

Contents

1	Classification, Mineralogy and Industrial Potential of SiO₂ Minerals and Rocks	1
1.1	Introduction	2
1.2	Classification and Properties of SiO ₂ Minerals	2
1.2.1	SiO ₂ Modifications and Varieties	2
1.2.2	Real Structure and Properties of Quartz	3
1.3	Origin and Nomenclature of SiO ₂ Rocks	12
1.3.1	Magmatic and Metamorphic SiO ₂ Rocks	12
1.3.2	Sedimentary SiO ₂ Rocks	13
1.4	Formation and Industrial Use of SiO ₂ Raw Materials	16
1.4.1	Magmatic and Postmagmatic Quartz	17
1.4.2	Metamorphic Quartz	19
1.4.3	Sedimentary SiO ₂ Rocks	19
1.4.4	Synthetic SiO ₂ Raw Materials	20
1.5	Conclusions	21
	References	22
2	Assessment of High Purity Quartz Resources	29
2.1	Introduction	29
2.2	Present Quartz Supplying Countries	30
2.3	Typical High Purity Quartz Applications	31
2.4	Demand Situation	33
2.4.1	Lighting Industries	33
2.4.2	Semiconductor Industry	34
2.4.3	Photovoltaic Industry	34
2.4.4	Optical Fibers	35
2.5	Resource Estimation	35
2.6	Analytics	37
2.6.1	Bulk Chemical Analysis	39
2.6.2	Characterization of Mineral Inclusions	39

2.6.3	Analysis of Fluid (Liquid and Gaseous) Inclusions . . .	42
2.7	High Purity Quartz Processing	45
2.7.1	Pre-processing	45
2.7.2	Physical Processing.	47
2.7.3	Chemical Treatment	48
2.7.4	Thermal Treatment	49
2.8	Conclusion.	49
	References	50
3	Quality Requirements of Quartz Sand	
	in the Building Industry	53
3.1	Introduction	53
3.1.1	The Idea Behind.	53
3.1.2	General Development	54
3.2	Special Developments of Individual Construction Products and Increasing Requirements for Siliceous Raw Materials. . . .	55
3.2.1	Autoclaved Aerated Concrete Industry	55
3.2.2	Calcium Silicate Unit Industry	56
3.2.3	Cement Industry.	59
3.2.4	Clay Brick Industry/Roof Tile Industry	60
3.2.5	Concrete Industry	62
3.2.6	Mortar and Render Industry.	63
3.3	Recent Developments in Mining and Processing	64
3.3.1	Processing of Quartz Sand.	65
3.3.2	Tendencies in Grinding of Quartz.	66
3.4	Quartz Sand Deposits for the Use in Construction Industry . .	67
3.5	Conclusions	69
	References	69
4	Petrological and Chemical Characterisation of High-Purity Quartz Deposits with Examples from Norway	71
4.1	Introduction	72
4.2	Impurities in Quartz	73
4.2.1	Lattice-Bound Trace Elements	73
4.2.2	Submicron and Nano-scale Inclusions	77
4.2.3	Mineral, Melt and Fluid Inclusions	81
4.3	Quality Definition of High-Purity Quartz.	82
4.4	Methods	84
4.4.1	Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS).	84
4.4.2	Backscattered Electron and Cathodoluminescence Imaging.	85

4.5	Norwegian HPQ Deposits	85
4.5.1	The Melkfjell Quartzite	85
4.5.2	Kyanite Quartzites	96
4.5.3	The Nedre Øyvollen Pegmatite	100
4.5.4	The Nesodden Quartz Vein	103
4.5.5	The Kvalvik Deposit	106
4.5.6	The Svanvik Quartz Vein	108
4.6	Summary and Outlook	111
	References	113
5	Evaluation of the Potential of the Pegmatitic Quartz Veins of the Sierra de Comechigones (Argentina) as a Source of High Purity Quartz by a Combination of LA-ICP-MS, ICP, Cathodoluminescence, Gas Chromatography, Fluid Inclusion Analysis, Raman and FTIR spectroscopy	119
5.1	Introduction	120
5.2	Geology	122
5.3	Methods	123
5.3.1	Bulk Chemical Composition by ICP-MS	123
5.3.2	Spot Chemical Analysis by LA-ICP-MS	123
5.3.3	Cathodoluminescence	123
5.3.4	Fluid Inclusion Investigations	124
5.4	Results	125
5.4.1	Petrography	126
5.4.2	Cathodoluminescence	126
5.4.3	Bulk Chemical Composition by ICP-MS	127
5.4.4	Chemical Composition by LA-ICP-MS Spot Analysis	128
5.4.5	Fluid Inclusions	129
5.5	Discussion	134
5.6	Conclusion	134
	References	135
6	Brazilian Quartz Deposits with Special Emphasis on Gemstone Quartz and its Color Treatment	139
6.1	Introduction	140
6.2	Geology of Brazilian Quartz Deposits	141
6.2.1	Brazilian Pegmatite Provinces	141
6.2.2	Hydrothermal Quartz	145
6.2.3	Secondary Deposits	147
6.3	Color Enhancement of Quartz	149
6.3.1	A Brief Historic	149
6.3.2	Color-Enhancing of Gemological Crystalline Quartz in Brazil	150
6.3.3	Quartz Color-Enhancing in Brazil	152

