Volume



Metallography and Microstructures



## **Contents**

Introdu	tion1	Dendritic Microstructure	109
Metallography: An Introduction		Microsegregation	111
Meanio		Macrosegregation	111
	The Origins of Metallography4	Defects	112
	Macroanalysis5	Solidification Structures of Titanium Alloys	116
	Microscopic Examination10	Classification of Titanium Alloys	
	Image Analysis15	Phase Transformation in Titanium-Aluminum-Base	
Metallu	gy and Microstructure21	Alloys Solidification Structures of Titanium-Aluminum-Base	117
Introduct	ion to Structures in Metals	Alloys	
	General Features of Structure	Peritectic Reactions of α <sub>p</sub> and γ <sub>p</sub> Phases	110
	Origins of Structures	Directional Solidification	110
	Single-Phase Microstructures	Grain Refinement	
	Substructure	Microstructures Produced through Various Near-Net	141
	Multiphase Microstructures		
	Macrostructure	Shape Manufacturing Processes	122
Crustal S	tructure	Computer Modeling of Solidification Structures	
Ci yada c	Crystallographic Terms and Concepts	Standard Transport Models	127
	Metallurgically Important Crystal Types	Phase-Field Models	128
	Crystal Defects 41	Monte Carlo (MC) Models	
Dlacada a 1	Metallurgy Concepts in Interpretation of Microstructure44	Cellular Automaton (CA) Models	129
rnysicai	Metallingy Concepts in interpretation of Microstructure44		
	Structure and Properties	Solid-State Transformation Structures	
	Equilibrium Phase Diagrams	Introduction to Transformation Structures	
	Nonequilibrium Phase Nucleation and Growth53	Multiphase Microstructures	132
	Solidification57	Substructures	132
	Solid-State Phase Transformations	Crystallography	132
	Transformation Kinetics	Structures by Precipitation from Solid Solution	134
Solidifica	ution Structures	Nucleation and Growth	
	ntals of Solidification71	Precipitation Modes	137
rundazuc	Length Scale of Solidification Structures	Precipitation Sequences	139
	Undercooling	Spinodal Transformation Structures	
	Nucleation 74	Theory of Spinodal Decomposition	
		Microstructure	
	Growth and Interface Stability74	Ordered Structures	
	Basic Solidification Structures of Pure Metals	Antiphase Boundaries	
	Solidification Structures of Solid Solutions	Long-Range and Short-Range Order	
	Solidification Structures of Entectics		
	Solidification Structures of Peritectics84	L1 <sub>0</sub> Superlattice (CuAuI Structure)	
	Solidification Structures of Monotectics	L1 <sub>2</sub> Superlattice (Cu <sub>3</sub> An Structure)	
Solidifica	tion Structures of Pure Metals93	B2 Superlattice (FeAl Structure)	
	Polycrystalline Metals	DO <sub>3</sub> Superlattice (Fe <sub>3</sub> Al Structure)	
	Grain Boundaries94	Dislocation-Generated Antiphase Boundaries	
Solidifica	tion Structures of Steels and Cast Iron97	Massive Transformation Structures	
	Steel97	Pure Metals and Congruent Points	
	Cast Iron	Two-Phase Regions	
Solidifica	tion Structures of Aluminum Alloys107	Nucleation and Growth Kinetics	
	Basic Microstructures of Aluminum-Base Alloys 107	Feathery Structures	
	Grain Structure108	Single-Crystal Growth	
	Eutectic Microstructure of Aluminum-Silicon Alloys 109	Recent Developments	151

nvariant Transformation Structures	. 152	Certification Work	
Eutectoid Structures	.153	Process Control and Troubleshooting	239
Pearlite Colony Orientation and Nucleation	. 153	Component Failure Analysis	240
Nucleation of Pearlite on Procutectoid Ferrite or		Mounting of Specimens	242
Cementite	. 154	Cleaning	
Pearlite Growth	. 154	Mechanical Clamps	242
Alloy Effects	. 155	Plastic Mounts	243
Peritectic and Peritectoid Structures	. 156	Mount Size and Configuration	247
Peritectoid Structures		Compression Molded Mounts	
Peritectic Structures		Cast Mounts	
Martensitic Structures	. 165	Special Mounting Techniques	254
Ferrous Martensite		Mount Marking and Storage	
Crystallographic Theory		Mechanical Grinding and Polishing	
Orientation Relationships and Habit Plane		Surface Preparation	
Morphology		Abrasion Damage and Abrasion Artifacts	
Transformation Temperatures		Polishing Damage	
Tempering of Martensite	170	Final-Polishing Processes	
Nonferrous Martensite		Edge Retention	
Metallic Systems		Special Techniques for Unusual Materials	
Ceramic Systems		Semiautomatic Preparation Systems	
