Contents

| Foreword - | v |
|-------------|--|
| Preface — | -VII |
| About the | Editors —— XIV |
| List of Con | tributing Authors —— XVI |
| Barbara Fo | ster |
| 1 Th | e World of Nanotechnology —— 1 |
| 1.1 | Introduction —— 1 |
| 1.2 | What Is Nanotechnology? —— 2 |
| 1.3 | The Growing World of Nanomaterials —— 3 |
| 1.3.1 | Carbon-Based Nanomaterials —— 3 |
| 1.3.2 | Colloidal-Based Nanomaterials —— 5 |
| 1.3.3 | Quantum Dots — 5 |
| 1.3.4 | Biologically Based Nanomaterials —— 8 |
| 1.4 | Instrumentation for Investigating Nanotechnology —— 8 |
| 1.5 | Where Is Nanotechnology Today? —— 10 |
| 1.6 | Applications —— 11 |
| 1.7 | The Role of the Government in Promoting Nanotechnology —— 14 |
| 1.8 | The Nanotechnology Market —— 16 |
| 1.8.1 | Is There Really a "Nanotechnology Market"? —— 16 |
| 1.8.2 | What Is the Size of the Nanotechnology Market? —— 19 |
| 1.8.3 | Nanotechnology Market Sectors —— 21 |
| 1.8.4 | Report Synopses and Excerpts —— 23 |
| 1.9 | The Challenge of Nanotechnology Safety —— 28 |
| 1.10 | The Crucial Need for Education and Certification —— 29 |
| 1.11 | The Future —— 32 |
| 1.11.1 | Nanotechnology Signature Initiatives —— 32 |
| 1.11.2 | Future Research Projects —— 33 |
| 1.12 | Questions for Contemplation —— 36 |
| 1.13 | Bibliography —— 36 |
| Eylem Asm | atulu |
| - Th | - World of Fusing sing Non-materials 44 |

| 2 | ine world of Engineering Nanomaterials —— 41 |
|-------|---|
| 2.1 | Introduction —— 41 |
| 2.1.1 | How Did Engineering Nanomaterials Evolve? —— 41 |
| 2.2 | Stabilization of Nanomaterial Shape —— 43 |



| 2.2.1 | Surfactants — 43 |
|---------------|---|
| 2.2.2 | Nanomaterial Shape and Stabilization —— 43 |
| 2.3 | Classification and Labeling of Nanomaterials —— 46 |
| 2.3.1 | What Are Nanomaterials? —— 46 |
| 2.3.2 | Types of Nanoparticles —— 46 |
| 2.3.3 | Labeling of Nanomaterials —— 49 |
| 2.4 | Toxicity of Nanomaterials —— 51 |
| 2.4.1 | Particle Size —— 51 |
| 2.4.2 | Surface Chemistry —— 51 |
| 2.4.3 | Surface Charges —— 51 |
| 2.4.4 | Surface Area —— 52 |
| 2.5 | Exposure Assessment —— 52 |
| 2.5.1 | Exposure Limit for Nanoparticles —— 52 |
| 2.5.2 | Exposure Monitoring —— 56 |
| 2.6 | Conclusions — 57 |
| 2.7 | Bibliography —— 57 |
| W. S. Khan a | and R. Asmatulu |
| 3 The | Importance of Safety for Manufacturing Nanomaterials — 61 |
| 3.1 | Rapid Growth of Nanotechnology —— 61 |
| 3.2 | Nanotechnology Involvement —— 62 |
| 3.2.1 | Scope of Nanotechnology —— 62 |
| 3.2.2 | Nanotechnology Education and Research Programs —— 64 |
| 3.3 | Nanostructured Materials — 66 |
| 3.3.1 | Nanoparticles — 67 |
| 3.4 | Toxicity of Nanomaterials —— 70 |
| 3.4.1 | Toxicity of Carbon-Based Nanomaterials —— 71 |
| 3.4.2 | Toxicity of Metal-Based Nanomaterials — 73 |
| 3.5 | In Vitro Assessments of Nanomaterial Toxicity —— 75 |
| 3.5.1 | Detection of Surface Contamination —— 75 |
| 3.5.2 | Particle Sizing and Aggregation —— 76 |
| 3.6 | Nano-safety — 79 |
| 3.6.1 | Potential Safety Issues —— 80 |
| 3.6.2 | Exposure Assessment and Characterization —— 80 |
| 3.6.3 | Precautionary Measures —— 80 |
| 3.7 | Conclusions — 82 |
| 3.8 | Bibliography —— 82 |
| Jitendra S. T | ate and Roger A. Hernandez |
| 4 Saf | ety Approaches to Handling Engineered Nanomaterials —— 85 |
| 4.1 | Introduction —— 85 |
| 4.2 | Potential Health Concerns —— 85 |