6.4	Concluding Remarks	156
	References	156
7	First-Principles Calculations of the E'_1 Center in Quartz: Structural Models, ^{29}Si Hyperfine Parameters and Association with Al Impurity	161
7.1	Introduction	161
7.2	Computation Methodology	165
7.3	Results and Discussion	167
7.3.1	Single-Oxygen-Vacancy Models	167
7.3.2	Tri-Vacancy Models	168
	References	172
8	Gamma-Irradiation Dependency of EPR and TL-Spectra of Quartz	177
8.1	Introduction	178
8.2	Experimental	181
8.3	Results and Discussion	182
8.4	Conclusion.	187
	References	188
9	Analysis of Low Element Concentrations in Quartz by Electron Microprobe	191
9.1	Introduction	192
9.2	Excited Volume: Spatial Resolution	193
9.3	Pitfalls in Quartz Analysis	196
9.3.1	Influence of Bremsstrahlung	196
9.3.2	Beam Induced Damage	197
9.3.3	Secondary Fluorescence Near Phase Boundaries.	206
9.4	Detection Limits, Precision and Accuracy	210
9.5	Analysis Protocol for Trace Elements in Quartz by EMP	214
	References	215
10	In Situ Analysis of Trace Elements in Quartz Using Laser Ablation Inductively Coupled Plasma Mass Spectrometry	219
10.1	Introduction	220
10.2	Instrumentation	221
10.2.1	Inductively Coupled Mass Spectrometry	221
10.2.2	Laser Ablation Systems.	223
10.3	Experimental Set-Up at NGU.	225
10.4	Standards and Standard Preparation	228
10.5	Measurement Procedure, Calibration and Data Evaluation.	229
10.6	Limits of Detection.	231
10.7	Precision	231

10.8	Discussion	232
10.9	Conclusion.	234
	References	234
11	Cathodoluminescence Microanalysis of the Defect Microstructures of Bulk and Nanoscale Ultrapure Silicon Dioxide Polymorphs for Device Applications	237
11.1	Introduction	238
11.2	Materials and Methods	239
11.3	Results	242
11.4	Discussion	246
11.5	Bulk Single Crystal α -SiO ₂ (Quartz)	247
11.6	Bulk Amorphous α -SiO ₂	248
11.7	Dry Thermal Oxide (Amorphous SiO ₂) on Si (001)	254
11.8	Buried Amorphous SiO ₂ in Si (001)	256
11.9	Conclusions	260
	References	262
12	Trace Element Characteristics, Luminescence Properties and Real Structure of Quartz	265
12.1	Introduction	266
12.2	Methods	269
	12.2.1 CL-Microscopy and -Spectroscopy	269
	12.2.2 Trace Element Analyses	269
12.3	Luminescence and Trace-Element Characterisation of Quartz	270
	12.3.1 Cathodoluminescence Spectroscopy	270
	12.3.2 Trace Element Composition	272
12.4	Correlation of CL-Properties to Point Defects and Trace-Element Composition.	277
	12.4.1 Ultra-Violet to Blue Luminescence Between 330 and 400 nm	277
	12.4.2 Blue to Bluish-Green Luminescence: The 450 and 505 nm-Bands	279
	12.4.3 Greenish-Yellow Luminescence at 580 nm	280
	12.4.4 Brown to Reddish Luminescence Between 630 and 650 nm	280
12.5	Conclusions	282
	References	283
13	Mineralogy, Geochemistry and Cathodoluminescence of Authigenic Quartz from Different Sedimentary Rocks	287
13.1	Introduction	288
13.2	Materials and Methods	289
13.3	Results and Discussion	291

13.3.1	Mineralogy	291
13.3.2	Cathodoluminescence	293
13.3.3	Geochemistry	296
13.3.4	Sources of Silica and Conditions of Quartz Formation	299
13.4	Conclusions	302
	References	303
14	Cathodoluminescent Textures and Trace Elements in Hydrothermal Quartz.	307
14.1	Introduction	308
14.2	CL Textures in Quartz	309
14.2.1	Primary Textures	313
14.2.2	Secondary Textures.	313
14.2.3	CL Textures and Environment of Formation	317
14.3	Trace Elements in Hydrothermal Quartz	317
14.3.1	Analytical Techniques.	317
14.3.2	Trace Element Concentrations in Hydrothermal Quartz	318
14.3.3	Correlations Between CL and Trace Elements in Hydrothermal Quartz.	320
14.3.4	Implications for Hydrothermal Systems and Ore Deposits	323
14.4	Conclusions	325
	References	325
15	Quartz Regeneration and its Use as a Repository of Genetic Information	331
15.1	Introduction	332
15.2	Quartz with Metamorphic Micro-Fabrics and Hydrothermal Trace Element Signatur from Wall Rocks of the Ehrenfriedersdorf Tin Deposit, Erzgebirge, Germany	333
15.3	Limitations to Provenance Analysis: Cathodoluminescence (CL) Colour Imaging of Quartz Pebbles from the Witwatersrand Basin, South Africa	337
15.4	Fluid Inclusions in Quartz: Relationships to Fluids Involved in Wolframite Precipitation in Tungsten Deposits of the Mongolian Altai, Mongolia	341
15.5	Intergrowth Relationships Between Quartz and Ore Minerals: Evidence for South Crofty Tungsten Mine, Cornwall, United Kingdom	345
15.6	Discussion and Conclusions.	347
	References	350
	Index	357