Other Systems		Chemical and Electrolytic Polishing	
Shape Memory Materials		Chemical Polishing	
Bainitie Structures		Electrolytic Polishing	
Upper Bainite		Contrast Enhancement and Etching	
Surface Relief		Etching Nomenclature	
		Optical Enhancement of Contrast	
Lower Bainite			
Inverse Bainite		Contrast Enhancement by Film Deposition	
Granular Bainite		Etching	
Columnar Bainite		Etching for Effect	
Bainite in Nonferrous Systems		Etchants and Etching Practice	
Recent Developments	184	Preparation and Handling of Etchants	
Other Structures		Macroetching	
Interdiffusion Structures	186	Procedures	
Analysis of Interdiffusion Microstructures		Apparatus	
Examples of Interdiffusion Microstructures		Etching Solutions	
		Etching Operations	
Conclusions		Macroetching of Iron and Steel	316
		Macroetching of High-Alloy Steels, Stainless Steels,	
Microstructural Evolution by Grain Subdivision	192	and High-Temperature Alloys	
Microstructure Parameters: Quantitative and Theoretical		Macroetching of Titanium	319
Analysis			
and the second s		Macroetching of Aluminum and Aluminum Alloys	320
Macroscopic Properties	203		
Conclusion	203	Macroetching of Aluminum and Aluminum Alloys	323
Conclusion	203 205 207	Macroetching of Aluminum and Aluminum Alloys  Macroetching of Copper and Copper Alloys	323
Conclusion	203 205 207 207	Macroetching of Aluminum and Aluminum Alloys  Macroetching of Copper and Copper Alloys	323
Conclusion  Recovery, Recrystallization, and Grain Growth Structures The Deformed State  Recovery	203 205 207 207 208	Macroetching of Aluminum and Aluminum Alloys  Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy	323
Conclusion  Recovery, Recrystallization, and Grain Growth Structures The Deformed State Recovery Recrystallization	203 205 207 207 208 209	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts	323
Conclusion  Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth	203 205 207 207 208 209 212	Macroetching of Aluminum and Aluminum Alloys  Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy	323 324 325
Conclusion  Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures	203 205 207 207 208 209 212 215	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts Light and Electron Microscopy Methods of Image Formation Pixels	323 324 325 325
Conclusion  Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth	203 205 207 207 208 209 212 215	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope	323 324 325 325 325
Conclusion  Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures	203 205 207 207 208 209 212 215	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification	323 324 325 325 325 325
Conclusion .  Recuvery, Recrystallization, and Grain Growth Structures The Deformed State Recovery Recrystallization Grain Growth  Textured Structures Texture Evolution and Control	203 205 207 207 208 209 212 215 216	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution	323 324 325 325 325 327 327
Conclusion  Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures  Texture Evolution and Control  Texture Characterization and Experimental	203 205 207 207 208 209 212 215 216	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts Light and Electron Microscopy Microscopy Microscopy The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus	323 324 325 325 325 327 327 327
Conclusion  Recuvery, Recrystallization, and Grain Growth Structures The Deformed State	203 205 207 207 208 209 212 215 216	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems	323 324 325 325 325 327 327 329 330
Conclusion Recuvery, Recrystalization, and Grain Growth Structures The Deformed State Recovery Recrystallization Grain Growth Textured Structures Texture Evolution and Control Texture Characterization and Experimental Determination Microckutre, Grain-Boundary Character, and Texture	203 205 207 207 208 209 212 215 216 218	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems Electrons versus Light	323 324 325 325 325 327 327 329 330
