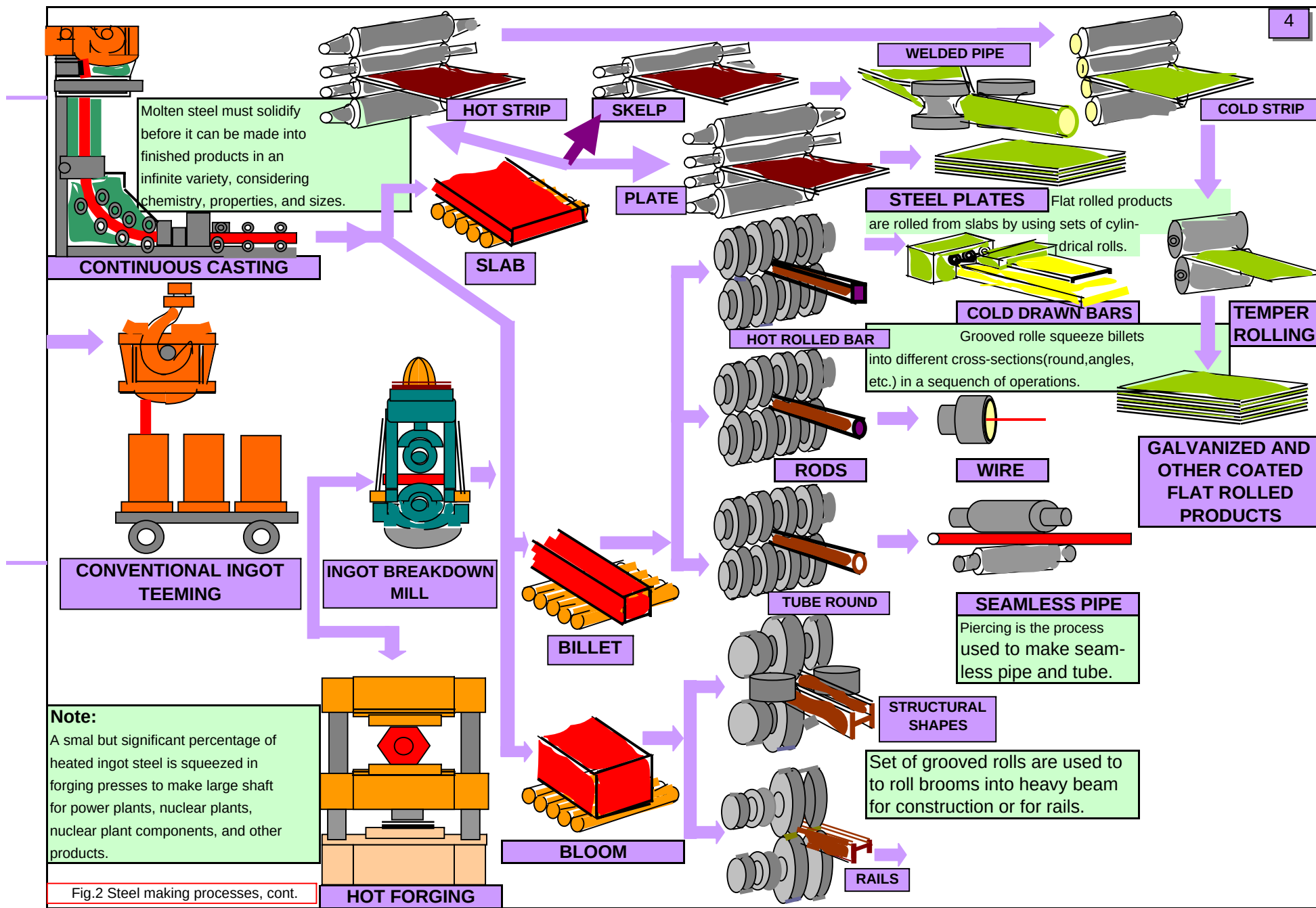
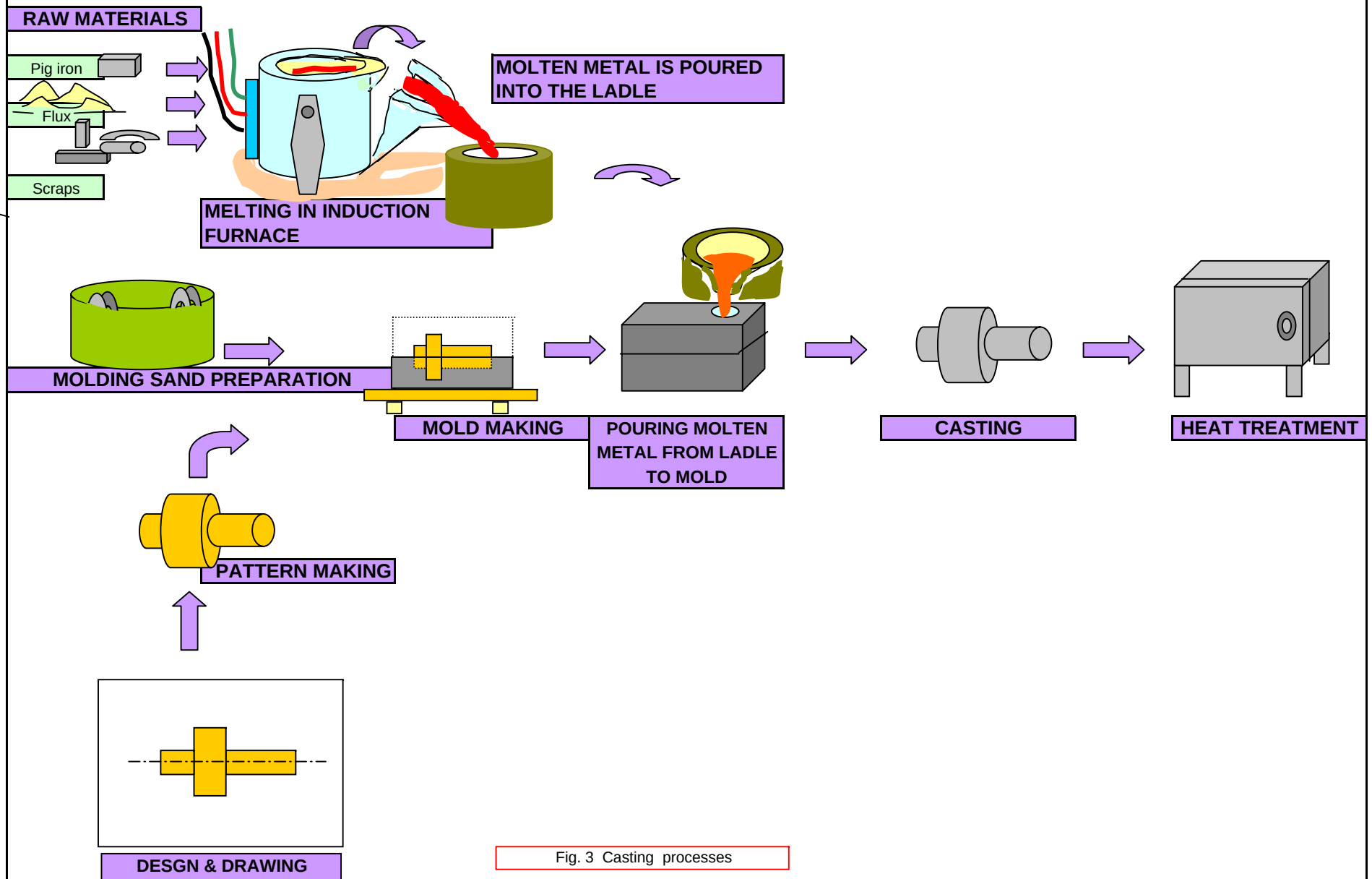


Fig.2 Steel making processes, cont.



Specimen preparation

6

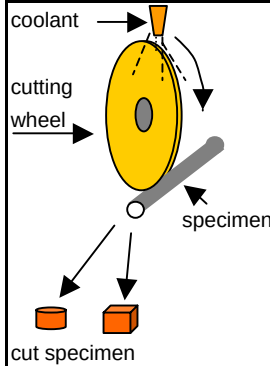
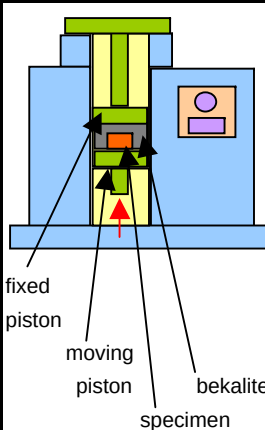
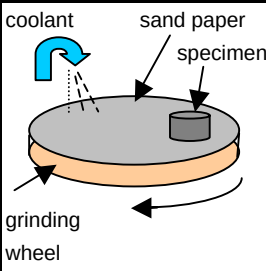
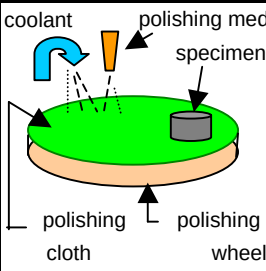
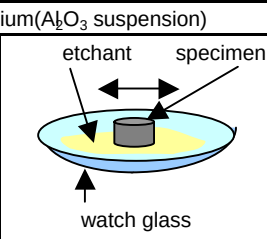
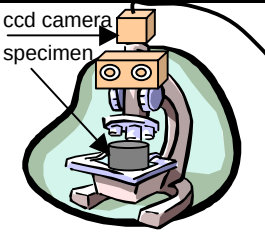
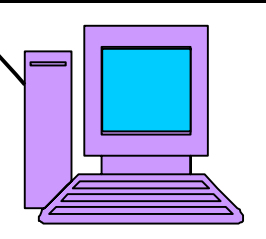
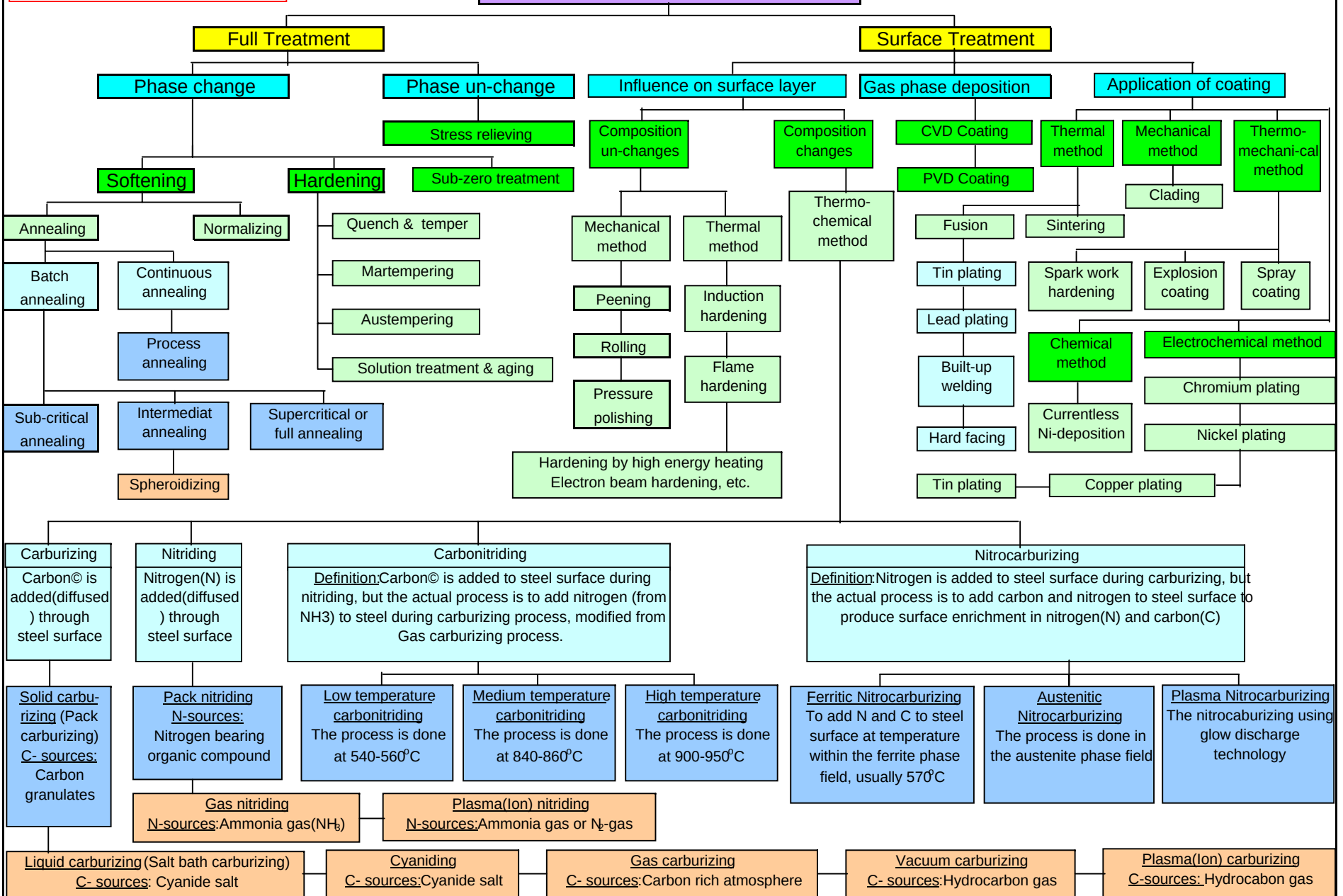
1.Cutting	2.Mounting	3.Grinding	4.Polishing	5.Etching	6.Examination	7.Micro-photography
 coolant cutting wheel specimen cut specimen	 fixed piston moving piston specimen bekalite	 coolant sand paper specimen grinding wheel	 coolant polishing medium (Al_2O_3 suspension) specimen polishing cloth polishing wheel	 etchant specimen watch glass (Keep the specimen moving during etching)	 ccd camera specimen metallurgical microscope	 computer set and printer
1.Equipment:	1.Equipment:	1.Equipment:	1.Equipment:	1.Equipment:	1.Equipment:	1.Equipment:
Lab cut-off machine	Hot mounting machine	Grinding machine	Polishing machine	Watch glass	Metallurgical microscope, CCD camera, and specimen leveller.	Computer, printer.
2.Cut-off wheel:	2.Resin type:	2.Grinding medium:	2.Polishing medium:	2. Quenchant:	2.The magnification:	
Resin bonded, both soft type(for hard specimen) and hard type(for soft specimen)	Phenolic resin(Bekelite) or Acrylic resin(transpa-lent type)	Water proof sand paper grit No.240,400,800,1200, and 2400	Polishing cloth and water suspended Alumina powder, 0.3 micron	2.1 Reagent 7a. 2.2 Nital 3 %	50x,100x, 200x, 500x. and 1000x.	
3.Coolant:	3.Temperature:	3.Coolant:	3.Coolant:	3.Etching time:		
Water mixed with cooling medium and anti-bacteria solution.	170-180°C	Water	Water	15-30 seconds		
Note:	4.Time:	Note:	Note:	4.Cleaning:		
The specimen must be well selected and may be round square or other irregular shape. The cutting must be carried out carefully and enough coolant to prevent overheating during cutting.	8-12 min.	The grinding must start from the coarse sand paper and change to finer sand paper. Before changing to the finer sand paper, the grinding line from the previous sand paper must be disappeared and the new grinding lines must be in the same direction. And before starting the new sand paper, the specimen and hands must be clean.	Before polishing, the specimen and hands must be clean. During the polishing, the specimen must be kept clockwise, and counter-clockwise to prevent comet tail. The water must be used together with the polishing powder. After polishing, the specimen must be rinsed with water and alcohol and dry with hot air.	After etching, the specimen must be rinsed with flowing water and washed with alcohol and immediately blown with hot air. Note: 1. Nital 3%: Nitric acid(HNO_3): 3 cc Alcohol: 97 cc 2. Reagent 7a: 3 g potassium metabi-sulfite 1 g sulfamic acid 100 ml. Distilled water (Reagent 7a is for color etch)		
	5.Coolant:					
	Water					
	Note:					
	The mounted specimen must be marked carefully to avoid confusing.					

Fig. 4 Specimen preparation

Fig. 5 Heat treatment processes

HEAT TREATMENT PROCESSES



Record of Microstructures						Specimen No.: 1	Specimen name		Material			Condition	
							Ferrous Metal		Low Carbon Steel			Annealed	
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	0.18-0.23	0.15-0.35	0.30-0.60	0.04 max	0.04max	-	-	-	-	-	-	-	-
Similar steels	USA		GERMANY		FRANCE	RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK	
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	GOST1050	GB 699	SS14	JIS	UNI5598	AS1442	BS	
	1020	A29:1020	1.0402	-	CC20	20	20	1450	S20C	3CD20	CS1020	BS970:040A20	

Characteristics: Most widely used of several grades containing about 0.20% carbon. Available in a variety of product forms. Excellent formability and weldability.

No preheating and post heating required before or after welding. Machinability is notably poor. Wildy used as a carburizing steel.

Applications: Parts for case hardened condition where core strength is not critical, and shaft for large section that are not highly stressed, case hardened gears pins and chain.

Heat treatment guide	Descriptions	Processes	Normalizing	Through hardening	Carburizing	Tempering	Carbonitriding	Tempering	Nitriding
	Temperature, °C		925	Because of low carbon and no alloying element Through hardening is not advisable.	870-955	200-250	850-870	200-250	Nitriding is not recommended.
	Soaking time, min.		1/2hr./25 mm.+1 hr.		depend on case depth.	2 hrs min.	depend on case depth.	2 hrs min.	
	Quenching medium		air or nitrogen		oil	air	oil	air	
	Hardness		120-130 HB		60-62 HRC	55-60 HRC	60-62 HRC	55-60 HRC	

Final heat treatment process of this specimen	°C 870 60 500 30 min. preheat furnace cool min.	Process: The specimen is heated to 880°C for 60 min., the steel microstructures will transform to austenite, then cooldown slowly in the furnace austenite will transform to ferrite and pearlite. The steel will be softened, better machinability, better cold workability, and improve dimensional stability, etc.
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Microstructures

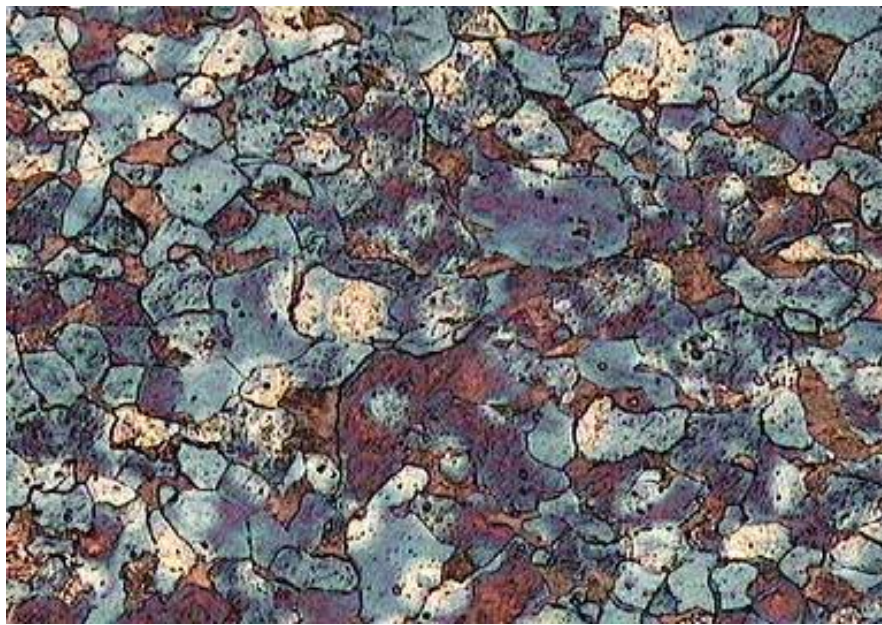


Photo.1: 200x, Microstructures consist of Ferrite(yellow, blue, and purple), and Pearlite (brown), small black dots are inclusions remain in steel.

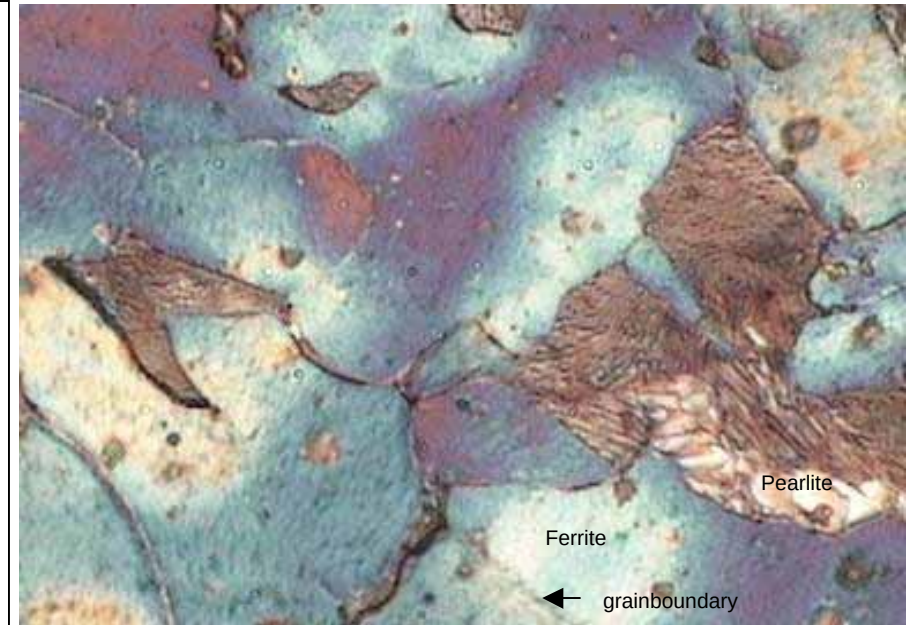


Photo.2. 1000x, same as in Photo. 1 but higher magnification. Brown area can be clearly seen Cementite and Ferrite in Pearlite. Grain boundaries are also clearly seen.