| 4.3 | Proactive Measures to Examine Precautions —— 86 |
|----------|--|
| 4.4 | Assessment of Engineered Nanomaterials —— 87 |
| 4.4.1 | Hazard Assessment —— 87 |
| 4.4.2 | Hazardous Communication —— 88 |
| 4.4.3 | Exposure Assessment —— 88 |
| 4.5 | Characterization of Engineered Nanomaterials —— 90 |
| 4.5.1 | Fullerenes —— 90 |
| 4.5.2 | Carbon Nanotubes —— 90 |
| 4.5.3 | Carbon Black —— 91 |
| 4.5.4 | Quantum Dots —— 91 |
| 4.5.5 | Metals and Metal Oxides —— 91 |
| 4.6 | Control Preferences —— 92 |
| 4.6.1 | Elimination —— 93 |
| 4.6.2 | Substitution —— 93 |
| 4.6.3 | Isolation — 93 |
| 4.6.4 | Engineering Controls —— 93 |
| 4.6.5 | Administrative Controls —— 94 |
| 4.6.6 | Personal Protective Equipment —— 96 |
| 4.7 | Management of Engineered Nanomaterials —— 96 |
| 4.7.1 | Waste Disposal —— 97 |
| 4.7.2 | Management of Spills —— 97 |
| 4.8 | Overview of National and International Associations that Adopted the |
| | Handling and Use of Nanomaterials —— 98 |
| 4.8.1 | British Standards Institution —— 98 |
| 4.8.2 | Health and Safety Executive —— 98 |
| 4.8.3 | International Organization for Standardization —— 99 |
| 4.8.4 | Organisation for Economic Co-operation and Development —— 100 |
| 4.8.5 | US National Institute for Occupational Safety and Health —— 101 |
| 4.8.6 | Safe Work Australia —— 102 |
| 4.9 | Concluding Remarks —— 103 |
| 4.10 | Questions for Contemplation —— 104 |
| 4.11 | Bibliography —— 105 |
| Christie | e M. Sayes |
| 5 | Certification: Validating Workers' Competence in Nano-safety —— 108 |
| 5.1 | Introduction —— 108 |
| 5.2 | Definition of Nanotechnology for Training and Certification —— 109 |
| 5.3 | Occupational and Environmental Health and Safety |
| | Management —— 109 |
| 5.4 | Anticipating Hazards in Nanotechnology —— 112 |
| 5.5 | Recognizing Hazards in Nanotechnology —— 113 |
| 5.6 | Evaluating Hazards in Nanotechnology —— 115 |
| 5.7 | Controlling Hazards in Nanotechnology —— 115 |