Conclusion Conclusion Recovery, Recrystallization, and Grain Growth Structures The Deformed State Recovery Recrystallization Grain Growth Textured Structures Texture Evolution and Control Texture Characterization and Experimental Determination Microtexture, Grain-Boundary Character, and Texture Gradients Modeling of Texture Evolution	203 205 207 207 208 209 212 215 216 218 223	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems Electrons versus Light Light Microscopy	323 324 325 325 325 327 327 329 330 330
Conclusion Conclusion Recovery, Recrystallization, and Grain Growth Structures The Deformed State Recovery Recrystallization Grain Growth Textured Structures Texture Evolution and Control Texture Characterization and Experimental Determination Microtexture, Grain-Boundary Character, and Texture Gradients	203 205 207 207 208 209 212 215 216 218 223	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberations in Optical Systems Electrons versus Light Light Microscopy Microscopy Components	323 324 325 325 325 327 327 330 330 332
Conclusion  Recovery, Recrystallization, and Grain Growth Structures The Deformed State Recovery Recrystallization Grain Growth  Textured Structures Texture Evolution and Control Texture Evolution and Control Otermination Determination Microtexture, Grain-Boundary Character, and Texture Gradients Modeling of Texture Evolution  Metallographic Techniques	203 205 207 207 207 208 209 212 215 216 218 223 224	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Microscopy  The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems Electrons versus Light Light Microscopy Microscopy Microscopy Microscopy Optical Performance	323 324 325 325 325 327 327 329 330 330 332 332 332
Conclusion  Recuvery, Recrystallization, and Grain Growth Structures The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures  Texture Evolution and Control  Texture Evolution and Experimental  Determination  Microtexture, Grain-Boundary Character, and Texture Gradients  Modeling of Texture Evolution  Metallographic Techniques  Metallographic Sectioning and Specimen Extraction	203 205 207 207 207 208 209 212 215 216 218 223 224 227	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems Electrons versus Light Light Microscopy Microscopy Microscopy Optical Performance Examination Modes	323 324 325 325 325 327 329 330 330 332 332 332 333
Conclusion  Recovery, Recrystallization, and Grain Growth Structures  The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures  Texture Evolution and Control  Texture Characterization and Experimental  Determination  Microtexture, Grain-Boundary Character, and Texture Gradients  Modeling of Texture Evolution  Metallographic Techniques  Metallographic Techniques  Metallographic Sectioning and Specimen Extraction  Process and Practices	203205207207208209212215216218223224227	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysts Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberations in Optical Systems Electrons versus Light Light Microscope Omponents Optical Performance Examination Modes Auxiliary Techniques	323 324 325 325 327 327 330 330 332 332 332 332 332
Conclusion  Recuvery, Recrystallization, and Grain Growth Structures The Deformed State  Recovery  Recrystallization  Grain Growth  Textured Structures  Texture Evolution and Control  Texture Evolution and Experimental  Determination  Microtexture, Grain-Boundary Character, and Texture Gradients  Modeling of Texture Evolution  Metallographic Techniques  Metallographic Sectioning and Specimen Extraction	203205207207208209212215216218223224227229230233	Macroetching of Aluminum and Aluminum Alloys Macroetching of Copper and Copper Alloys Other Metals and Alloys  Microscopy and Image Analysis Light and Electron Microscopy Methods of Image Formation Pixels The Light-Optical Microscope Magnification Resolution Depth of Field and Depth of Focus Aberrations in Optical Systems Electrons versus Light Light Microscopy Microscopy Microscopy Optical Performance Examination Modes	323 324 325 325 327 327 329 330 330 332 332 332 332 3346 348

Scanning Electron Microscopy	Special Applications and Methods
Beam/Sample Interactions	Metallography of Archaeological Alloys
Basic Design of the Scanning Electron Microscope 356	Metallography and the Archaeometallurgist
Types of Contrast357	Case Studies
Special Instrumentation and Accessory Equipment 360	Field Metallography Techniques
Sample Preparation	Background479