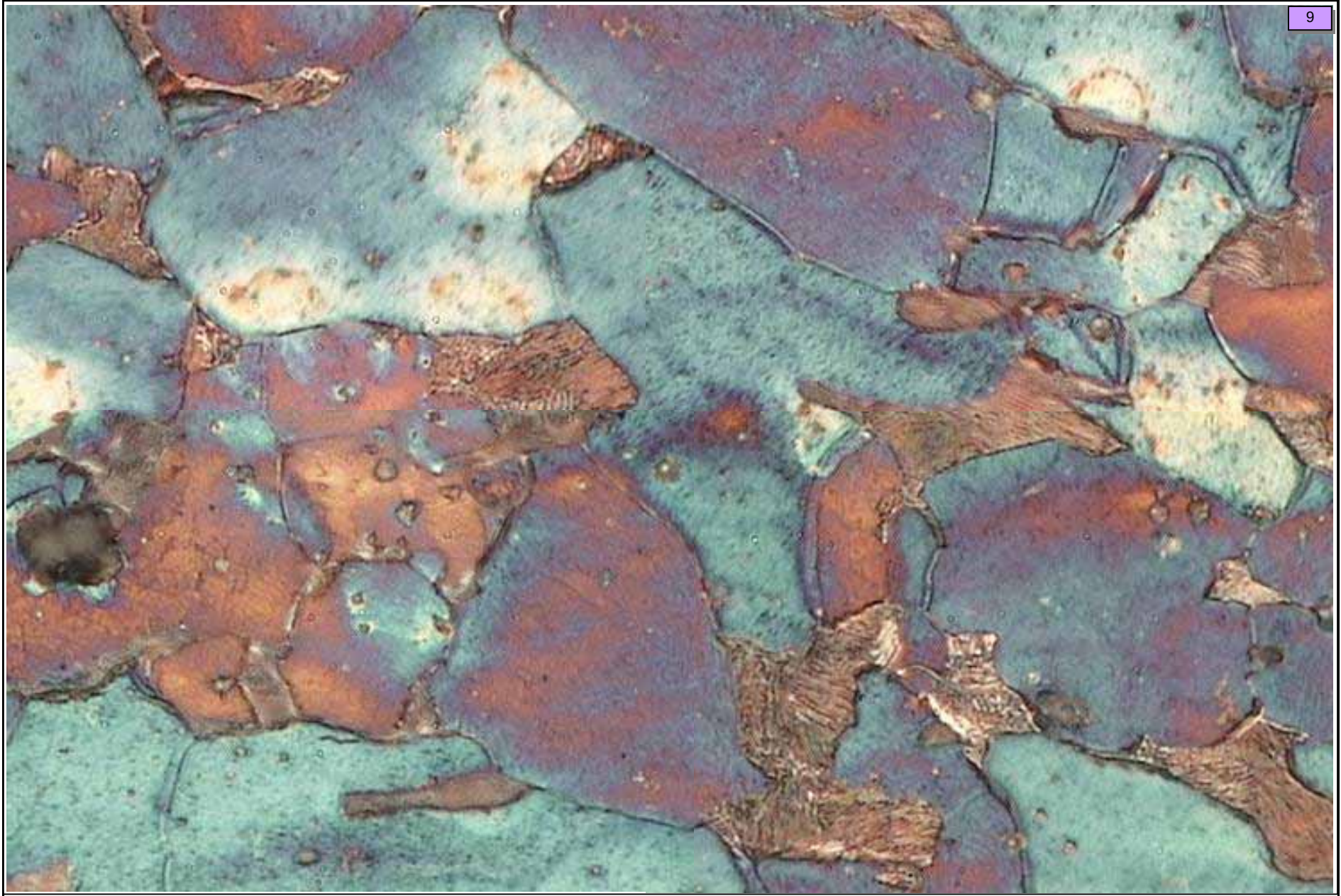


Photo.3: 1000x, Same as in Photo.1,2 but in large area. The microstructures consist of Ferrite(blue, green, purple, yellow) and Pearlite(brown area with Cementite strips on Ferrite).

Record of Microstructures						Specimen No.: 2	Specimen name		Material			Condition	
							Ferrous Metal		Low Carbon Steel			Carburized	
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	0.18-0.23	0.15-0.35	0.30-0.60	0.04 max	0.04max	-	-	-	-	-	-	-	-
Similar steels	USA		GERMANY		FRANCE	RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK	
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	GOST1050	GB 699	SS14	JIS	UNI5598	AS1442	BS	
	1020	A29:1020	1.0402	-	CC20	20	20	1450	S20C	3CD20	CS1020	BS970:040A20	
Characteristics: Most widely used of several grade s containing about 0,20%carbon. Available in a variety of product forms. Excellent forgability and weldability. No preheating and post heating required before or after welding. Machinability is notably poor. Wildy used as a carburizing steel.													
Applications: Parts for case hardened condition where core strength is not critical, and shaft for large section that are not highly stressed, case hardened gears pins and chain.													
Heat treatment guide	Descriptions	Processes	Normalizing		Through hardening		Carburizing		Tempering	Carbonitriding		Tempering	Nitriding
	Temperature, °C		925		Because of low carbon		870-955		200-250	850-870		200-250	Nitriding is not recommended.
	Soaking time, min.		1/2hr./25 mm.+1 hr.		and no alloying element		depend on case depth.		2 hrs min.	depend on case depth.		2 hrs min.	
	Quenching medium		air or nitrogen		Through hardening is not		oil		air	oil		air	
	Hardness		120-130 HB		advisable.		60-62 HRC		55-60 HRC	60-62 HRC		55-60 HRC	
Final heat treatment process of this specimen						Process: The specimen is heated to 920°C for 180 min. in atmosphere controlled furnace with carbon potential 0.9%. Carbon atom will diffuse into the specimen surface and combine with Fe to form Fe ₃ C or cementite in surface area, so pearlite increases in the surface area.							
Microstructures													
Photo.4: 100x, The photo was taken from surface to core of the specimen. At the surface, the microstructure become Pearlite because of increasing carbon.							Photo.5: 1000x, At the carburized surface of the specimen, the original structure are Ferrite and Pearlite, now no more free Ferrite because of carburization.						

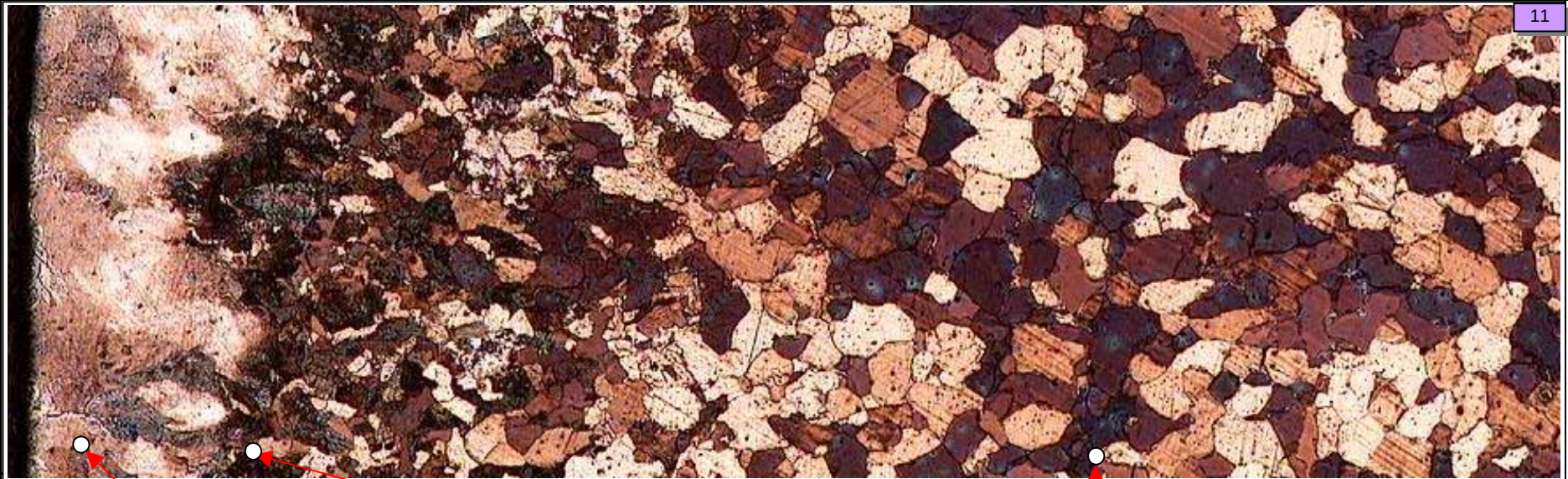


Photo. 6



Photo. 7



Photo. 8



Photo. 9

The original microstructures of the steel are Ferrite and Pearlite. After carburization, carbon diffused through the surface to the core. The structure at the surface becomes Pearlite which consists of Cementite, Fe_3C , and Ferrite (see Photo.7). Below the surface, the structures consist of Pearlite and Ferrite (see Photo.8) and at the core, the structures are unchanged, it still be Pearlite and Ferrite as in the original condition (see Photo.9).

Record of Microstructures						Specimen No.: 3	Specimen name		Material		Condition			12
							Ferrous Metal		Low carbon steel		Carburized, quenched and tempered			
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others	
	0.18-0.23	0.15-0.35	0.30-0.60	0.04 max	0.04max	-	-	-	-	-	-	-	-	
Similar steels	USA		GERMANY		FRANCE	RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK		
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	GOST1050	GB 699	SS14	JIS	UNI5598	AS1442	BS		
	1020	A29:1020	1.0402	-	CC20	20	20	1450	S20C	3CD20	CS1020	BS970:040A20		

Characteristics: Most widely used of several grades containing about 0.20% carbon. Available in a variety of product forms. Excellent formability and weldability.

No preheating and post heating required before or after welding. Machinability is notably poor. Wildy used as a carburizing steel.

Applications: Parts for case hardened condition where core strength is not critical, and shaft for large section that are not highly stressed, case hardened gears pins and chain.

Heat treatment guide	Descriptions	Processes	Normalizing	Through hardening	Carburizing	Tempering	Carbonitriding	Tempering	Nitriding
	Temperature, °C		925	Because of low carbon and no alloying element Through hardening is not advisable.	870-955	200-250	850-870	200-250	Nitriding is not recommended.
	Soaking time, min.		1/2hr./25 mm.+1 hr.		depend on case depth.	2 hrs min.	depend on case depth.	2 hrs min.	
	Quenching medium		air or nitrogen		oil	air	oil	air	
	Hardness		120-130 HB		60-62 HRC	55-60 HRC	60-62 HRC	55-60 HRC	

Final heat treatment process of this specimen		Process: The specimen is heated to 920°C for 180 min. in atmosphere controlled furnace with carbon potential 0.9%. C atom diffused into specimen surface and combined with Fe to form Fe₃C (Cementite) which gives more pearlite and less ferrite. After hardened and tempered, pearlite and ferrite transformed to austenite and then martensite accordingly. Tempered martensite + P + F will be achieved finally.
	Microstructures	

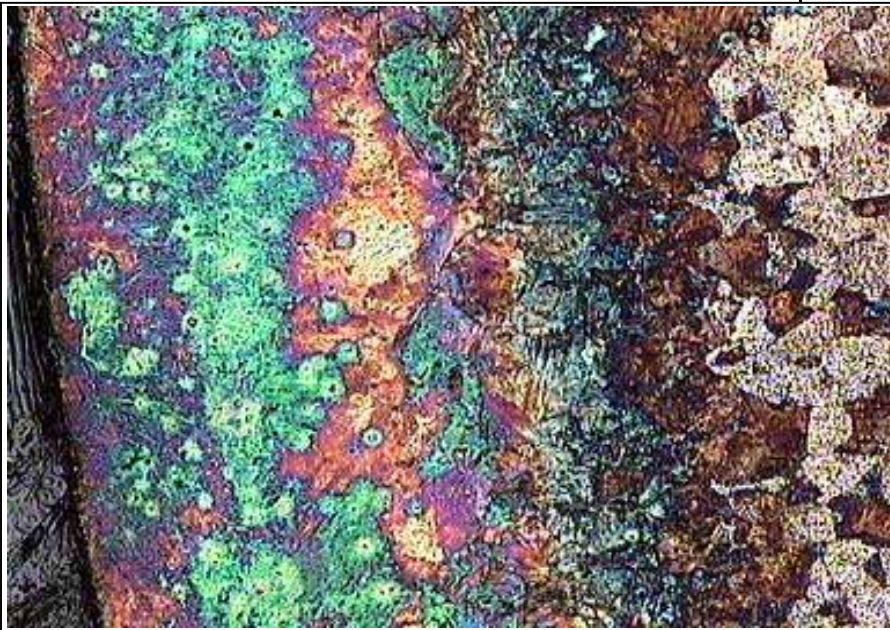


Photo.10: 50x, The specimen was carburized, quench, and tempered. Pearlite at the surface and below surface transformed to Martensite(left, colorfull area)

Photo.11: 1000x, At the case area, the acicular or needle like structure(Martensite) will be seen(purple, green, and brown).



Photo.12,50x

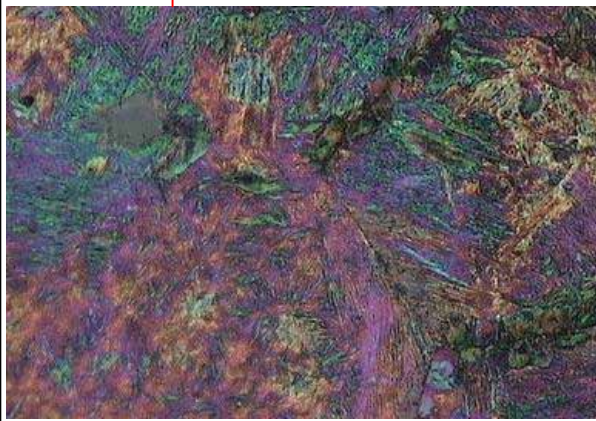


Photo.13 1000x



Photo.14 1000x



Photo.15 1000x

Photo.12 shows the microstructures from the surface of low carbon steel to the core after carburized, quenched, and tempered. The case with green, purple, and yellow is Martensite(see Photo.13). Between case and core are Martensite and Ferrite(see Photo.14). At the core, the microstructures remain the same as the original, Pearlite and Ferrite, some Pearlite may transfer to Martensite, but Ferrite still unchanged(see Photo.15).

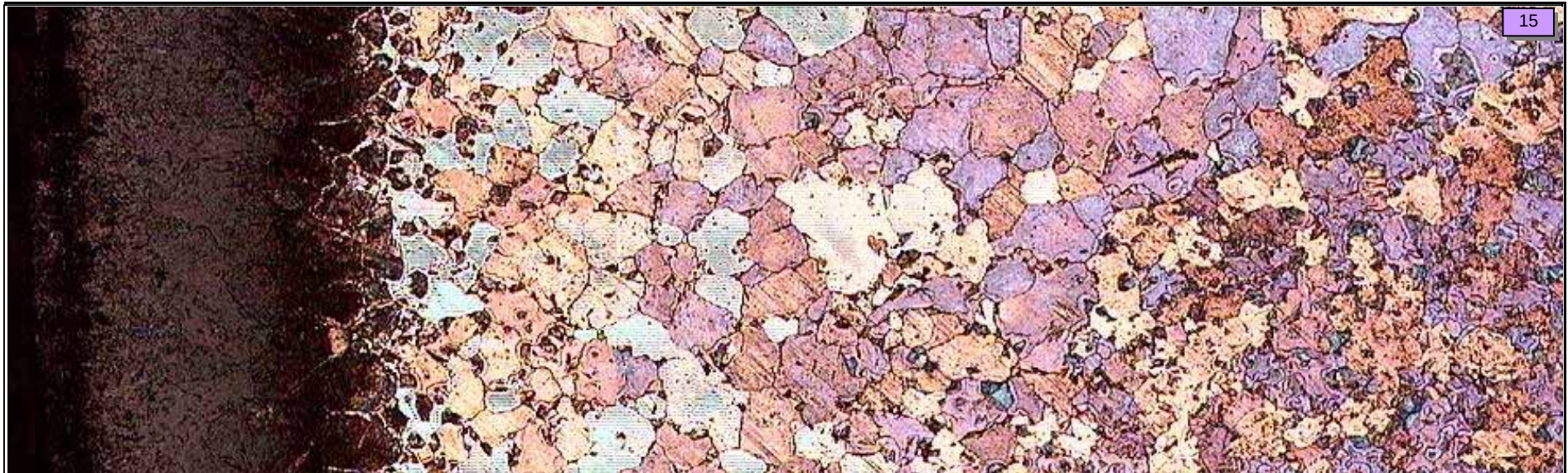
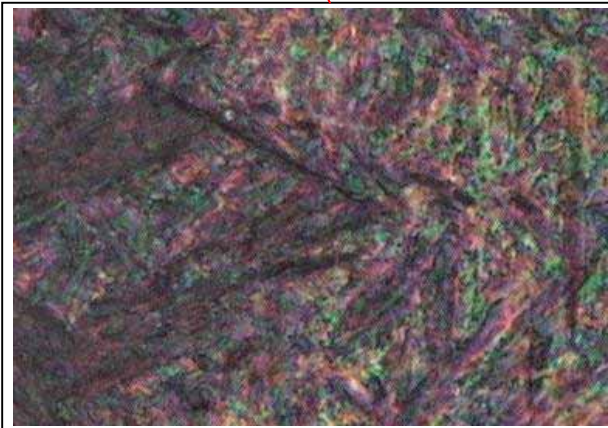


Photo.18:50x



:Photo.19:500x

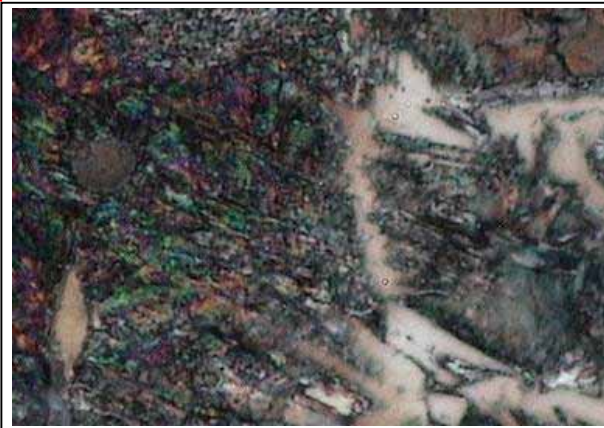


Photo.20:500x

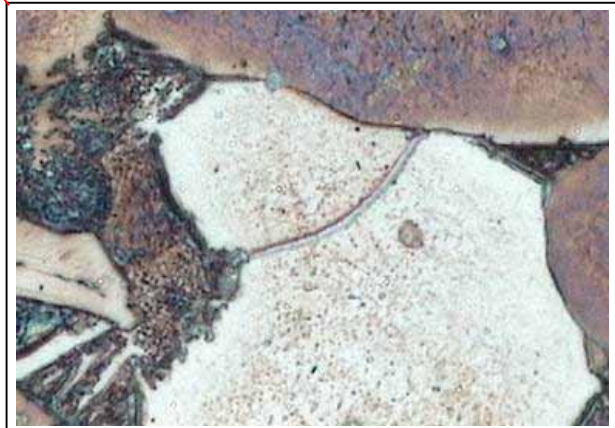


Photo.21:500x

Photo.18 shows the microstructures from the surface to the core of low carbon steel after carbonitrided, quenched and tempered. The case consists of Martensite(see Photo.19). Between the case and core, consists of Martensite and Ferrite(see Photo.20). And at the core, the original microstructures, Pearlite and Ferrite still remain(see Photo.21).

A close-up photograph of a textured surface, likely a rock or mineral specimen. The texture is highly irregular and granular, with a complex pattern of brown, tan, and dark green colors. The colors are distributed unevenly, creating a mottled appearance. The surface appears to be composed of small, interlocking grains or crystals. The lighting is somewhat uneven, with brighter areas in the center and darker areas towards the edges. The overall impression is one of a natural, unpolished material.



Photo.24: 500x, Same as in Photo.23, but in the larger area. The microstructures consist of Pearlite and Ferrite.

