

# Contents

|          |                                               |           |
|----------|-----------------------------------------------|-----------|
| <b>1</b> | <b>Introduction to Metallic Biomaterials</b>  | <b>1</b>  |
| 1.1      | Brief Overview                                | 1         |
| 1.2      | General Requirements                          | 3         |
| 1.3      | Type of Mostly Used Metals                    | 4         |
| 1.3.1    | Stainless Steels                              | 5         |
| 1.3.2    | Co-Cr Alloys                                  | 5         |
| 1.3.3    | Ti and Ti Alloys                              | 5         |
| 1.3.4    | Precious Alloys                               | 5         |
| 1.3.5    | Other Metals and Alloys                       | 6         |
| 1.4      | Other Biomaterials                            | 6         |
| 1.4.1    | Polymers                                      | 6         |
| 1.4.2    | Ceramics                                      | 7         |
| 1.4.3    | Composites                                    | 7         |
| 1.5      | Recent Development                            | 8         |
| 1.5.1    | Low Elastic Modulus Alloys                    | 8         |
| 1.5.2    | Nickel-Free Alloys                            | 8         |
| 1.5.3    | Metallic Glasses                              | 8         |
| 1.5.4    | Porous Metals                                 | 9         |
| 1.5.5    | Biodegradable Metals                          | 9         |
| 1.6      | Conclusion                                    | 9         |
|          | References                                    | 10        |
| <b>2</b> | <b>Biodegradable Metals: State of the Art</b> | <b>13</b> |
| 2.1      | Paradigm Shifted                              | 13        |
| 2.2      | The Concept                                   | 14        |
| 2.3      | Proof of Concept                              | 16        |
| 2.3.1    | Mechanical Support                            | 16        |
| 2.3.2    | Degradation                                   | 17        |
| 2.4      | Recent Development                            | 17        |
|          | References                                    | 20        |

|          |                                                                     |           |
|----------|---------------------------------------------------------------------|-----------|
| <b>3</b> | <b>Biodegradable Metals for Cardiovascular Applications</b>         | <b>23</b> |
| 3.1      | The Need for Biodegradable Stent                                    | 23        |
| 3.2      | Proposed Metals for Biodegradable Stent                             | 25        |
| 3.2.1    | Iron and its Alloys                                                 | 25        |
| 3.2.2    | Magnesium and its Alloys                                            | 26        |
| 3.3      | Mechanical Property of the Proposed Metals                          | 27        |
| 3.4      | Validation of the Proposed Metals                                   | 28        |
| 3.5      | Idealization of Biodegradable Metals for Stent                      | 31        |
| 3.6      | Strategy to Develop the Ideal Biodegradable Metals for Stent        | 32        |
| 3.6.1    | New Alloys Development                                              | 32        |
| 3.6.2    | New Processing Technique                                            | 32        |
| 3.6.3    | Iterative Validation Method                                         | 33        |
|          | References                                                          | 33        |
| <b>4</b> | <b>Metallic Biodegradable Coronary Stent: Materials Development</b> | <b>39</b> |
| 4.1      | Materials Design                                                    | 39        |
| 4.2      | Materials Production                                                | 40        |
| 4.3      | Microstructure Analysis                                             | 41        |
| 4.4      | Mechanical Property                                                 | 42        |
| 4.5      | Magnetic Property                                                   | 44        |
| 4.6      | Conclusion and Benchmarking                                         | 44        |
|          | References                                                          | 46        |
| <b>5</b> | <b>Metallic Biodegradable Coronary Stent: Degradation Study</b>     | <b>49</b> |
| 5.1      | Static Degradation                                                  | 49        |
| 5.2      | Dynamic Degradation                                                 | 50        |
| 5.3      | In Vitro Cytotoxicity                                               | 52        |
| 5.4      | Conclusion and Benchmarking                                         | 55        |
|          | References                                                          | 56        |
| <b>6</b> | <b>Metallic Biodegradable Coronary Stent: Stent Prototyping</b>     | <b>59</b> |
| 6.1      | Stent Design                                                        | 59        |
| 6.2      | Minitube Fabrication                                                | 60        |
| 6.3      | Stent Fabrication                                                   | 60        |
| 6.3.1    | Laser Cutting                                                       | 60        |
| 6.3.2    | Annealing                                                           | 62        |
| 6.3.3    | Descaling                                                           | 62        |
| 6.4      | Stent's Mechanical Testing                                          | 63        |
| 6.5      | Critics to the Fabrication Process                                  | 64        |
| 6.6      | Stent's Degradation Testing                                         | 64        |
| 6.7      | Conclusion                                                          | 66        |
| 6.8      | Suggestion                                                          | 66        |
|          | References                                                          | 67        |
| <b>7</b> | <b>Perspective</b>                                                  | <b>69</b> |