Applications in Materials Science and Technology 365	Advantages and Disadvantages
Digital Imaging	Basic Equipment and Supplies
Image Acquisition	Planning for Field Metallography
Image Output—Printing	Specimen Preparation
Image Processing and Analysis	Using Field Metallography in the Laboratory
Case Studies 400	Case Studies
Conclusions 401	Conclusions
	Color Metallography 493
Quantitative Image Analysis 403	Optical Methods for Producing Color
Digital versus Manual Methods	
Basic Definitions	Film Formation and Interference Techniques496
Specimen Preparation and Image Acquisition	Conclusions507
Image Processing Necessary for Quantitative Image	Selected Color Images
Analysis411	Metallography and Microstructures of Ferrous Alloys
Digital Measurements	· ·
Counting Objects and Size Distributions	Metallography and Microstructures of Cast Iron
Evaluation of Basic Stereological Parameters416	Preparation for Microexamination
Shape Analysis416	Microexamination Methods570
Spatial Distribution and Three-Dimensional Analysis418	Microstructures581
Quantification and Minimizing the Bias of	Metallography and Microstructures of Low-Carbon and
Measurements	Coated Steels588
Examples of Automatic Quantitative Image Analysis 422	Microstructural Constituents
Quantitative Characterization and Representation of Global	Metallographic Procedures590
Microstructural Geometry	Specimen Preparation591
Numerical Extents of Microstructural Features (How	Manual Preparation of Coated Steel Specimens
	Metallography and Microstructures of Carbon and Low-Alloy
Much?)	Steels
Number Density of Microstructural Peatures (How	Microstructural Constituents 609
Мапу?)	Metallographic Procedures 614
Derived Microstructural Properties	Metallography and Microstructures of Case-Hardening Steel627
Feature-Specific Size, Shape, and Orientation	Carburized and Carbonitrided Steels
Distributions440	Nitrided Steels
Spatial Clustering and Correlations	Metallographic Techniques for Tool Steels
Three-Dimensional Microscopy	Metanographic Techniques for Tool Steels
Serial Sectioning	Macroexamination 644
Serial-Sectioning Experimental Techniques	Microexamination
Scrial-Sectioning Case Study Examples	Microstructure of Tool Steels
Focused Ion Beam Tomography458	Metallography and Microstructures of Stainless Steels and
Sectioning	Maraging Steels670
Case Study	Macroexamination670
Atom Probe Tomography	Microexamination670
Principles of Atom Probe Tomography	Microstructures of Stainless Steels
	Austenitic Manganese Steel Castings
Methods of Representation	Specimen Preparation701
X-Ray Microtomography461	Macroexamination
General Concepts461	Microexamination
Transmission Tomography461	Microstructure
Phase Contrast Imaging462	Markette 1 1850 de la companya della companya de la companya della
Edge Contrast Tomography463	Metallography and Microstructures of Nonferrous Alloys
X-Ray Fluorescence Tomography463	Metallography Techniques for Aluminum and Its Alloys
Direct-Imaging Methods	Composition and Phases
Computer Reconstruction and Visualization of	Examination of Macrostructure
Three-Dimensional Data	Examination of Microstructure
Preprocessing	SEM Examination
Segmentation 465	Metallography and Microstructures of Beryllium,
Algorithms	Copper-Beryllium, and Nickel-Beryllium Alloys
Virtual Reality	
403	Health and Safety752

Specimen Preparation	Macroexamination	905
Macroexamination755	Microexamination	
Microexamination756	Other Techniques	
Microstructures of Copper-Beryllium Alloys	Metallography and Microstructures of Uranium and Its Alloys	918
Microstructures of Nickel-Beryllium Alloys	Principles of Uranium Alloy Metallurgy	
Beryllium760	Structures of Uranium and Uranium Alloys	920
Metallography and Microstructures of Cobalt and Cobalt Alloys 762	Sample Preparation	
Cobalt Alloy Metallurgy	Macroetching and Macroexamination	930
Metallographic Preparation	Microetching and Microexamination	
Wear-Resistant Cobalt Alloys	Metallography and Microstructures of Zinc and Its Alloys	
Heat-Resistant Cobalt Alloys	Microstructures of Zinc and Zinc Alloys	
Cobalt-Base Corrosion Resistant Alloys	Specimen Preparation	
Metallography and Microstructures of Copper and Its Alloys	Preparation of Zinc Coating Specimens	
Alloving Systems	Microexamination	