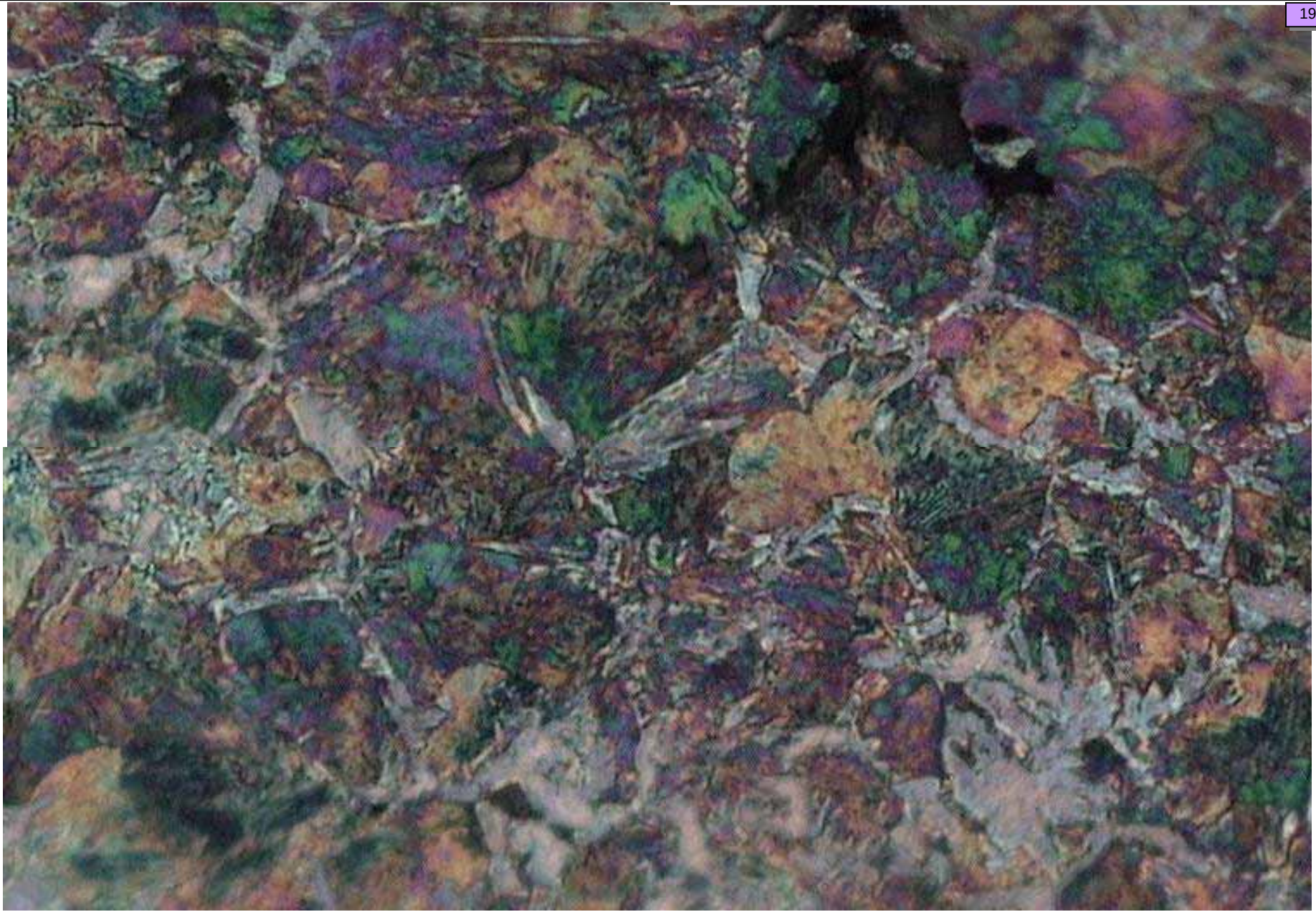


Photo.27: 1000x, Same as in Photo.26, but in larger area. The microstructures consist of Martensite and un-changed Ferrite.

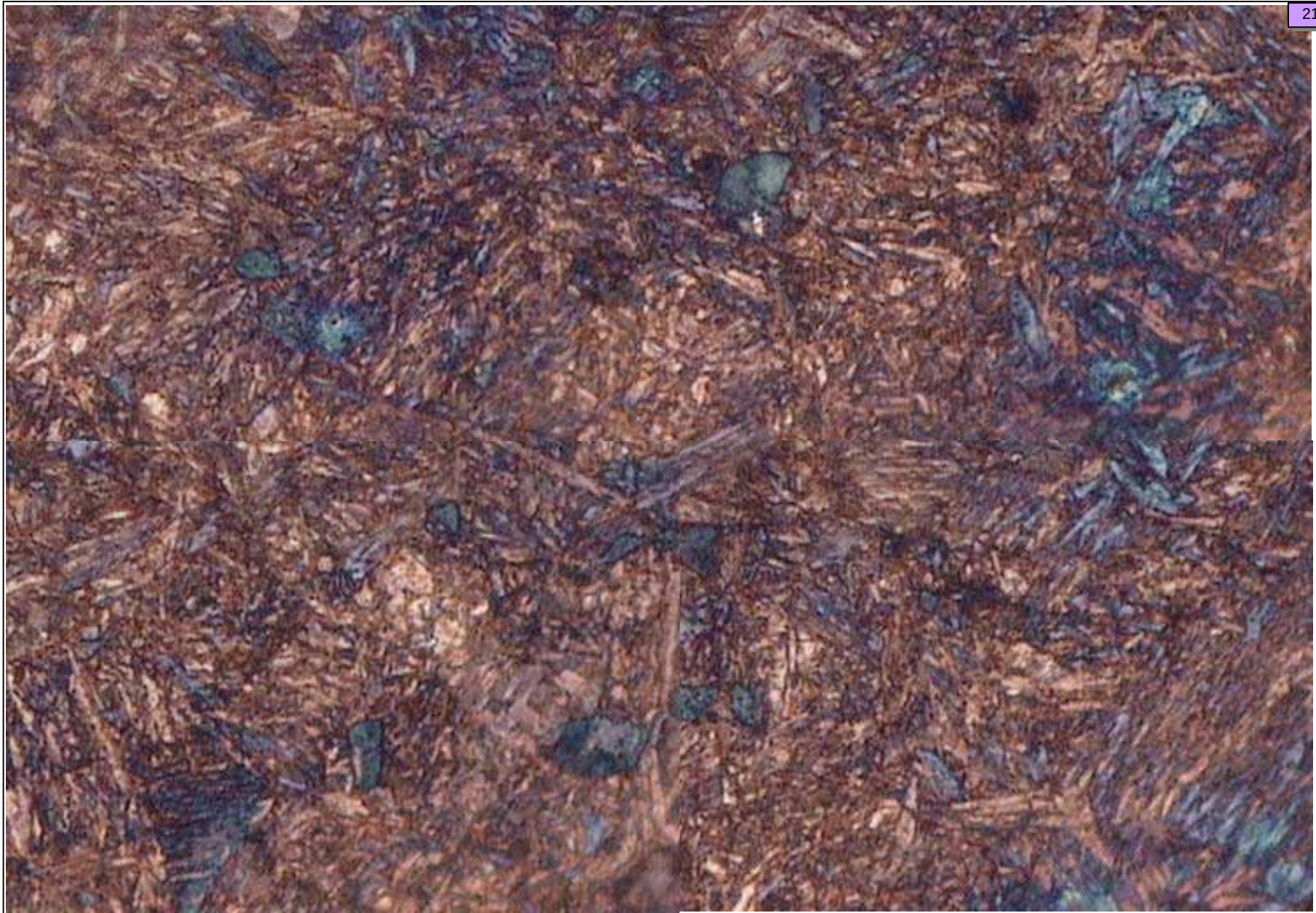


Photo.30: 1000x, Same as in Photo.29, but in larger area. The microstructures consist of tempered martensite.

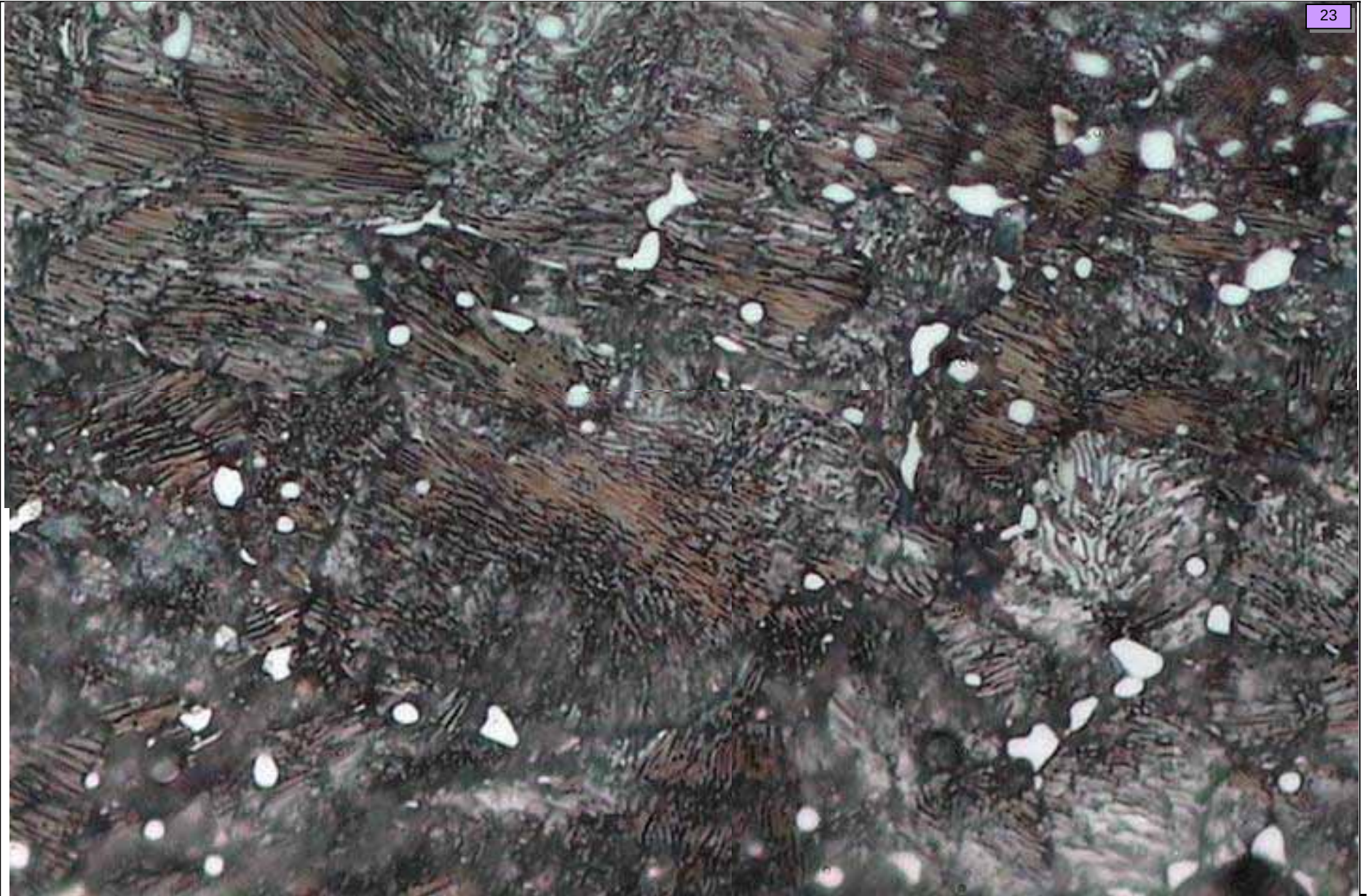


Photo.33:1000x, Same as in Photo.32, but in larger area. Microstructures consist of Pearlite matrix and Carbides particles.

24

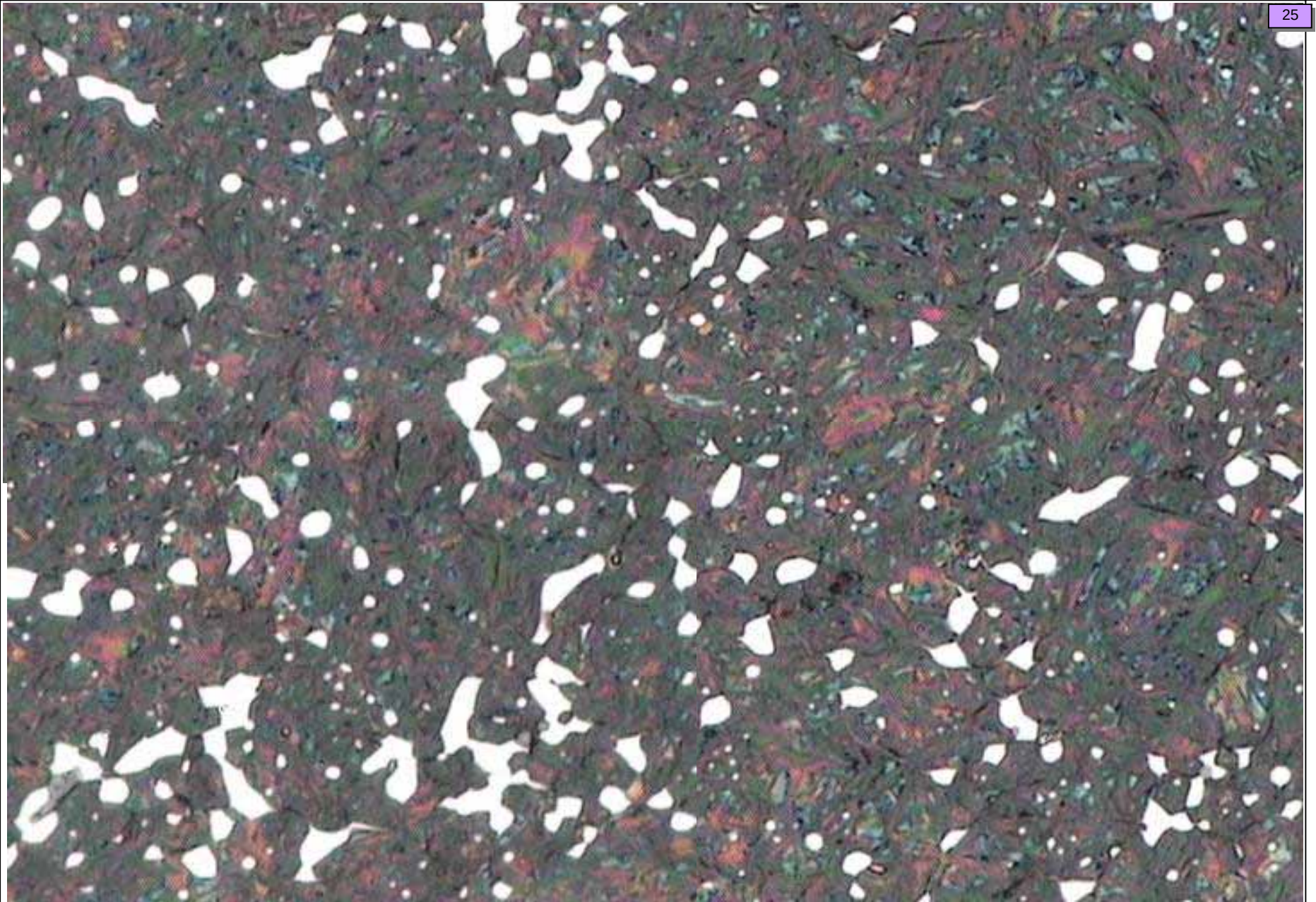


Photo.36: 1000x, Same as in Photo.35, but in larger area. The microstructures consist of Martensite, Carbides and retained Austenite.

Record of Microstructures						Specimen No.: 10	Specimen name		Material		Condition		
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	0.90-1.03	0.15-0.35	0.30-0.50	0.04 max	0.050max	-	-	-	-	-	-	-	-
Similar steels	USA		GERMANY		FRANCE	INDIA	POLAND	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK	
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	IS 1570	PN84028	SS14	JIS G4801	UNI3545	AS1442	BS 1449	
	1095	A510;A586	1.1275	-	CX100	C98	DS105	1870	SUP 4	C100	K1095	95CS	
Characteristics: The higher carbon of 1095 steel provides maximum surface hardness with improved wear resistance and high strength. Ther is, however, a loss of toughness. Because cold forming methods are not suitable for this steel, uses are limited to flat stampings and springs coiled from small diameter wire.													
Applications: Edge tools, wear-resistant parts, mower knives, scraper blades, discs, etc.													
Heat treatment guide	Descriptions	Processes		Normalizing		Annealing		Full hardening		Tempering		Austempering	
	Temperature, °C			855		800		800		370-675		800	
	Soaking time, min.			1/2hr./25 mm.+1 hr.		1/2hr./25 mm.+1 hr.		1/2hr./25 mm.+1 hr.		2 hrs min.		1/2hr./25 mm.+1 hr.	
	Quenching medium			air or nitrogen		furnace cool		oil or water		air		salt bath at 315°C, 2 hrs., air cool	
	Hardness			269-290 HB		269-290 HB		63-66 HRC		27-43 HRC		63-66 HRC	
Final heat treatment process of this specimen						Process: The specimen was heated to 800°C for austenitizing and soaked for 60 minutes, pearlite will transform to austenite, and some cementite may remain. Then quench in water, austenite will transform to martensite, needlelike structure, high stress, hard and brittle. The specimen was reheated to 300°C for 120 minutes, the hardness and brittleness will be decreased and toughness increased.							
		Microstructures											
Photo.37: 100x, The microstructures consist of Martensite, and carbides.						Photo.38: 1000x, Same as in Photo.37, but in higher magnification. The matrix is Martensite. White particles are carbides.							

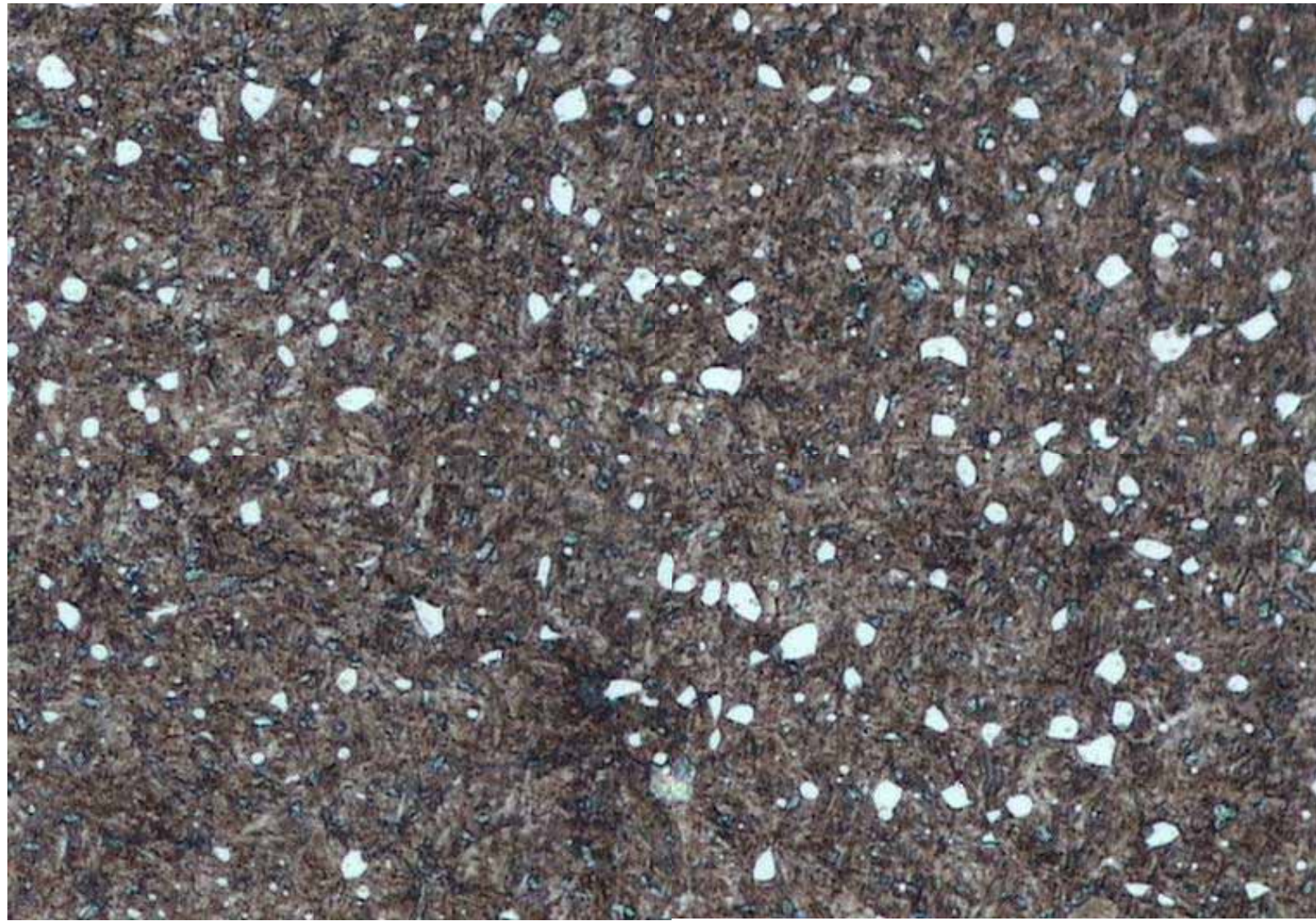


Photo.39: 1000x, Same as in Photo.38, but in larger area. The microstructures consist of Martensite, and carbides.



Photo.42:1000x, The brown area are non-metallic inclusions.
The specimen is un-etched.