| 5.8 | Confirming Hazards in Nanotechnology —— 117 |
|---------|--|
| 5.9 | Conclusions —— 118 |
| 5.10 | Questions for Contemplation —— 118 |
| 5.11 | Bibliography —— 119 |
| Walt Tr | ybula and Deb Newberry |
| 6 | Understanding the Implications of Nanomaterial Unknowns —— 121 |
| 6.1 | Introduction —— 121 |
| 6.2 | Background on Nanotechnology Safety Programs —— 122 |
| 6.3 | What are Nanomaterial Unknowns? —— 125 |
| 6.4 | Impact on the public —— 127 |
| 6.5 | Risk Avoidance —— 130 |
| 6.6 | Ethics 131 |
| 6.7 | Government Pressure to Create Facts —— 133 |
| 6.8 | There Is No Place for Politics or Opinions —— 134 |
| 6.9 | Summary —— 137 |
| 6.10 | Questions for Contemplation —— 137 |
| 6.11 | Bibliography —— 137 |
| Evelyn | H. Hirt and Walt Trybula |
| 7 | What Is Considered Reliable Information? —— 139 |
| 7.1 | Introduction —— 139 |
| 7.2 | Background on the Use of "nano" —— 140 |
| 7.3 | Information "Fact and Fiction" – the Dangers —— 142 |
| 7.3.1 | Questionable Correlations in Chinese Workers' Deaths —— 143 |
| 7.3.2 | Questionable Identification of "nano" Specific Dangers —— 143 |
| 7.3.3 | Questionable Correlation of Carbon Nanotubes to Asbestos — 144 |
| 7.3.4 | Issues with Nanosilver Particles —— 144 |
| 7.3.5 | Overgeneralization of Human Contact with Nanomaterials —— 145 |
| 7.3.6 | Impacts of Litigation on Fact Finding and Misleading |
| | Correlations —— 146 |
| 7.3.7 | Sources with Conflicting Information —— 146 |
| 7.3.8 | Separating 'Fact and Fiction' —— 147 |
| 7.4 | Validity and Availability of Information Sources —— 147 |
| 7.4.1 | Professional Societies: Resources and Publications —— 148 |
| 7.4.2 | Government-Sponsored Publications and Resources —— 150 |
| 7.4.3 | Other Information Resources —— 150 |
| 7.5 | Summary and Observations —— 151 |
| 7.6 | Questions for Contemplation —— 151 |
| 7.7 | Bibliography —— 152 |

| J. Craig | Hanks and Emily Kay Hanks |
|----------|---|
| 8 | Ethics and Communication: The Essence of Human Behavior —— 153 |
| 8.1 | Introduction —— 153 |
| 8.2 | The Challenge of Ethics for Emerging Technologies —— 154 |
| 8.3 | What Does It Take to Be a Good Professional? —— 155 |
| 8.4 | Technical and Procedural Knowledge and Skill Are Necessary, but not |
| | Enough —— 156 |
| 8.5 | Guidance from Rules Is Necessary, but Compliance |
| | Is not Enough —— 157 |
| 8.6 | Considering Ethical Frameworks —— 160 |
| 8.6.1 | Deontology and Kant: Autonomy and Respect for Persons —— 160 |
| 8.6.2 | The Pursuit of Happiness: Utilitarian Ethics —— 163 |
| 8.6.3 | Virtue: Character and Practice —— 165 |
| 8.7 | Communication and Ethics —— 168 |
| 8.8 | Final Remarks —— 170 |
| 8.9 | Questions for Contemplation —— 171 |
| 8.10 | Bibliography —— 171 |
| Christie | M. Sayes, Patrick Van Burkleo, and Grace V. Aquino |
| 9 | Behavior-Based Worker Safety for Engineered Nanomaterials —— 177 |
| 9.1 | Introduction —— 177 |
| 9.2 | Traditional Behavior-Based Worker Safety —— 178 |
| 9.3 | The ABC Model as applied to Nanotechnology in the Workplace —— 179 |
| 9.4 | Exposure Scenarios Along the Nanomaterial Value Chain —— 180 |
| 9.4.1 | Stage 1: Production and Manufacturing —— 182 |
| 9.4.2 | Stage 2: Distribution and Transportation —— 183 |
| 9.4.3 | Stage 3: Formulators and Users —— 184 |
| 9.4.4 | Stage 4: Disposal, Recycle, and Reuse —— 185 |
| 9.5 | The Role of the Employer —— 186 |
| 9.6 | Questions for Contemplation —— 187 |
| 9.7 | Bibliography —— 187 |
| Dominio | k Fazarro |
| 10 | The Future of Nanotechnology Safety —— 191 |
| 10.1 | Bibliography —— 192 |

Index ---- 193