Microstructures of Copper and Copper Alloys	Metallography and Microstructures of Zirconium,	737
	Hafnium, and Their Alloys	040
Metallographic Examination		
Metallography and Microstructures of Lead and Its Alloys	Metallurgy of Zirconium and Hafnium Alloys	
Specimen Preparation	History of Zirconium Metallography	
Microscopic Examination	Specimen Preparation	
Microstructures of Lead and Lead Alloys	Examination and Interpretation	951
Lead Alloys in Sleeve Bearings794	Metallography and Microstructures of Ceramics, Composite-M	etal
Metallography and Microstructures of Magnesium and Its Alloys 801	Forms, and Special-Purpose Alloys	
Specimen Preparation		
Macroexamination	Metallography of Biomedical Orthopedic Alloys	
Microexamination	Implant Devices	
Metallurgy and Microstructures	Stainless Steels	962
Metallography and Microstructures of Nickel and Nickel-Copper	Cobalt-Base Alloys	963
Alloys	Titanium and Titanium Alloys	964
Preparation for Microscopic Examination	Porous Coatings	966
Preparation for Macroscopic Examination	Emerging Materials	967
Microstructures of Nickel and Nickel-Copper Alloys 819	Microstructure and Domain Imaging of Magnetic Materials	969
Metallography and Microstructures of Heat-Resistant Alloys 820	Specimen Preparation	
Macroetching	Microstructures of Magnetically Soft Materials	
Specimen Preparation	Microstructures of Permanent Magnets	
Microstructures of Heat-Resistant Alloys	Magnetism and Magnetic Domains	
Phases in Wrought Heat-Resistant Alloys	Metallography and Microstructures of Powder Metallurgy Alloys .	
Metallography and Microstructures of Precious Metals and Precious	Sample Preparation	
	Automatic Grinding and Polishing	
Metal Alloys	Manual Grinding and Polishing	
Specimen Preparation	Uncompacted Powder	
Microstructures of Gold and Gold Alloys		
Microstructures of Platinum and Platinum Alloys 868	Compacted and Consolidated Powders	
Other Precious Metals872	Representative Microstructures of P/M Alloys	
Metallography and Microstructures of Refractory Metals and Their	Metallography and Microstructures of Semisolid Formed Alloys	
Alloys 877	Semisolid Processes	1021
Niobium, Tantalum, Molybdenum, Tungsten and Their	Compositions of Common Alloys Produced Using	
Alloys 877	Semisolid Metalworking	
General Specimen Preparation	Macrostructural Examination	
Alternate Preparation Procedures for Niobium and	Specimen Preparation, Bulk Extraction, and Etching	1032
Tantalum878	Microstructure of Semisolid-Processed Metals and	
Alternate Preparation Procedures for Molybdenum 879	Alloys	1032
Alternate Preparation Procedures for Tungsten	Future Developments	1036
Microstructures	Microstructural Characterization of Thermal Spray Coatings	1038
Rhenium and Its Alloys	Process Variations	
Specimen Preparation	Microstructural Characteristics	
Metallography and Microstructures of Tin and Tin Alloys	Microstructural Analysis by Light Microscopy	
Specimen Preparation 889	Other Methods of Analysis	
Techniques for Tin and Tin Alloy Coatings	Metallography and Microstructures of Weldments	
Microstructures of Tin and Tin Alloys	Sample Preparation	
Metallography and Microstructures of Titanium and Its Alloys 899	Weld Bead Morphology	
	Solidification Structures in Welded Joints	
Types of Titanium Alloys	Solid-State Transformation Structures in Welded Joints	
Specimen Preparation	Sond-State Transformation Structures in Welded Joints	.,1030

Defects in Welded Joints	Laboratory Safety1079
Additional Welding Processes1053	I -b C-E-t- i- M-t-IIb
Preparation and Microstructural Analysis of High-Performance	Laboratory Safety in Metallography
Ceramics	
Specimen Preparation	Laboratory Equipment
Microscopic Examination1058	Personal Protective Equipment
Ceramographic Etching	Chemicals, Storage, and Handling
Classification and Microstructure of Frequently Used	Hydrofluoric Acid Exposure
Ceramics 1060	Conclusions1088
Metallography of Cemented Carbides	Reference Information1091
Metallographic Considerations	Grit Sizes and Grain Size Conversions
Specimen Preparation	Tables of Chemicals and Etchants
Macroexamination	Glossary of Terms
Microexamination1068	Metric Conversion Guide
Microstructures of Cemented Carbides1071	Abbreviations and Symbols
Quantitative Metallography	Index