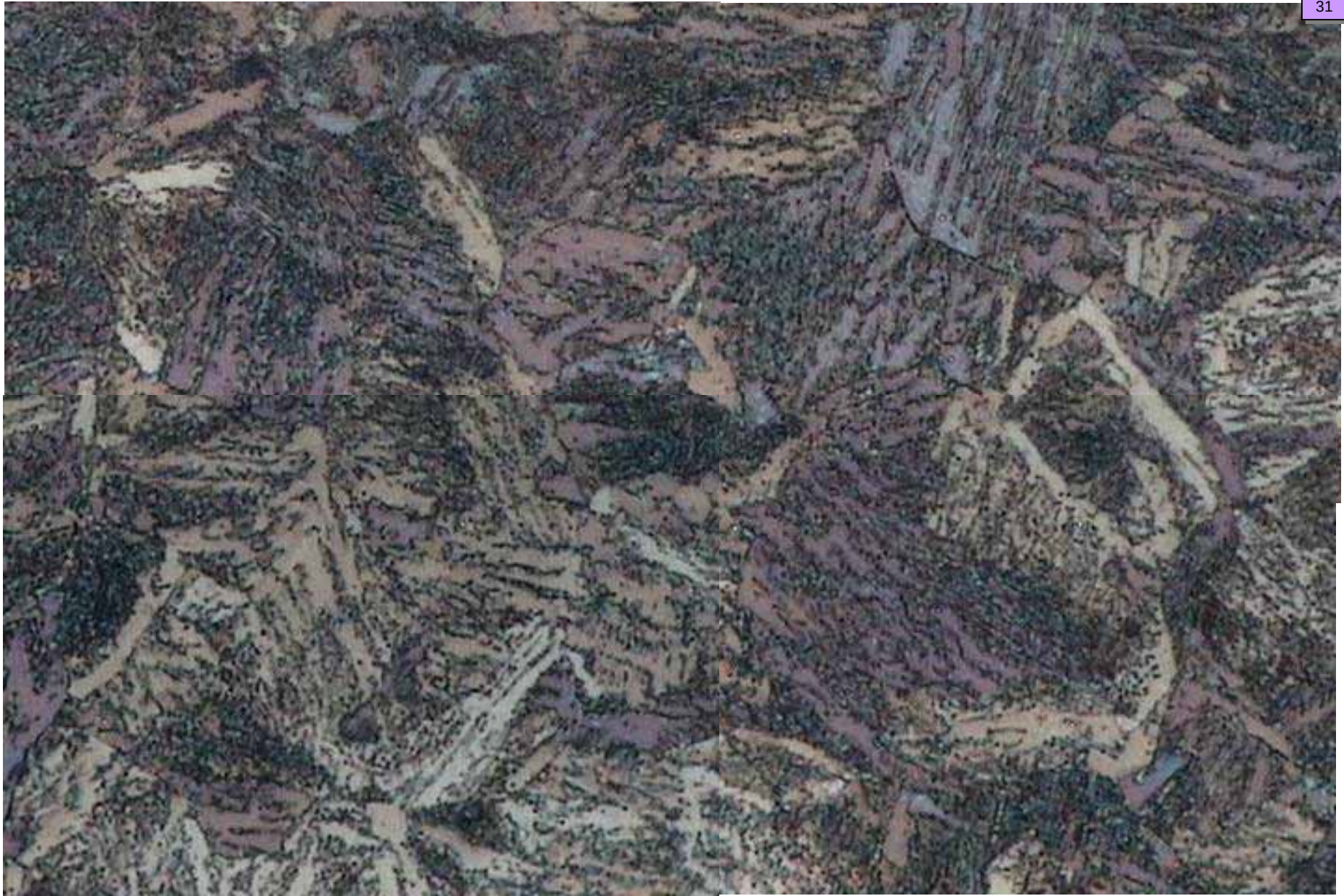


Photo.45:1000x, Same as in Photo.44, but in larger area. Light area are Ferrite, dark area are Pearlite.

Record of Microstructures						Specimen No.: 13	Specimen name	Material		Condition			32
							Ferrous Metal		AISI 4130		Hardened by quenching and tempering		
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	0.28-0.33	0.15-0.30	0.40-0.60	0.035 max	0.040max	0.80-1.10	0.15-0.25	-	-	-	-	-	-
Similar steels	USA		GERMANY		FRANCE	RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK	
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	GOST1050	GB 699	SS14	JIS	UNI5598	AS1442	BS 1449	
	4130	A510;A586	1.1259	-	CX80	80	80	1778-02	S80C	3CD80	K1082	80CS	

Characteristics and applications:	A medium carbon, Chromium-Molybdenum steel. Available as hot rolled and cold finished bar and seamless tube, this steel is for general purpose applications. Variations in heat treatment can obtain a broad range of strength and toughness. This steel has good hardenability, strength, wear resistance, toughness and ductility. In heat treated condition, it offers good strength and toughness for moderately stressed parts. It is available in forging quality, and aircraft quality.
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Heat treatment guide	Descriptions Processes	Normalizing	Annealing	Full hardening	Tempering	Carbonitriding	Tempering	Nitriding
	Temperature, °C	900	855	880	250-650	850-870	200-250	Nitriding is not recommended.
	Soaking time, min.	1/2hr./25 mm.+1 hr.	1/2hr./25 mm.+1 hr.	1/2hr./25 mm.+1 hr.	2 hrs min.	depend on case depth.	2 hrs min.	
	Quenching medium	air or nitrogen	furnace cool	oil or water	air or faster	oil	air	
	Hardness	163-217 HB	217 HB	45-50 HRC	48-22 HRC	60-62 HRC	58-60 HRC	

Final heat treatment process of this specimen		Process: The specimen was heated at 880°C and soak for 120 minutes for austenitizing, the original microstructure will be transformed to austenite, then quench in water, austenite will be transformed to martensite, high stresses, high hardness, then tempered at 250oC for 120 minutes. Martensite will be transformed to tempered martensite with lower hardness and higher toughness.
	Microstructures	

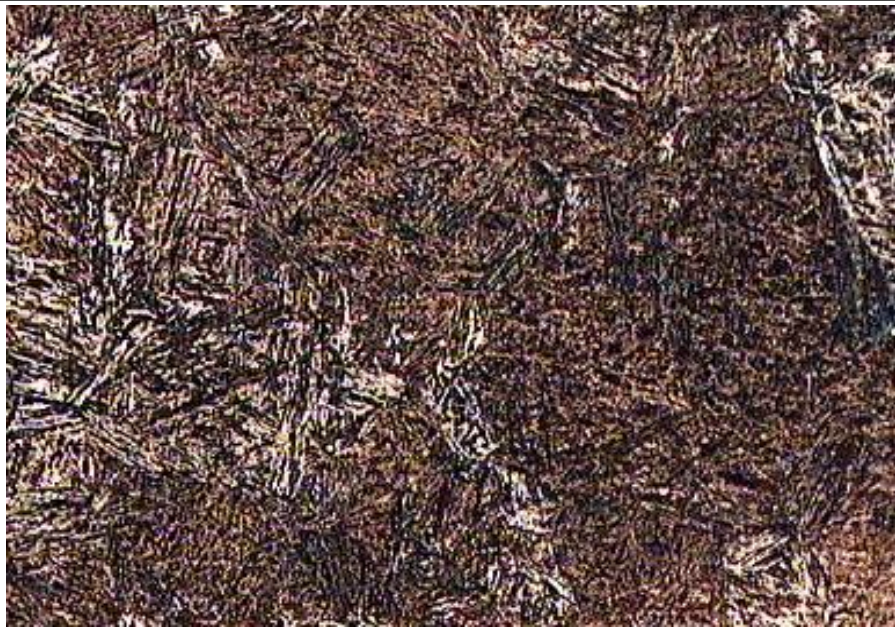


Photo.46:100x, Microstructure after quenching and tempering is Martensite.

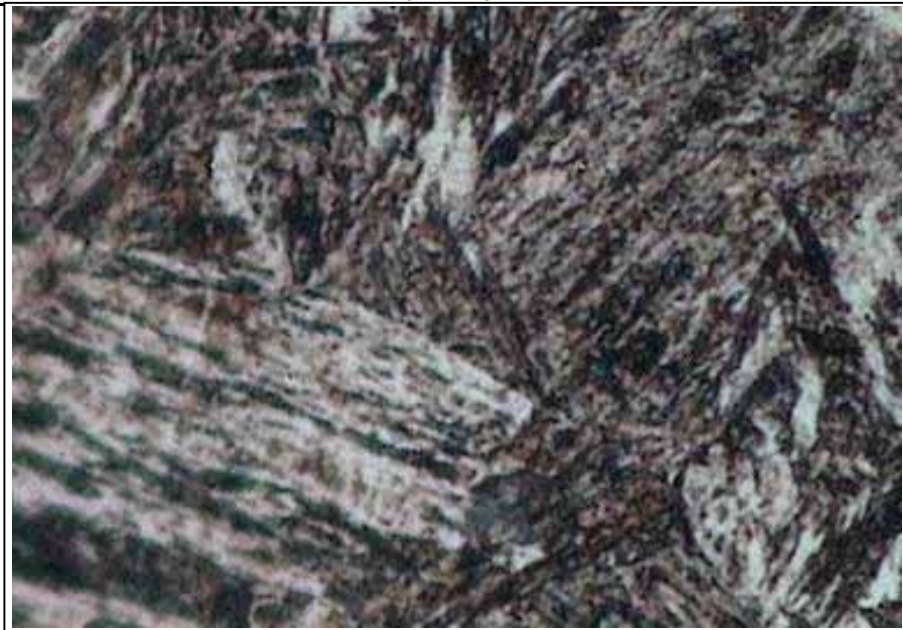


Photo.47:1000x, Same as in Photo.46, but in higher magnification. The structures are Martensite.

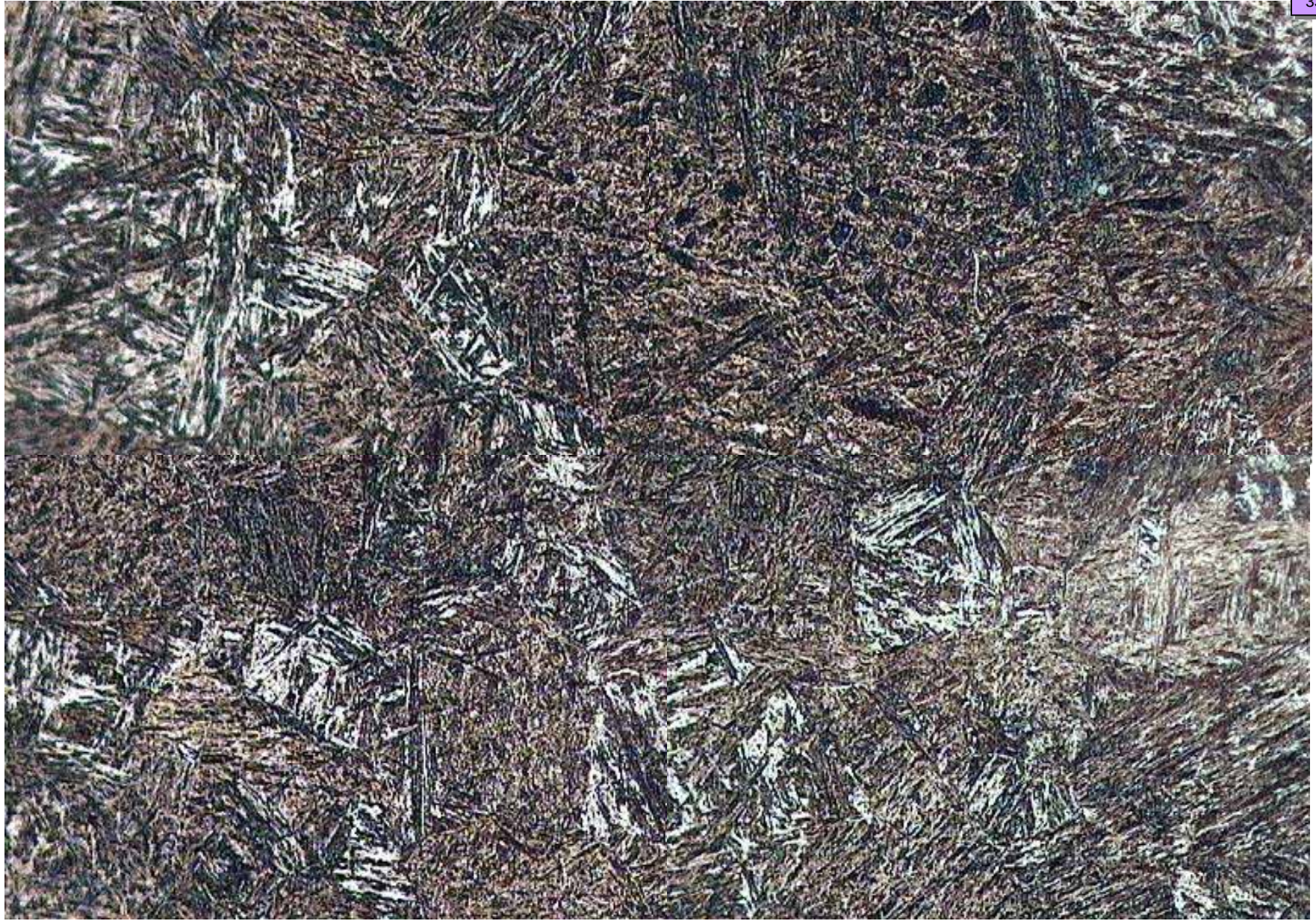


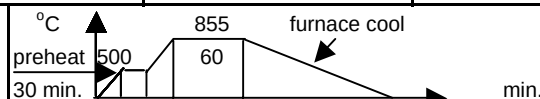
Photo.48:500x, The microstructures are Martensite

Record of Microstructures						Specimen No.: 14	Specimen name	Material		Condition			34
							Ferrous Metal		AISI 4340		Annealed		
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	0.38-0.43	0.15-0.30	0.60-0.80	0.05 max	0.040max	0.70-0.90	0.20-0.30	1.65-2.00	-	-	-	-	-
Similar steels	USA		GERMANY		FRANCE	RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	AUSTRALIA	UK	
	AISI/SAE	ASTM	DIN	KRUPP	AFNOR	GOST1050	GB 699	SS14	JIS	UNI5332	AS1444	BS 4670	
	4340	A29: 4340	1.6582	6582	-	-	-	1778-02	SNCM439	40NiCrMo7	4340	818Mo	

Characteristics and applications:	A high hardenability steel, higher in hardenability than other standard AISI grade. AISI 4340 steel is nickel-chromium-molybdenum alloy steel. It is normally heat treated by quenching in oil and tempering to the desired hardness. It exhibits good response to heat treatment and possesses a good combination of strength, ductility, and toughness in quenched and tempered condition. AISI 4340 is found in aircraft and truck parts and some ordnance materials, and also for gear, shafts, die blocks, etc.
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Heat treatment guide	Descriptions \ Processes	Normalizing	Annealing	Full hardening	Tempering	Carbonitriding	Tempering	Nitriding
	Temperature, °C	900	855	880	250-650	850-870	200-250	Nitriding is
	Soaking time, min.	1/2hr./25 mm.+1 hr.	1/2hr./25 mm.+1 hr.	1/2hr./25 mm.+1 hr.	2 hrs min.	depend on case depth.	2 hrs min.	not recom-
	Quenching medium	air or nitrogen	furnace cool	oil or water	air or faster	oil	air	mended.
	Hardness	163-217 HB	217 HB	45-50 HRC	48-22 HRC	60-62 HRC	58-60 HRC	

Final heat treatment process of this specimen		Process: The specimen was heated at 855°C and soak for 60 minutes for austenitizing, the original microstructure will be transformed to austenite, then cooled down slowly in the furnace, austenite will be transformed to pearlite and ferrite. Strength and hardness decrease, ductility increases.
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Microstructures



Photo.49:100x, Microstructures are Pearlite and ferrite.

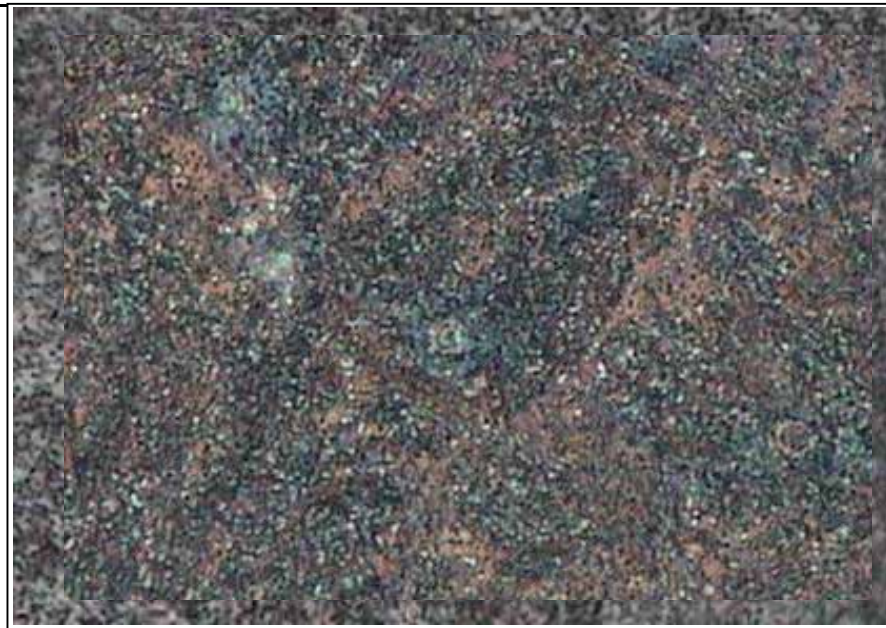


Photo.50: 1000x, Same as in Photo.49, but in higher magnification. Light area are Ferrite, dark area are Pearlite. Fine bright particles are Carbides.

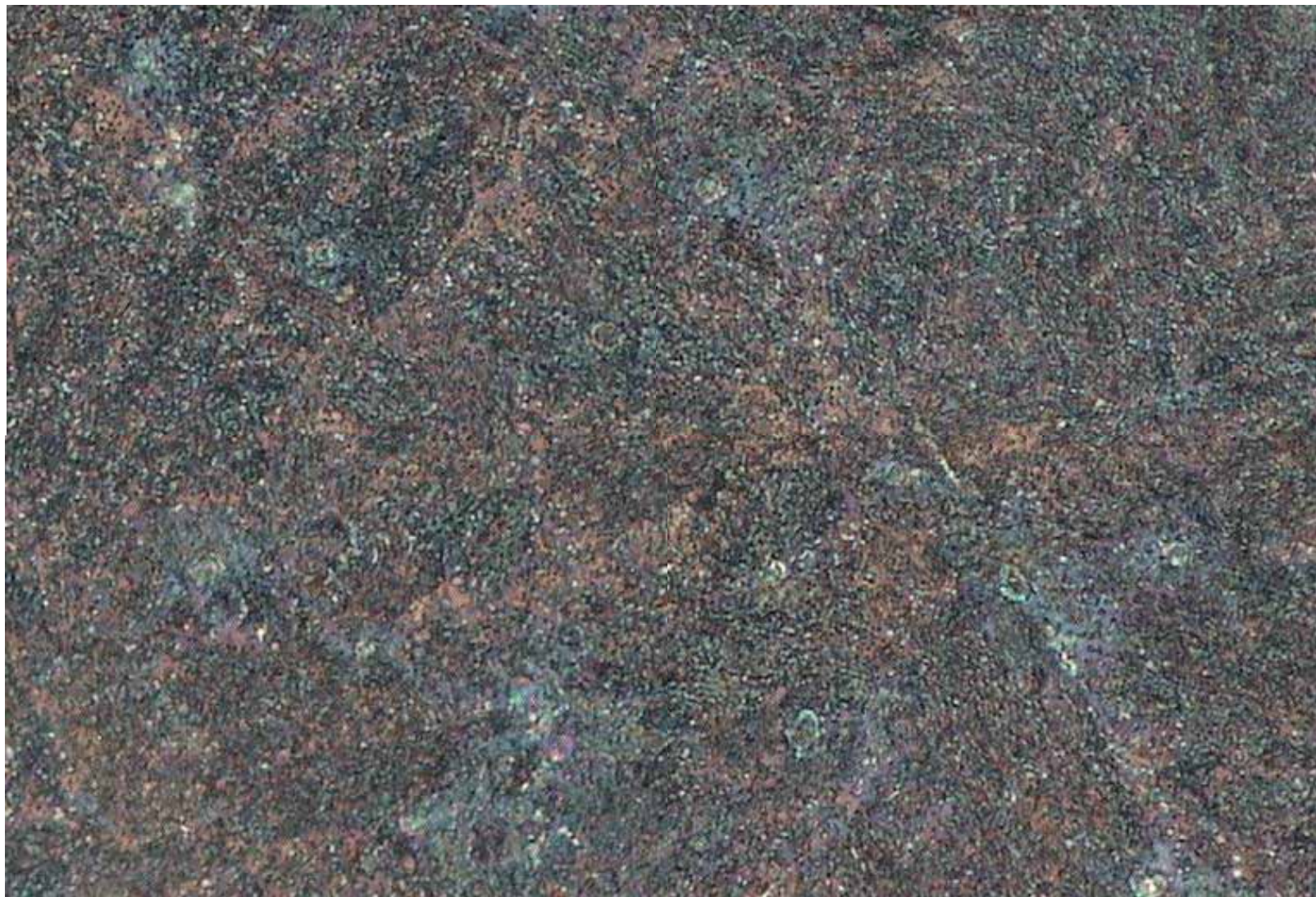


Photo.51: 500x, The microstructures are Pearlite and Ferrite. Fine bright particles are Carbides.

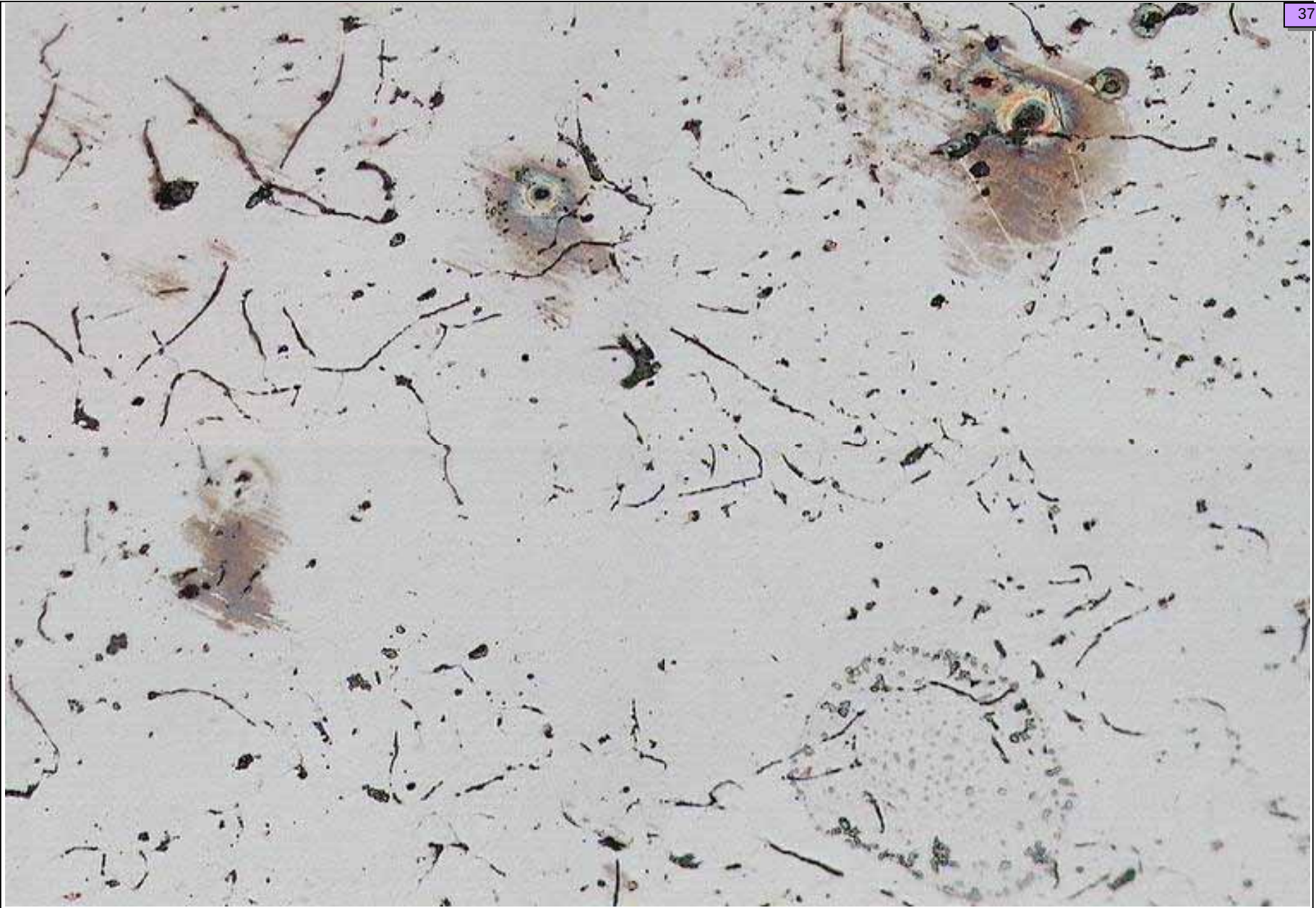


Photo.54: 200x, Showing graphite flake distribution and orientation. Dark gray particles and scripts are graphite flakkes. The matrix is un-revealed.

Characteristics and applications: Cast irons are alloys of iron(Fe), carbon(C), and silicon(Si) in which more carbon is present than can be retained in solid solution in austenite at the eutectic temperature. The carbon that exceeds the solubility in austenite precipitates as flake graphite. Gray cast iron is used for many different types of parts in a very wide variety of machines and structures. For example: machine bed, motor housing, gear, pulley, wheel, etc.

Manufacturing process of this specimen		Process: The charges (consist of pig iron, cast iron scraps, steel scraps, FeSi, FeMn, flux) were charged into induction furnace and melted into liquid metal, then the molten metal was discharged into the crucible and then poured into the sand mould. Molten metal will be solidified into solid(casting). The casting was cut, mounted, ground, polished, and etched to show both graphite flakes and matrix.
	Microstructures	

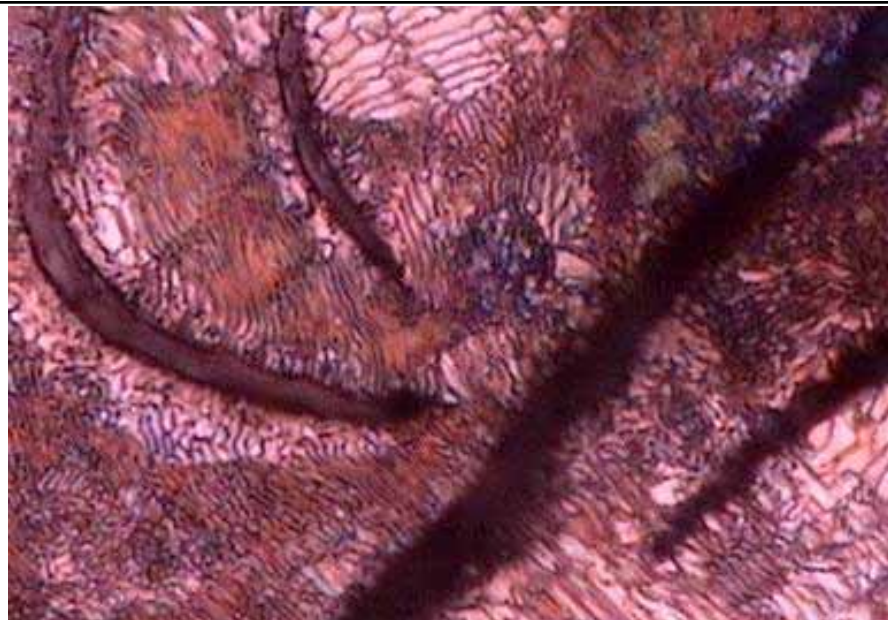


Photo.56:1000x, Same as in Photo.55, but in higher magnification, dark scripts are graphite flakes, matrix are Pearlite and Ferrite.



Photo.57: Same as in photo.56, but in larger area. Dark gray branches are graphite flakes. The matrix consists of Pearlite (small lines of cementite and Ferrite), and Ferrite.

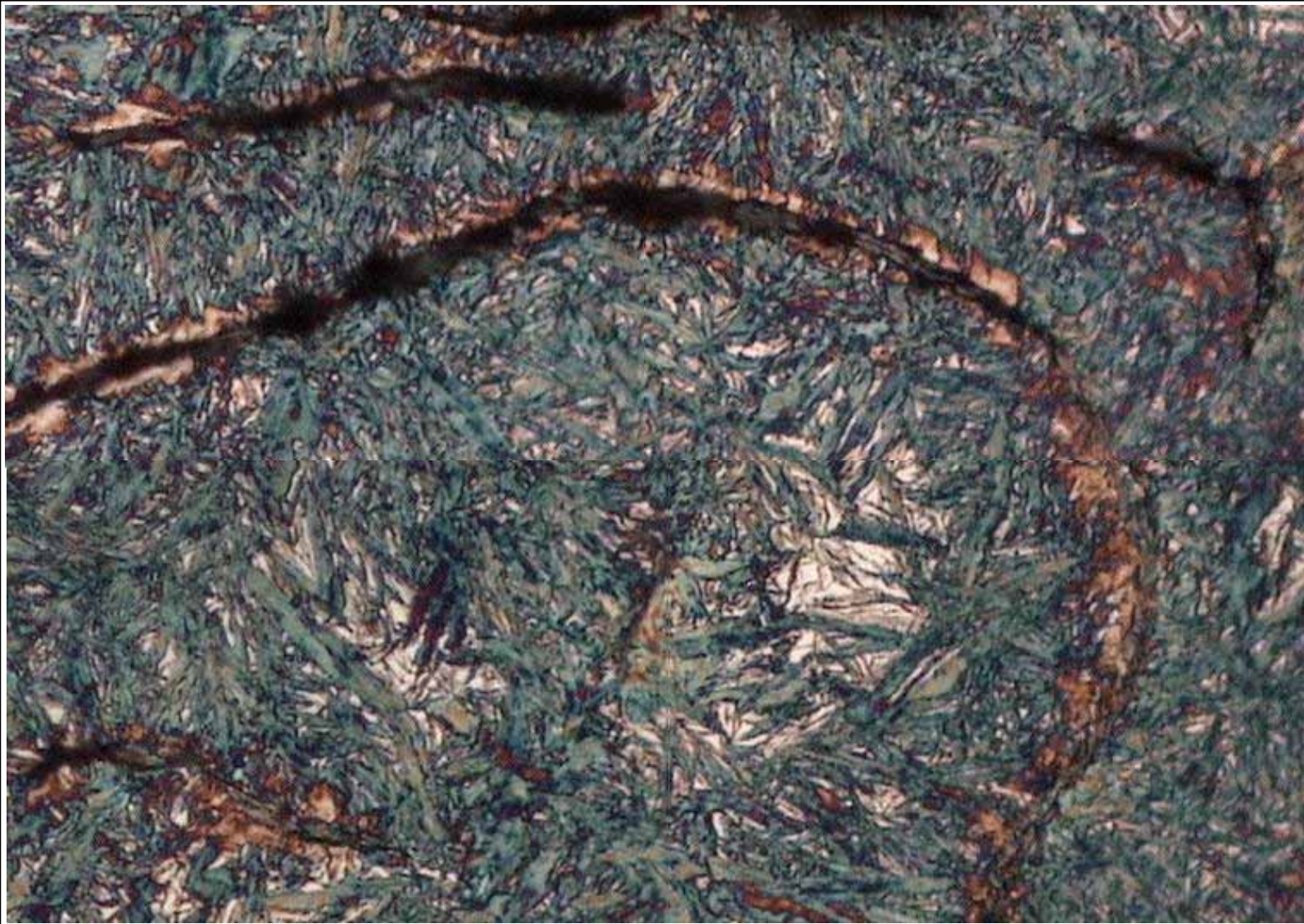


Photo.60:1000x, Acicular structures are Martensite, dark gray scripts are graphite flakes, and the yellow and light brown surrounded the graphite flakes are Ferrite.

Record of Microstructures						Specimen No.: 18	Specimen name		Material		Condition		
Chemical composition	C	Si	Mn	P	S	Cr	Ferrous Metal		White Cast Iron		As cast, etched		
	1.80-3.60	0.50-1.90	0.25-0.80	0.06-0.20	0.06-0.20	-	Mo	Ni	V	Ti	Co	W	Others
Similar steels	USA	Germany		FRANCE		RUSSIA	CHINA	SWEDEN	JAPAN	ITALY	INDIA	UK	
	AISI/SAE	DIN 1695		AFNOR NF A32-401		-	-	-	-	-	IS7925	BS 4844	
	-	G-X300NiMo3Mg		FBO		-	-	-	-	-	1	1A	

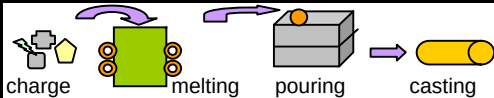
Characteristics and applications:

Exhibits a white, crystalline fracture surface because fracture occurs along the iron carbide plates; it is the result of metastable solidification(Fe_3C eutectic). Hard and brittle. Good wear resistant. Weldability is poor. Machinability is poor. If reheated above eutectoid interval, soaked and cooled through eutectic interval, malleable iron will be achieved. Alloying elements can be added to white iron to make alloy cast iron, e.g. Cr is added for wear resistant purpose.

Heat treatment guide:

Only stress relieving is recommended for white cast iron when high wear resistant is required. Stress relieving of white cast iron can be done by heating the parts to about 550-650°C, soaking time is 1 hour per 25 mm. of thickness and air cool. White cast iron can be hardened also to get martensite matrix but seldomly practice.

Manufacturing process of this specimen



charge

melting

pouring

casting

Process:

Raw materials (pig iron, scraps, ferro-alloy material, and fluxes) are put in the induction furnace and poured into prepared sand mould. The raw materials added must be calculated and weighed before charging into the furnace to achieve the composition required.

Microstructures

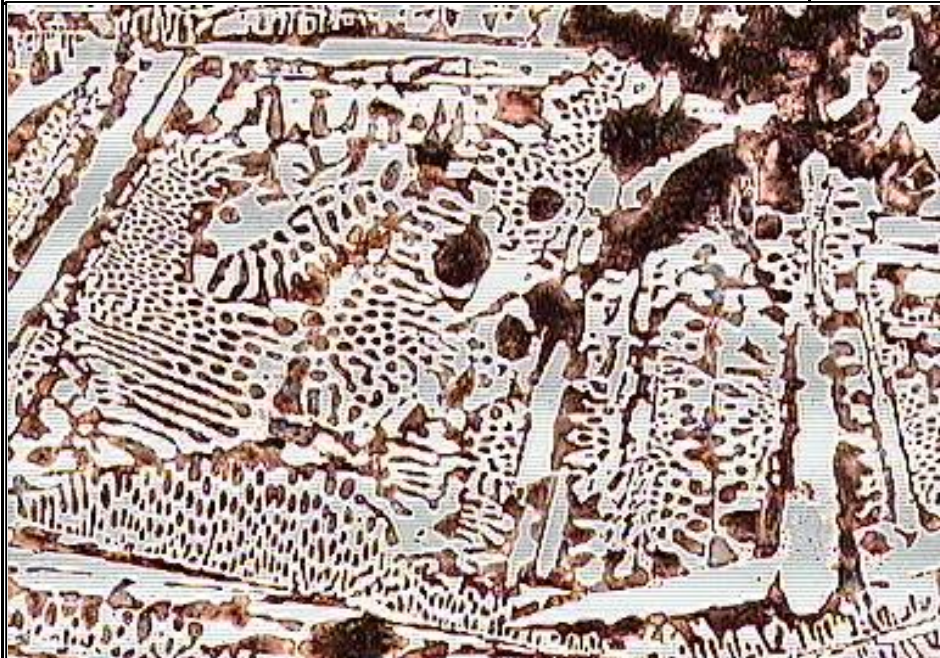


Photo.61:100x, White cast iron(hypo-eutectic cast iron), as cast, microstructures consist of Pearlite(brown and dark brown area), and Ledeburite(eutectic:Cementite and Pearlite).

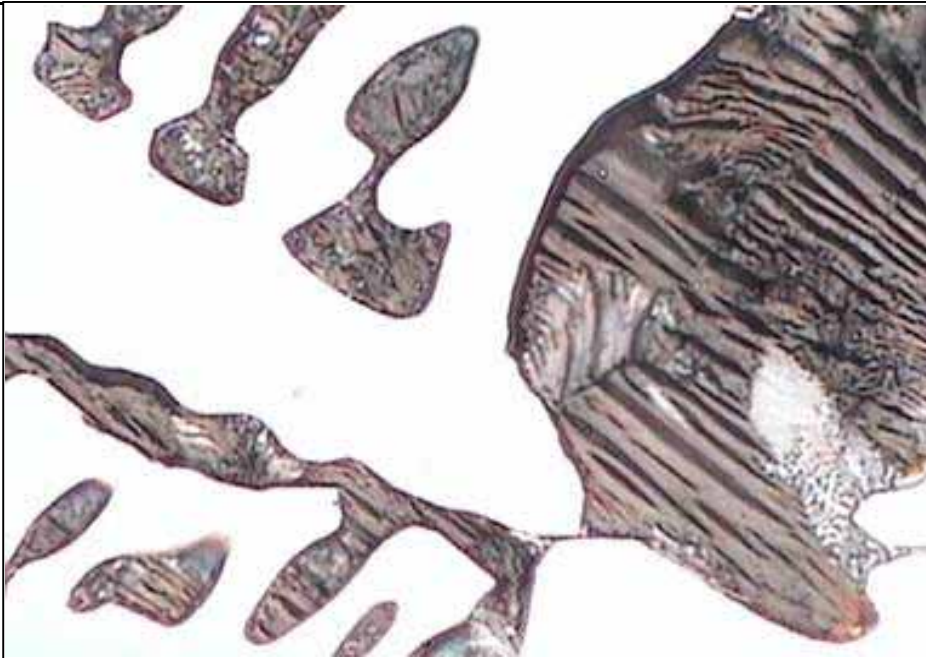


Photo.62:1000x, Same as in Photo.61, but in higher magnification. Large brown islands are free Pearlite which transformed from primary Austenite, small islands are Pearlite, parts of Ledeburite(eutectic). Bright area are cementite(Fe_3C), parts of Ledeburite.



Photo.63:1000x, Same as in Photo.62, but in larger area, showing Pearlite, and Ledeburite.

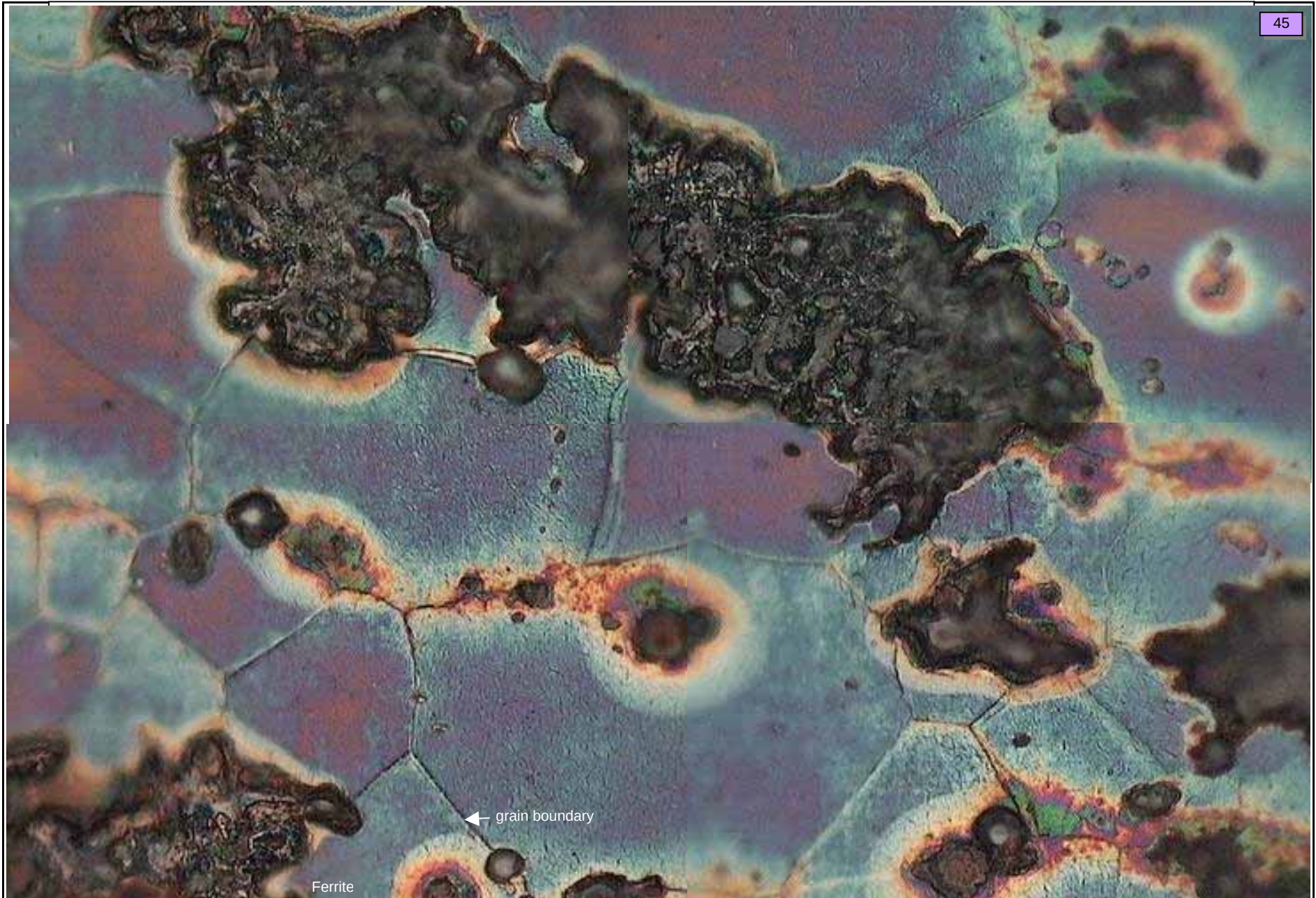


Photo.66:500x, Same as in Photo.65, but in larger area. Dark gray islands are tempered graphite. Purple and blue-green area are Ferrite.

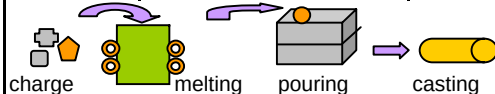
Record of Microstructures						Specimen No.: 20	Specimen name		Material		Condition		
						Ferrous Metal		Nodular Cast Iron		Annealed, un-etched			
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	3.000-4.00	1.80-2.80	0.10-1.00	0.01-0.10	0.01-0.03	-	-	-	-	-	-	-	-
Similar steels	USA		Germany	FRANCE		RUSSIA		SWEDEN	JAPAN	INTERNATIONAL		UK	
	ASTM A536-84		DIN 1693	AFNOR NF A32201		GOST7293		SIS 1407	JIS G5502	ISO 1083		BS 72892	
	60-42-10		GGG45	FGS450-10		VCh45		0722-00	FCD45	450-10		450/10	
Characteristics and applications: Nodular cast iron can be called Ductile cast iron or spheroidal graphite(SG) cast iron, it is cast iron in which the graphite is present as tiny spheres(nodules). The eutectic graphite separates from the molten iron during solidification and grows as spheres due to the additives introduced into the molten iron before casting. Some of the applications for nodular cast iron include: gears, high-fatigue strength application, high-impact application, automotive crankshafts, compressor crankshafts, joints, etc.													
Heat treatment guide	Descriptions	Processes	Normalizing		Annealing		Full hardening		Tempering		Austempering		Nitriding
	Temperature, °C		510-565		870-900		845-925		425-600		845-925		550-650
	Soaking time, min.		1hr./25 mm.+1 hr.		1hr./25 mm.+1 hr.		1hr./25 mm.+1 hr.		2 hrs min.		1hr./25 mm.+1 hr.		10-75 hrs.
	Quenching medium		air or nitrogen		furnace cool		oil or water		air or faster		oil or water		furnace cool
	Hardness		163-217 HB		160-180 HB		45-58 HRC		30HRC-80HRB		45-58 HRC		550-650HV
Manufacturing process of this specimen						Process: The charges (consist of pig iron, cast iron scraps, steel scraps, FeSi, FeMn, flux) were charged into induction furnace and melted into liquid metal, then the molten metal was discharged into the crucible and then poured into the sand mould. Molten metal will be solidified into solid(casting). The casting was cut, mounted, ground, and polished to show graphite shapes, sizes and distribution.							
Microstructures													
													
Photo.67:100x, Nodular cast iron, unetched, showing spheroidal graphites(dark brown particles).						Photo.68:1000x, Same as in Photo.67, but in higher magnification. Dark gray island is spheroidal graphite.							



Photo.69:200x, Round particles are spheroidal graphites. The matrix can not be revealed in unetched condition.

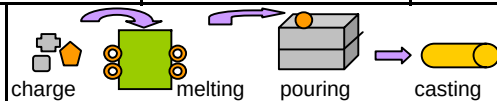
Record of Microstructures						Specimen No.: 21	Specimen name		Material		Condition		
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	3.00-4.00	1.80-2.80	0.10-1.00	0.01-0.10	0.01-0.03	-	-	-	-	-	-	-	-
Similar steels	USA		Germany	FRANCE		RUSSIA		SWEDEN	JAPAN	INTERNATIONAL	UK		
	ASTM A536-84		DIN 1693	AFNOR NF A32201		GOST 7293		SIS 1407	JIS G5502	ISO 1083	BS 72892		
	60-42-10		GGG45	FGS450-10		VCh45		0722-00	FCD45	450-10	450/10		

Characteristics and applications: Nodular can be called Ductile cast iron or spheroidal graphite(SG) cast iron, it is cast iron in which the graphite is present as tiny spheres(nodules). The eutectic graphite separates from the molten iron during solidification and grows as spheres due to the additives introduced into the molten iron before casting.

Some of the applications for nodular cast iron include: gears, high-fatigue strength application, high-impact application, automotive crankshafts, compreesor crankshafts, joints, etc.

Heat treatment guide	Descriptions Processes	Normalizing	Annealing	Full hardening	Tempering	Austempering	Nitriding
	Temperature, °C	510-565	870-900	845-925	425-600	845-925	550-650
	Soaking time, min.	1hr./25 mm.+1 hr.	1hr./25 mm.+1 hr.	1hr./25 mm.+1 hr.	2 hrs min.	1hr./25 mm.+1 hr.	10-75 hrs.
	Quenching medium	air or nitrogen	furnace cool	oil or water	air or faster	oil or water	furnace cool
	Hardness	163-217 HB	160-180 HB	45-58 HRC	30HRC-80HRB	45-58 HRC	550-650HV

Manufacturing process of this specimen



Process: The charges (consist of pig iron, cast iron scraps, steel scraps, FeSi, FeMn, flux) were charged into induction furnace and melted into liquid metal, then the molten metal was discharged into the crucible and then poured into the sand mould. Molten metal will be solidified to solid(casting). The casting was cut, mounted, ground, and polished to show graphite and matrix.

Microstructures

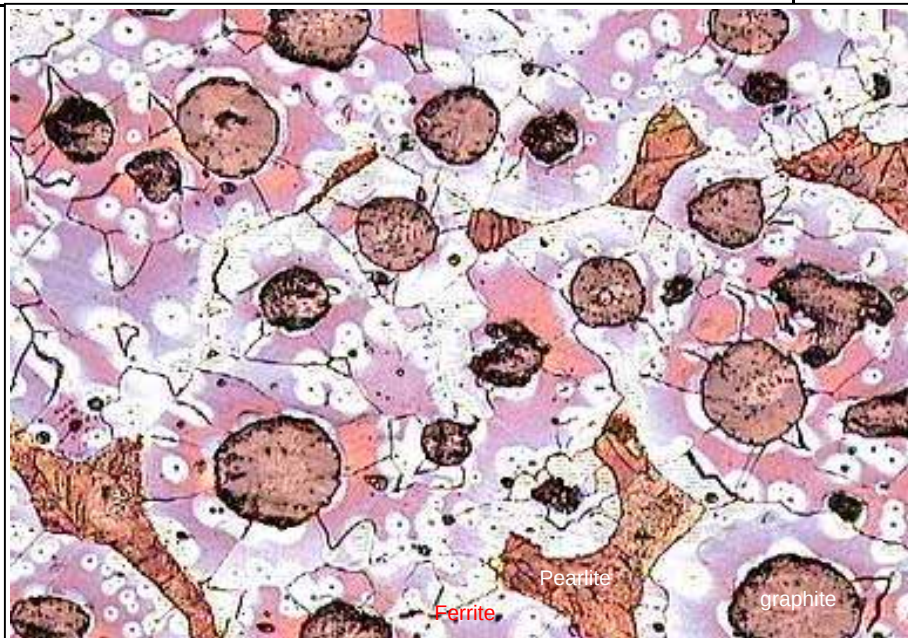


Photo.70:100x, Nodular cast iron, etched, brown round particles are spheroidal graphites. The matrix are Ferrite(white, purple area), and Pearlite(brown islands).

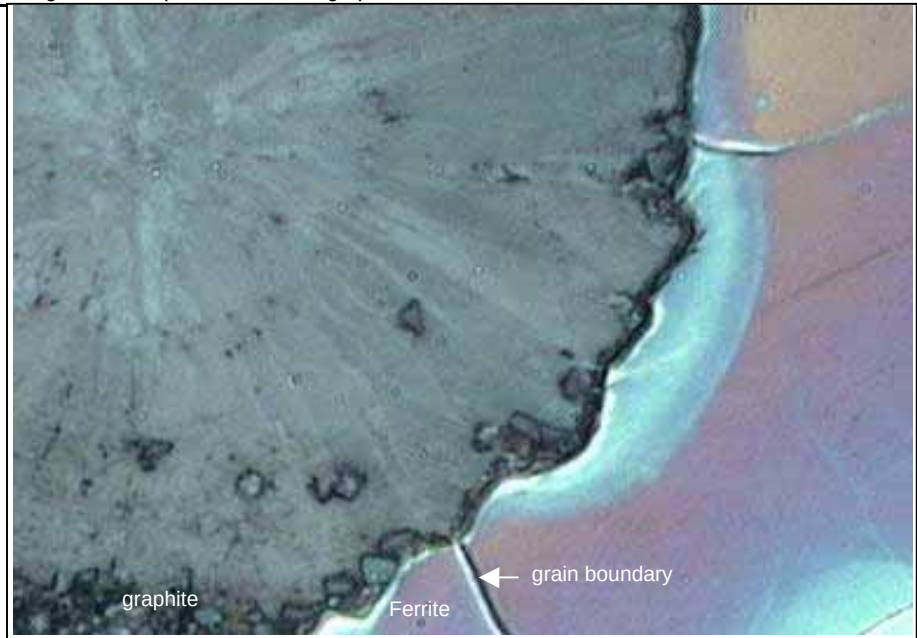


Photo.71:1000x, Same as in Photo.70, but in higher magnification. Gray area is graphite. Purple and blue-green area are Ferrite.

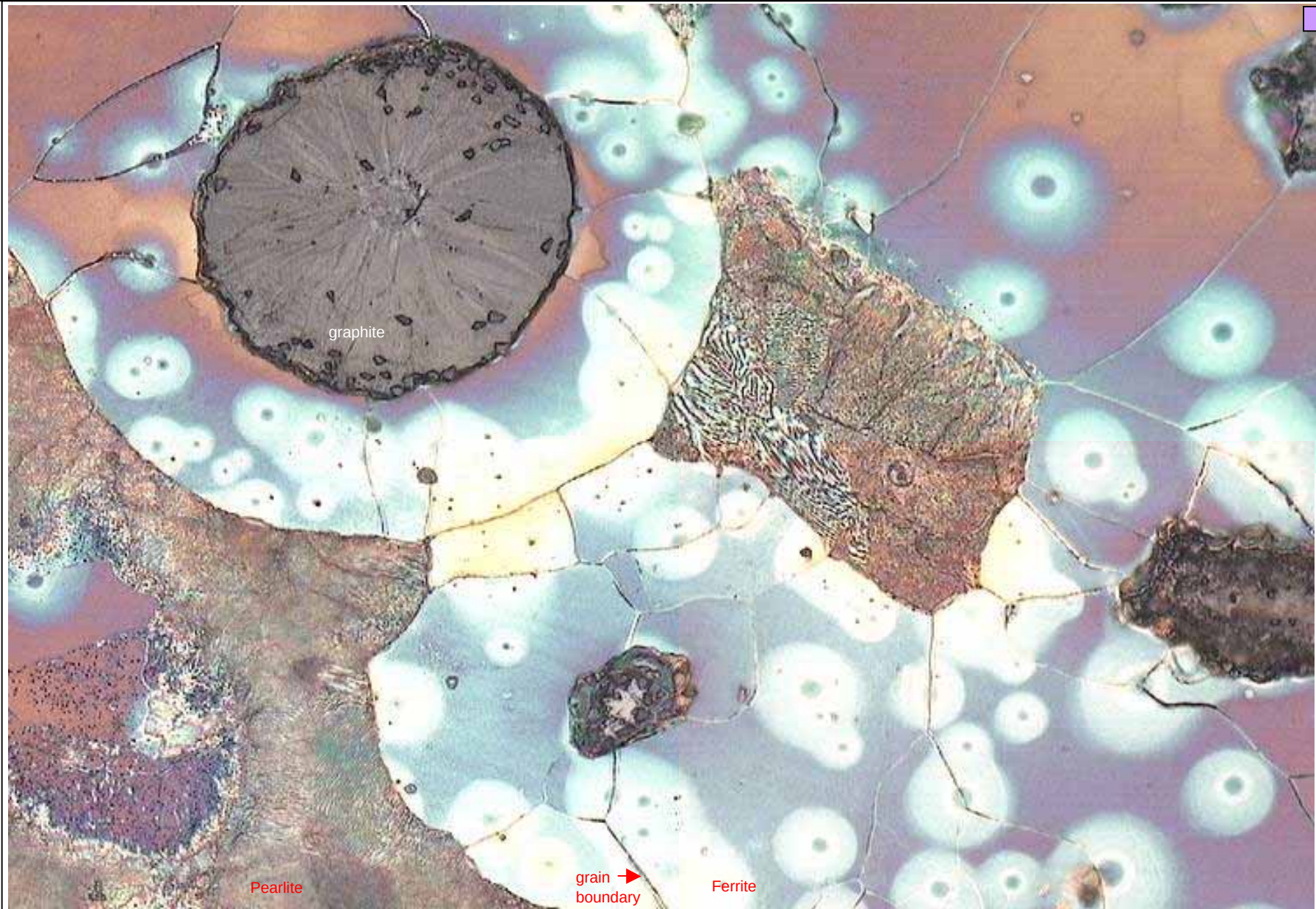


Photo.72:500x, Same as in Photo.71, but in larger area. The microstructures consist of spheroidal graphites, Pearlite and Ferrite. Bull's eyes structure can be seen in this Photo. (Bull's structure consists of graphite nodule in the center surrounded with Ferrite, and the outmost area is Pearlite. It looks like Bull's eyes.

Record of Microstructures						Specimen No.: 22	Specimen name		Material		Condition		
	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
Chemical composition	3.50	2.50	0.90	0.050	0.040	-	0.25	3.00	-	-	-	-	-
Similar grade of BDI: The common name of this special cast iron is Bainitic Ductile Iron or BDI. Most foundries are also produce this kind of cast iron under the name Bainitic Ductile or BDI.													
Characteristics and applications: Bainitic Ductile Iron(BDI) is the high strength and wear resistant alloy cast iron. Microstructure of BDI consists of graphite nodules and bainite as the matrix. BDI obtained through alloying during melting to produce bainite matrix which is hard and good wear resistant. Bainite matrix in BDI obtained in as cast condition without any heat treatment. The applications of BDI are: gear, crank shafts, etc.													
Heat treatment: BDI may be tempered to adjust the hardness. The tempering temperature depends on the hardness required. The other heat treatment processes may not be required because the casting has been aalready hardened by alloying.													
Manufacturing process of this specimen						Process: The charges (consist of pig iron, cast iron scraps, steel scraps, FeSi, FeMn, flux) were charged into induction furnace and melted into liquid metal, Ni, Mo, and inoculant were added during the process, the liquid metal was discharged into the crucible and then poured into the sand mould. The liquid metal will solidify as the casting then cut, mounted, ground, polished, and etched for the examination.							
						Microstructures							
Photo.73,100x, Bainitic Ductile Iron(BDI), etched, showing Bainite matrix and sphreoidal graphite.						Photo.74:1000x, Same as in Photo.73, but in higher magnification. Brown round area is spheroidal graphite surrounded with Bainite(purple,orange, blue-green, and brown area).							

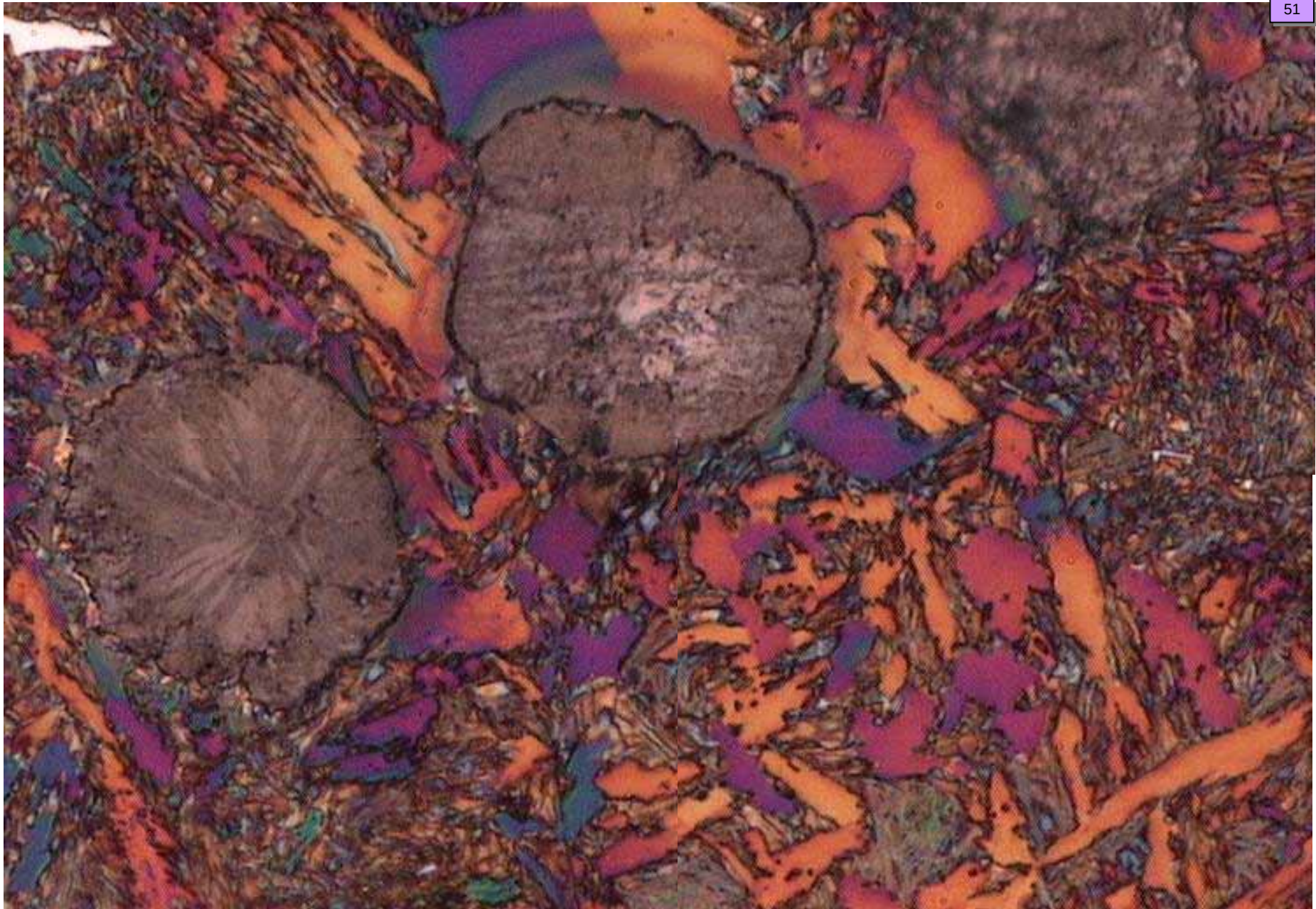
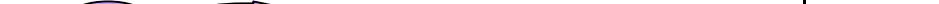


Photo.75:1000x, Same as in Photo.74, but in larger area. The microstructures consist of spheroidal graphites, and Bainite matrix. Some ferrite remained beside graphite.

Characteristics and applications:	This grade of cast iron is in the group of The high alloy white irons which are primarily used for abrasion-resistant applications and are readily cast in the shapes needed in the machinery used for crushing, grinding, and general handling of abrasive materials. The eutectic carbides in the microstructures provided the high hardness needed for crushing and grinding other materials. All high-alloy white irons contain chromium to prevent graphite formation and provide the stability of carbide phase.
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Manufacturing process of this specimen		Processes: The raw material (pig iron, scraps, ferro-alloys, etc.) were charged into the induction furnace for melting. Then the liquid metal was discharged and poured into the sand mould. After the solidification, the casting was taken out
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Microstructures

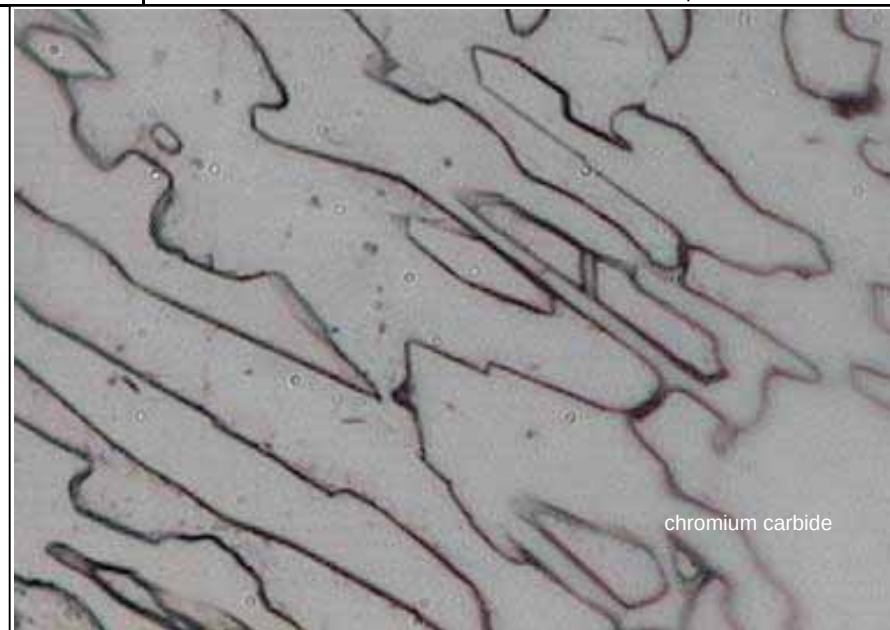


Photo.77:1000x. Same as in Photo.76. but in higher magnification.

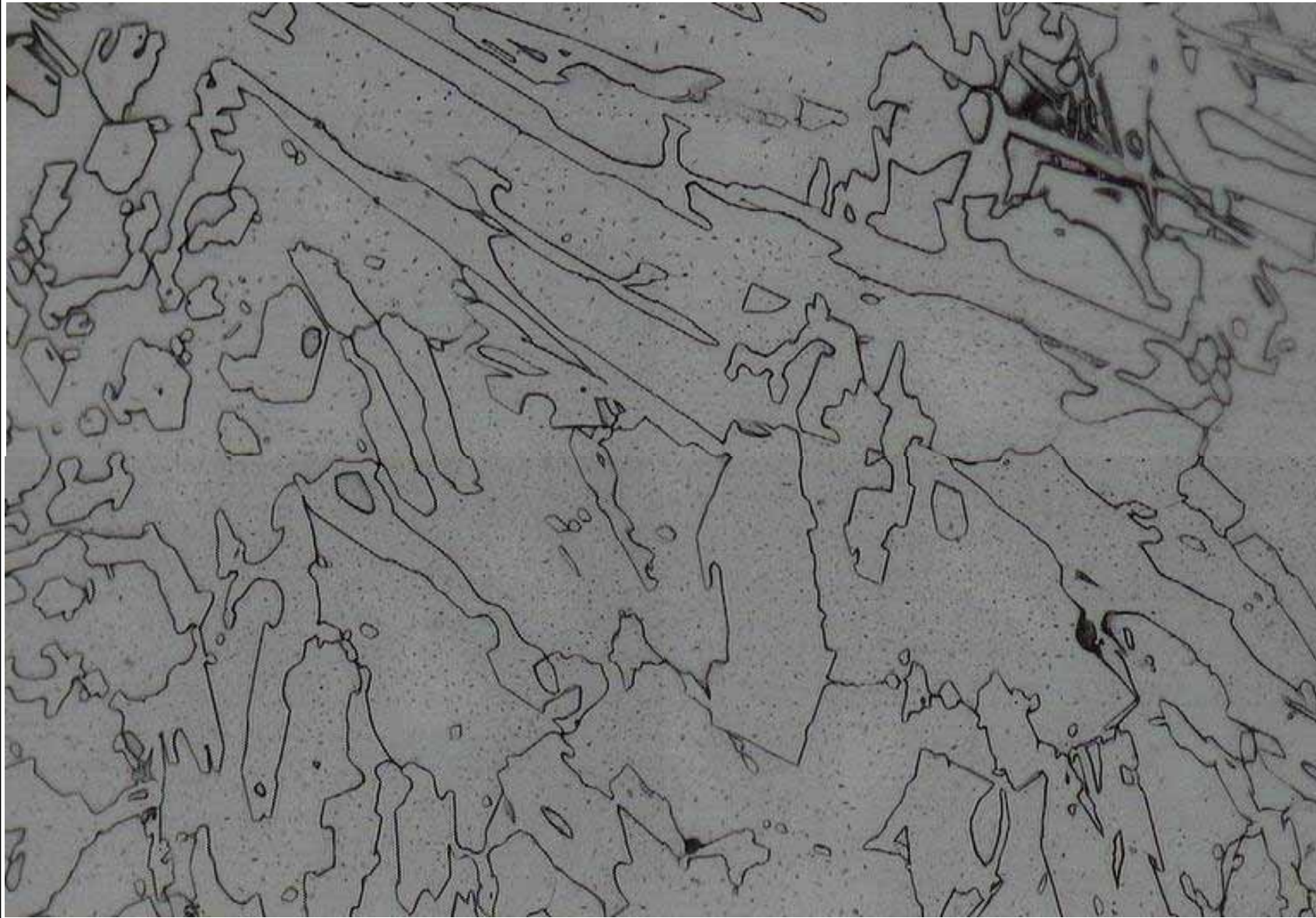
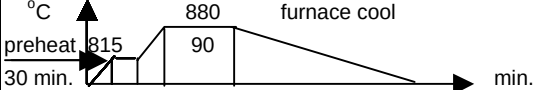
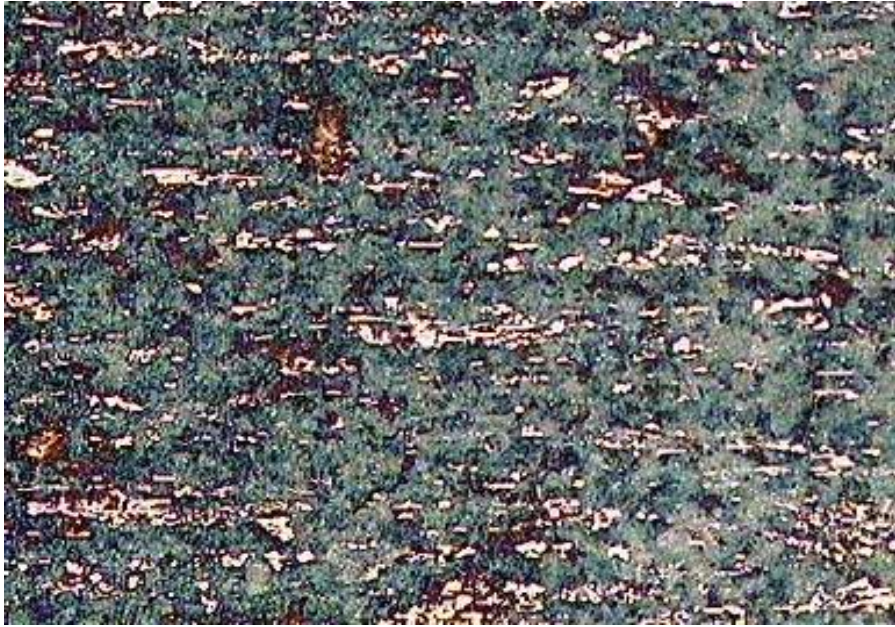
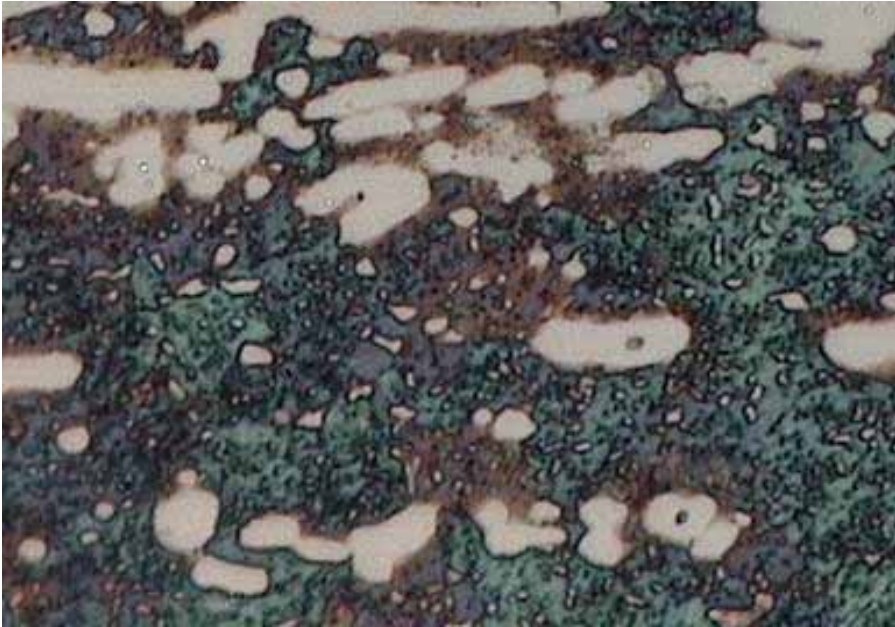


Photo.78:500x, Same as in Photo.77, but in larger area. The structures are chromium carbides.

Record of Microstructures						Specimen No.: 24	Specimen name		Material			Condition	
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	1.40-1.60	0.60 max	0.60 max	0.03	0.03	11.00-13.00	0.70-1.20	-	1.10 max	-	-	-	-
Similar steels	USA		GERMANY		FRANCE		CHINA	SWEDEN	JAPAN	ITALY	INDIA	UK	
	AISI/SAE	ASTM A681	DIN 17350	KRUPP	AFNOR NF A35-590		GB 1299	SIS14	JISG4404	UNI2955	IS 3749	BS 4659	
	D2	D2	1.2379	2379	Z160CDV 12		3-2Cr12MoV	2310	SKD11	DCT-AR	T160Cr12	BD2	
Characteristics and applications: Most available and most popular of the D series tool steels. Deep hardening, with low distorsion and high safety in weldability. resistant to softening and medium resistant to decarburization. Readily nitrided. D2 steel is air hardening and attain full hardness when cooled in still air. D2 steel contain massive amount of carbides, which make it susceptible to edge brittleness. Typical applications of D2 steel include long run dies for blanking, forming,thread rolling, deep drawing, slitter knives, etc.													
Heat treatment guide	Descriptions	Processes	Normalizing		Annealing		Stress relieving		Hardening			Tempering	Nitriding
	Temperature, °C		Do not normalize		870 - 900		675-705		Pre:815;Aus:980-1025			205-540	500
	Soaking time, min.	90 min./inch of thickness			60 min./inch of thickness		15 min.(small);45 min.(large)			2 hrs min.	10-75 hrs.		
	Quenching medium	furnace cool			air		air or nitrogen gas			air	furnace cool		
	Hardness	217-255 HB			-		62 to 64 HRC			61- 54 HRC	>750 HV		
Final heat treatment process of this specimen						Process: The specimen is heated to 880°C for 90 min., the steel microstructures will transform to austenite, then cool down slowly in the furnace, austenite will transform to ferrite and pearlite. The steel will be softened,better machinability,better cold workability,and improve dimensional stability,etc.							
Microstructures													
													
Photo.79:100x, AISI D2 Tool steel, annealed. Microstructures consist of Ferrite matrix and Carbides.							Photo.80:1000x, Same as in Photo.79, but in higher magnification. Ferrite matrix is colored greenand brown, Carbides remained bright particles.						

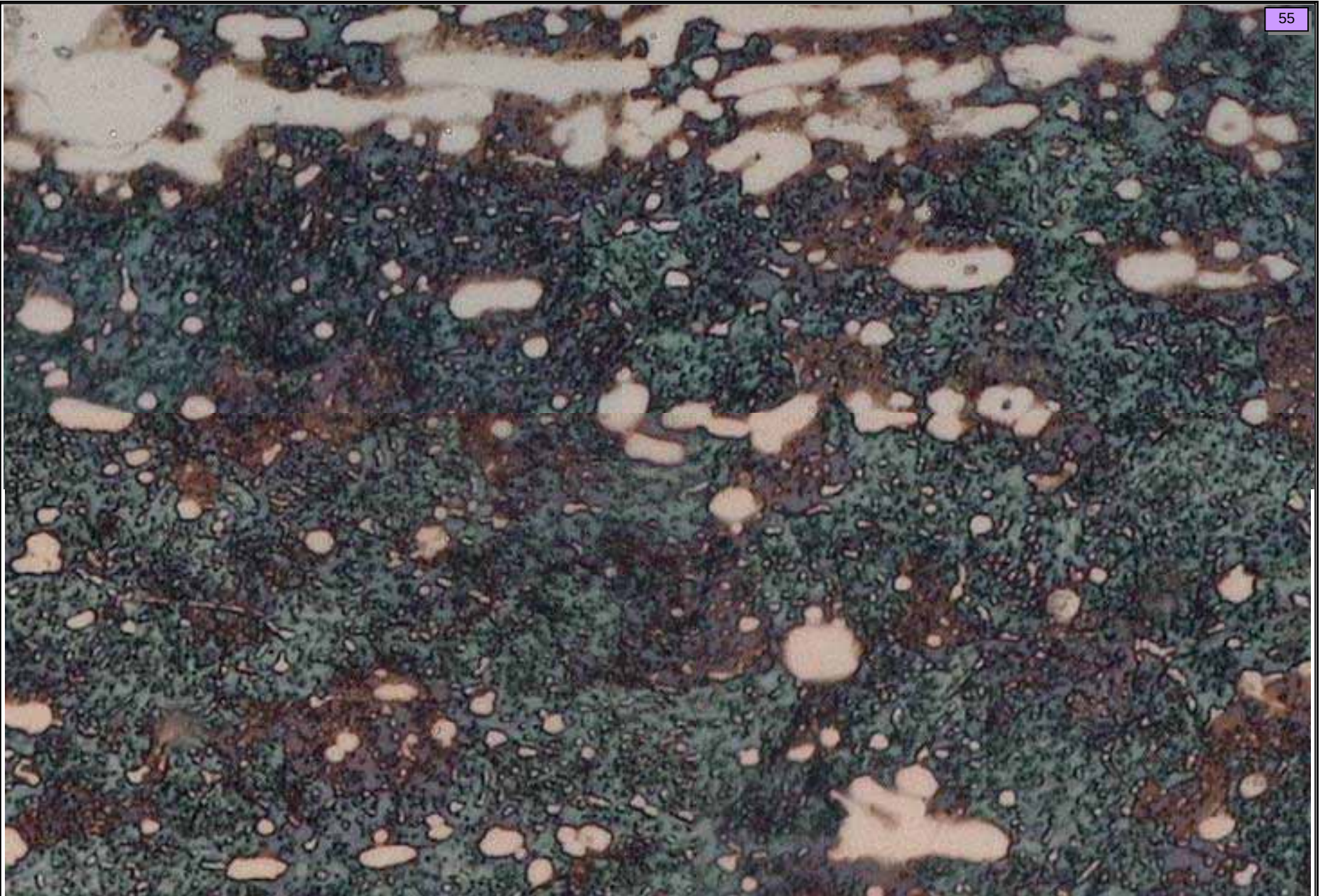


Photo.81:1000x, Same as in Photo.80, but in larger area, showing the distribution of Carbides in Ferrite matrix.

Record of Microstructures						Specimen No.: 25	Specimen name		Material			Condition	
							Ferrous Metal		High C-High Cr Tool steel(AISI D2)			Quenched and tempered	
Chemical composition	C	Si	Mn	P	S	Cr	Mo	Ni	V	Ti	Co	W	Others
	1.40-1.60	0.60 max	0.60 max	0.03	0.03	11.00-13.00	0.70-1.20	-	1.10 max	-	-	-	-
Similar steels	USA		GERMANY		FRANCE		CHINA	SWEDEN	JAPAN	ITALY	INDIA	UK	
	AISI/SAE	ASTM A681	DIN 17350	KRUPP	AFNOR NF A35-590		GB 1299	SIS14	JISG4404	UNI2955	IS 3749	BS 4659	
	D2	D2	1.2379	2379	Z160CDV 12		3-2Cr12MoV	2310	SKD11	DCT-AR	T160Cr12	BD2	
Characteristics and applications: Most available and most popular of the D series tool steels. Deep hardening, with low distortion and high safety in weldability. resistant to softening and medium resistant to decarburization. Readily nitrided. D2 steel is air hardening and attain full hardness when cooled in still air. D2 steel contain massive amount of carbides, which make it susceptible to edge brittleness. Typical applications of D2 steel include long run dies for blanking, forming,thread rolling, deep drawing, slitler knives, etc.													
Heat treatment guide	Descriptions	Processes	Normalizing		Annealing		Stress relieving		Hardening			Tempering	Nitriding
	Temperature, °C		Do not normalize		870 - 900		675-705		Pre:815;Aus:980-1025			205-540	500
	Soaking time, min.	90 min./inch of thickness			60 min./inch of thickness		15 min.(small);45 min.(large)			2 hrs min.	10-75 hrs.		
	Quenching medium	furnace cool			air		air or nitrogen gas			air	furnace cool		
	Hardness	217-255 HB			-		62 to 64 HRC			61- 54 HRC	>750 HV		
Final heat treatment process of this specimen						Process: The specimen is heated to 1025°C for 90 min., the steel microstructures will transform to austenite, then quench in nitrogen gas(in vacuum furnace), austenite will transform to martensite and then temper immediately at 520°C after the specimen has cooled to about 50°C, Double temper.							
Microstructures													
Photo.82:100x, AISI D2 Tool steel, quenched and tempered. Microstructures consist of Martensite and Carbides.							Photo.83:1000x, Same as in Photo.82, but in higher magnification. Martensite tinted variuos colors. Carbides remained bright particles.						

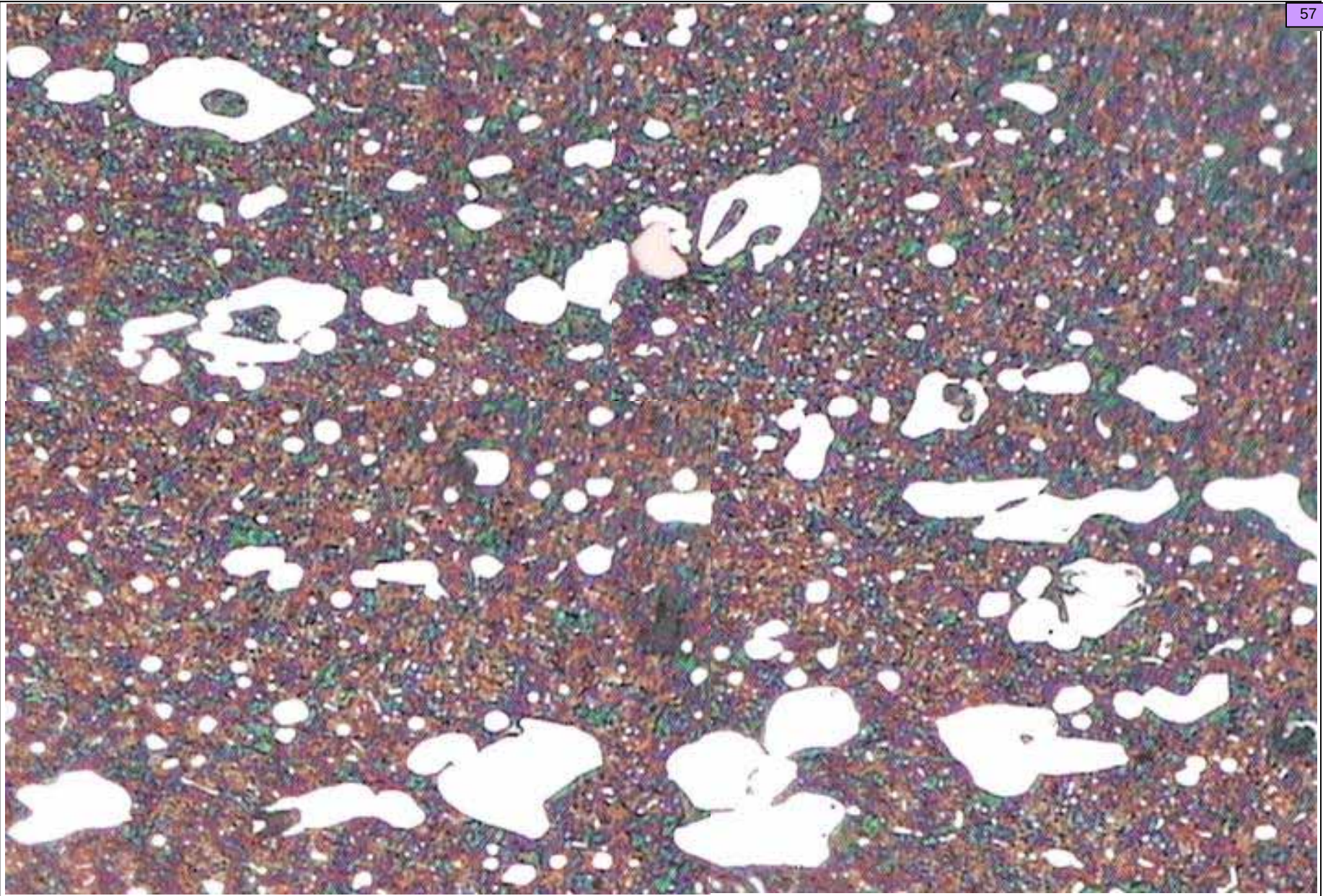


Photo.84:1000x, Same as in Photo.83, but in larger area. The matrix is Martensite tinted various colors, and bright particles are carbides.

Record of Microstructures						Specimen No.: 26	Specimen name		Material			Condition	
Chemical composition	C	Si	Mn	P	S	Cr	Ferrous Metal		Mould tool steel (AISI P20)			Annealed	
	0.10 max	0.10-0.40	0.10-0.40	0.025 max	0.025 max	0.75-1.25	Mo	Ni	V	Ti	Co	W	Others
Similar steels	USA		GERMANY		FRANCE		SWEDEN		JAPAN			RUSSIA	UK
	AISI/SAE	ASTM A681	DIN	KRUPP	AFNOR NF A35-590		SS14	ASSAB	DAIDO	HITACHI	N.KOSHUHA	GOST	BS4659
	P20	P20	1.2311	2311	35CM7D		USA P20	718Supreme	PX 4	YSS: HPM 2	Plasmold20	4ChS	USA P20
Characteristics and applications: Mold steel AISI P20 normally is supplied heat treated to 30-36 HRC, a condition in which it can be machined readily into large, intricate dies and molds. Because this steel is prehardened, no subsequench high temperature heat treatment is required, and distortion and size changes are avoided. However, when used for plastic mold, type P20 is sometimes carburized and hardened after the impression has been machined. Most application is for plastic mold making.													
Heat treatment guide	Descriptions	Processes	Normalizing		Annealing		Stress relieving		Hardening			Tempering	
	Temperature, °C		900		760-790		650-675		Carburize:920, Harden: 815-870			Carburized mold:175-230	
	Soaking time, min.		60 min./inch of thickness		60 min./inch of thickness		60 min./inch of thickness		Carburize:to case depth;Harden:15 min			2 hrs min.	
	Quenching medium		air		furnace cool		air		oil			air	
	Hardness		149-179 HB		149-212 HB		-		60 to 64 HRC			62- 58 HRC	
Final heat treatment process of this specimen		°C ↑ preheat 815 30 min. 780 60 furnace cool min.				Process: The specimen is heated to 780°C for 60 min., the steel microstructures will transform to austenite, then cool down slowly in the furnace, austenite will transform to ferrite and pearlite. The steel will be softened, better machinability, better cold workability, and improve dimensional stability,etc.							
Microstructures													
Photo.85:100x, AISI P20 Mold Tool steel, annealed. Microstructures consist of Ferrite and Carbides. Black dots are porosities.							Photo.86:1000x, Same as in Photo.85, but in higher magnification.Blue-green area are Ferrite. Bright particles are Carbides.						

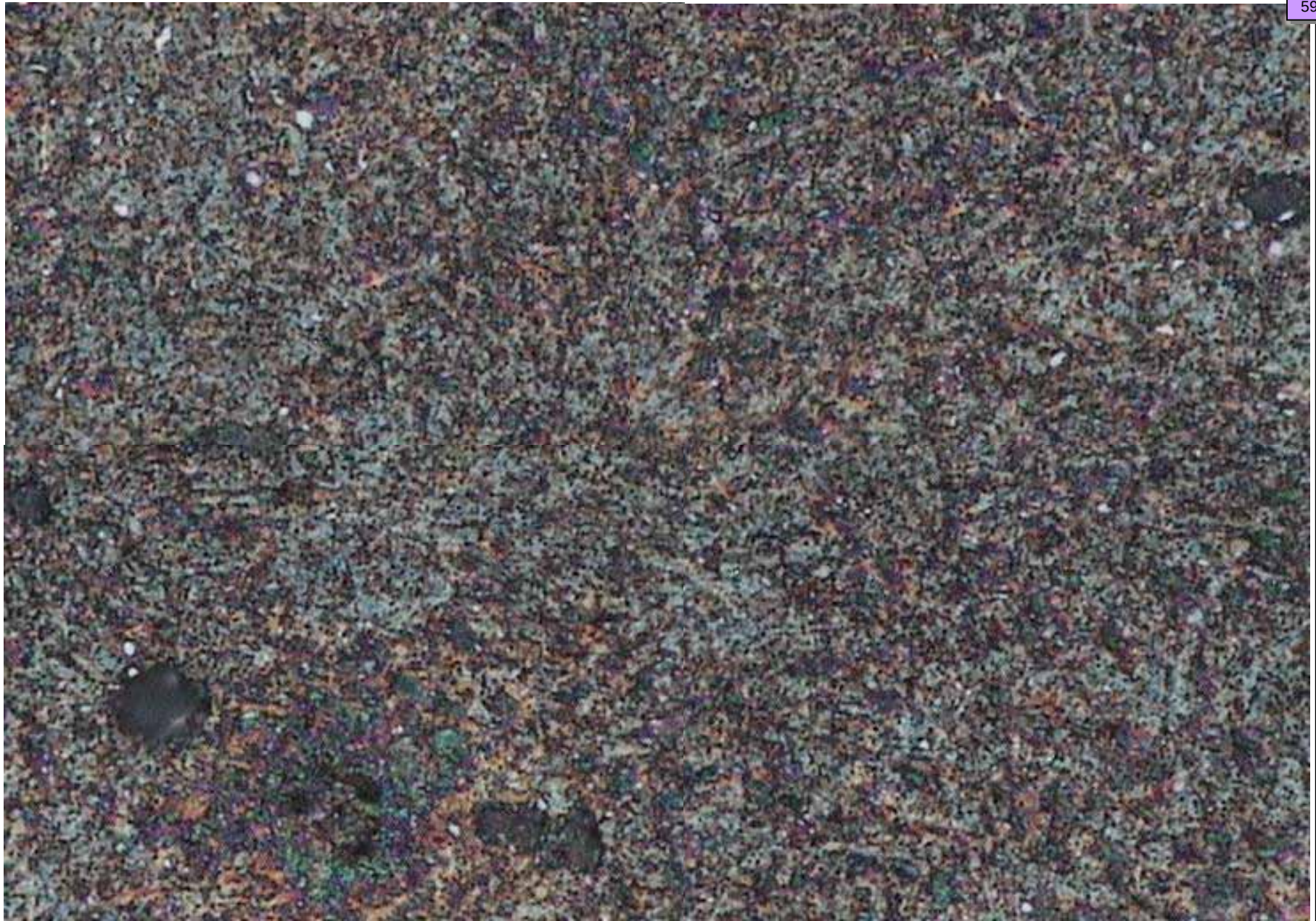


Photo.87:1000x, Same as in Photo.86, but in larger area.

Photo.89:1000x, Same as in Photo.88, but in higher magnification. Martensite is clearly seen in brown and gray.

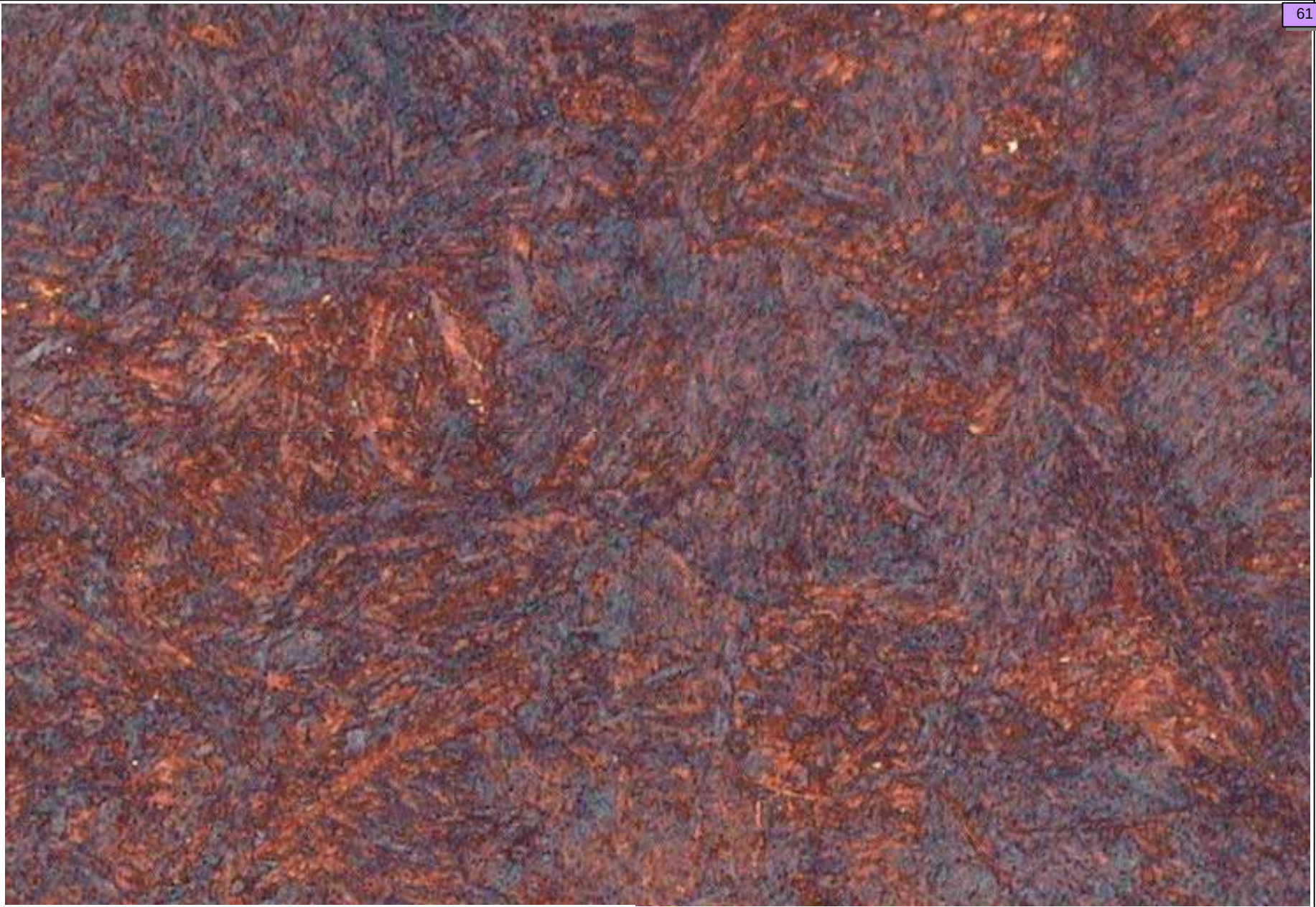


Photo.90:1000x, Same as in Photo.88, but in larger area. The structure is tempered martensite.

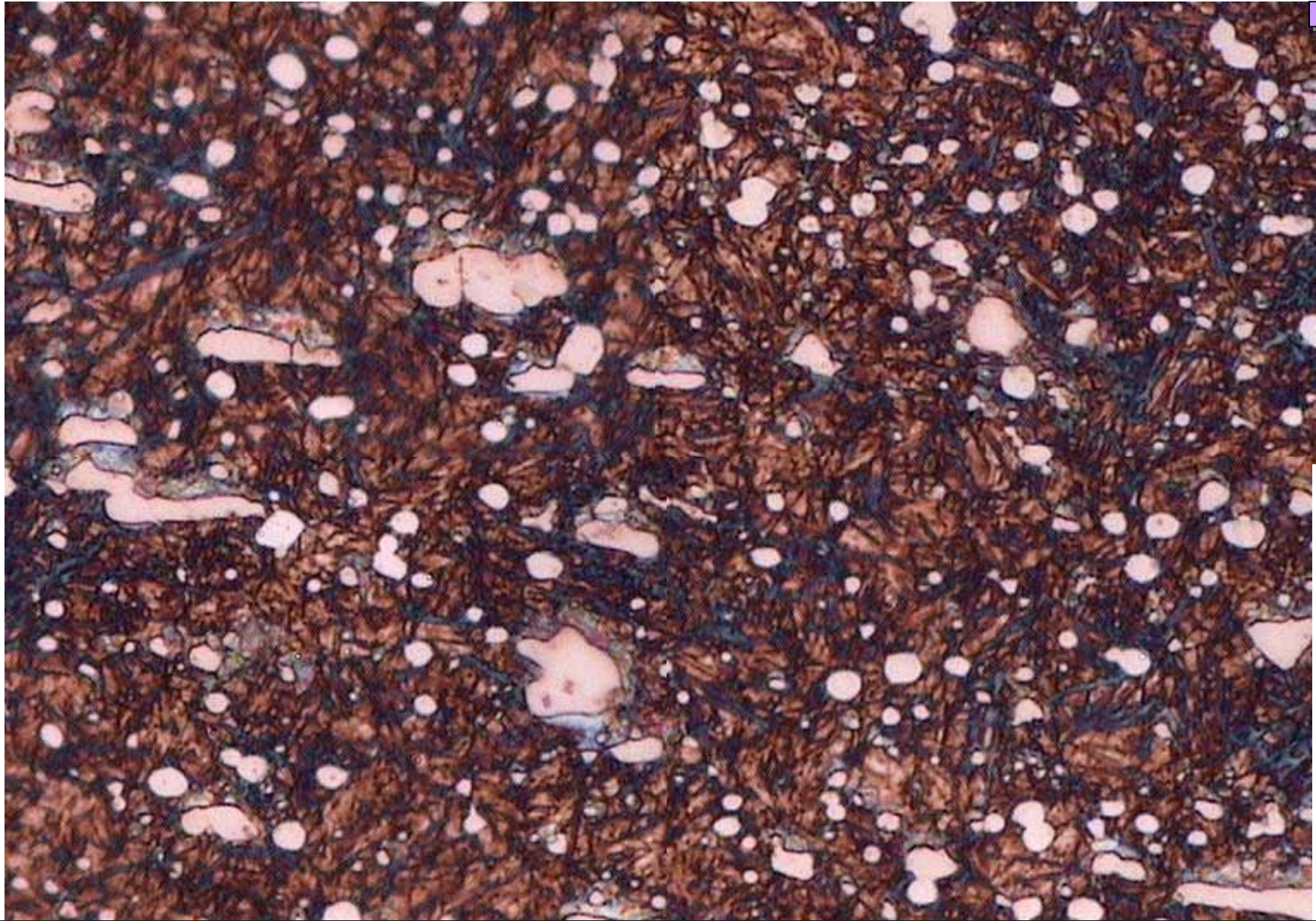


Photo.93:1000x, Same as in Photo. 92, but in larger area. Microstructures consist of Martensite(brown and dark gray needle structures), and carbides(light brown round and elongated particles).

Record of Microstructures						Specimen No.: 29	Specimen name		Material			Condition	
Chemical composition	C	Si	Mn	P	S	Cr	Ferrous Metal		High manganese steel			As cast	
	1.268	0.525	13.38	0.042	0.004	2.105	Mo	Ni	V	Ti	Cu	W	Others
							0.094	0.074	0.023	0.029	0.368	-	-
Similar steels	USA	AUSTRALIA	GERMANY	ITALY	JAPAN		MEXICO		ROMANIA	SPAIN		UK	
	ASTM A128	AS 2074	DIN	UNI 3160	G5131		MNC 720E		STAS3718	UNE 36253		BS3100	
	A	H19	1.3802	GX120Mn12	SCMnH3		2183		T105Mn120	AM-X-120Mn12		BW10(En 1457)	
Characteristics and applications: The original austenitic manganese steel, containing about 1.2%C and 12%Mn, was invented by Sir Robert Hadfield in 1882.It combined high toughness and ductility with high-hardening capacity and excellent resistance to wear. It is still used extensively, with composition and heat treatment modification, primarily in the fields of earthmoving, mining, quarrying, oil well drilling, railroading,and in the manufacture of cement and clay products.Example:rock crusher, bucket,wear plate, etc.													
Manufacturing process of this specimen						Process: The charges (consist of pig iron, cast iron scraps, steel scraps, FeSi, FeMn, flux) were charged into induction furnace and melted into liquid metal, Fe-Mn was added during the melting process. The liquid metal was discharged into the crucible and then poured into the sand mould. The liquid metal will solidify as the casting then cut, mounted, ground, polished, and etched for the examination.							
Microstructures													
Photo. 94:50x, High-Manganese steel casting, as cast. Microstructure are Austenite. White particles along grain boundaries and in the Austenite grains are Carbides.						Photo. 95:1000x, Same as in Photo. 94, but in higher magnification. Austenite grains are tinted various colors. Carbides along grain boundaries are colored light purple.							

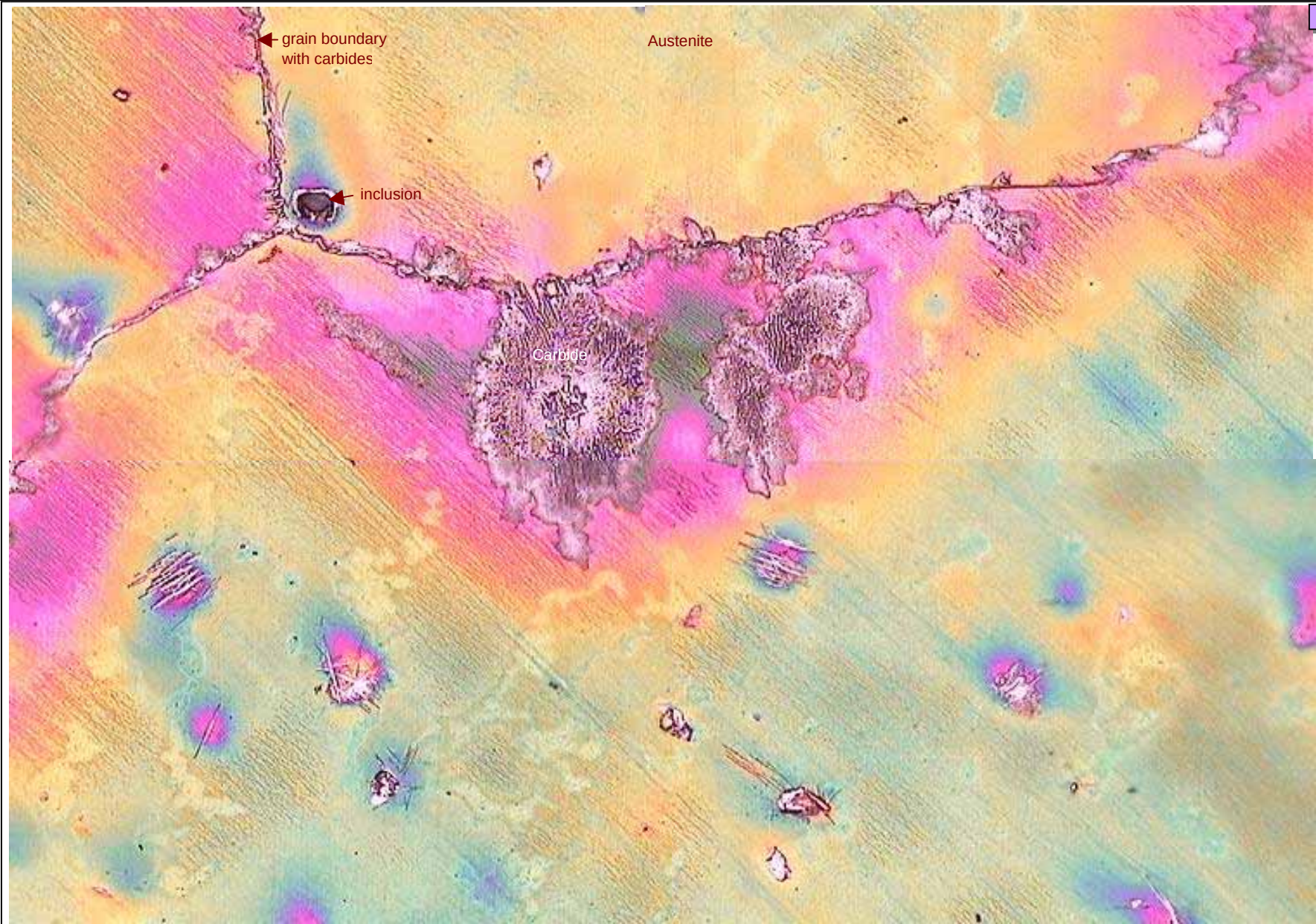


Photo. 96:200x, Same as in Photo. 95, but in larger area. Austenite grains are tinted various colors. Carbides are shown along grain boundaries and in Austenite grains.

Record of Microstructures						Specimen No.: 30	Specimen name		Material			Condition 66	
Chemical composition	C	Si	Mn	P	S	Cr	Ferrous Metal		High manganese steel			Solution annealed	
	1.268	0.525	13.38	0.042	0.004	2.105	Mo	Ni	V	Ti	Cu	W	Others
Similar steels	USA	AUSTRALIA	GERMANY	ITALY	JAPAN		MEXICO		ROMANIA	SPAIN		UK	
	ASTM A128	AS 2074	DIN	UNI 3160	G5131		MNC 720E		STAS3718	UNE 36253		BS3100	
	A	H19	1.3802	GX120Mn12	SCMnH3		2183		T105Mn120	AM-X-120Mn12		BW10(En 1457)	
Characteristics and applications: The original austenitic manganese steel, containing about 1.2%C and 12%Mn, was invented by Sir Robert Hadfield in 1882. It combined high toughness and ductility with high-hardening capacity and excellent resistance to wear. It is still used extensively, with composition and heat treatment modification, primarily in the fields of earthmoving, mining, quarrying, oil well drilling, railroading, and in the manufacture of cement and clay products. Example: rock crusher, bucket, wear plate, etc.													
Heat treatment guide: Heat treatment strengthens austenitic manganese steel so that it can be used safely and reliably in variety of engineering applications. Solution annealing and quenching are the standard processes.							Solution annealing and quenching						
							Temperature, °C		1010-1090				
							Soaking time		1 to 2 hours per 25 mm. of thickness				
							Quenchant		agitated water				
Manufacturing process of this specimen							Processes: The raw material (pig iron, scraps, ferro alloy, etc.) were charged into the induction furnace for melting. Then the liquid metal was discharged and poured into the sand mould. After the solidification, the casting was taken out of the mold and heated to 1050°C and quench in water.						
Microstructures													
Photo.97:50x, High Manganese Steel casting, annealed. Microstructures are Austenite. The purple area shows the trace of dendrite.							Photo.98:1000x, Same as in Photo. 97, but in higher magnification. The carbide along grain boundaries decreased after annealing.						

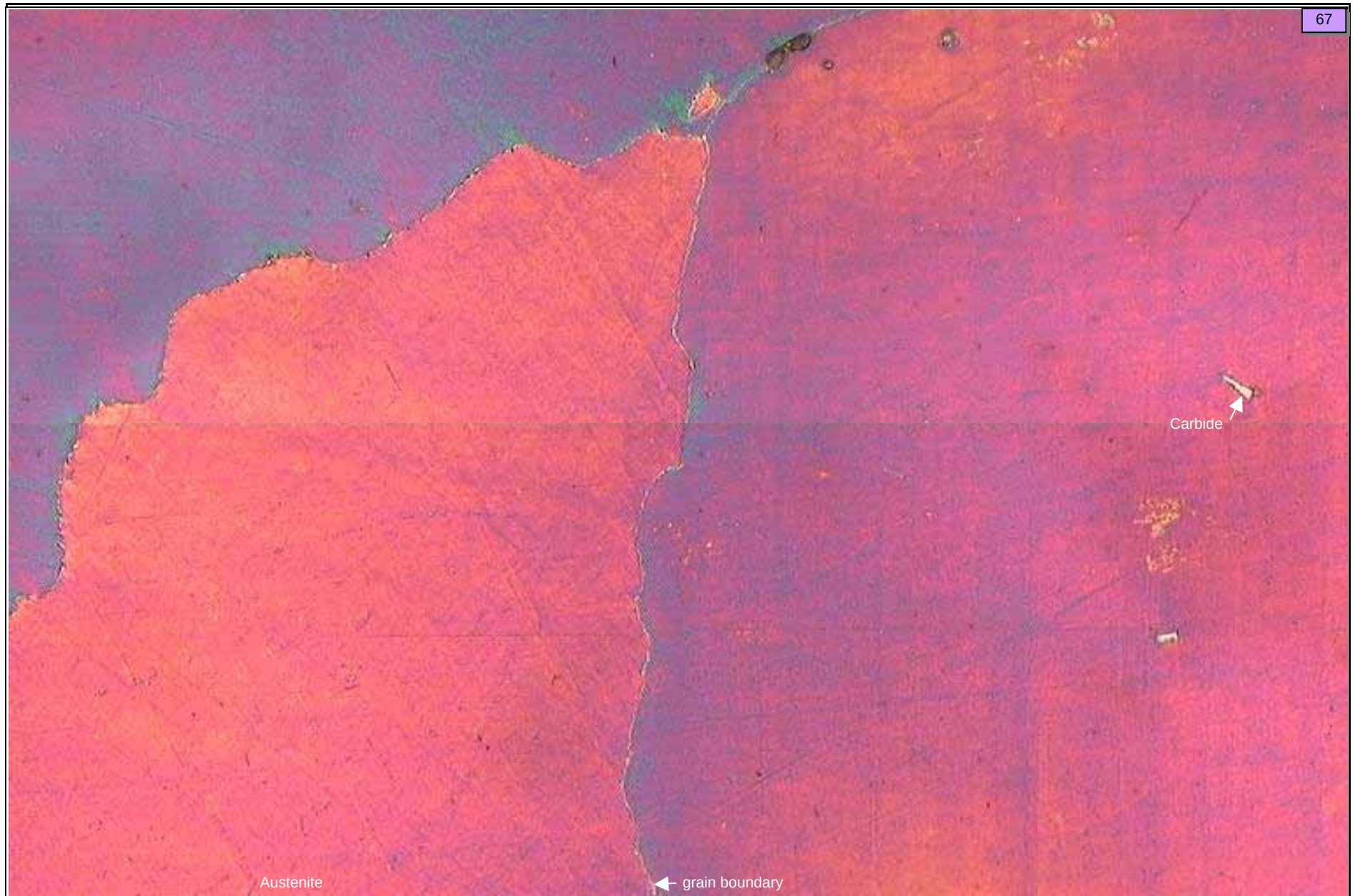


Photo.99:200x, Same as in Photo. 98, but in larger area. The microstructures are Austenite. The grain boundaries are thinner and less carbide after annealing.