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"Surgical Tools and Medical Devices" 2nd Edition

Edited by Waqar Ahmed (University of Central Lancashire, UK) and Mark J. Jackson (Kansas State University, USA), Springer International Publishing, Switzerland, 2016, 691 pages, ISBN: 978-3-319-33487-5, £163.00, €227.76, US$249.00

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Introduction

"Surgical Tools and Medical Devices" 2nd Edition provides a comprehensive overview containing 23 chapters written by experts in each field. The chapters are not grouped together according to specific topics, but rather each chapter covers a range of aspects of surgical tools, medical device manufacturing and characterisation, surface engineering and interactions between biomaterials and cells. Besides materials science and technology aspects the reader will find information on biological performance and interactions of cells with items such as carbon-based medical devices and bone graft materials.

While the book does not have a specific application focus, cardiovascular devices seem to get slightly more attention with a dedicated chapter (Chapter 5 'Cardiovascular Interventional and Implantable Devices') and several chapters on related topics, for example surface engineering, diamond like carbon (DLC) coatings and cell-cell interactions of carbon based materials, which are particularly relevant for cardiovascular applications.

The overall theme of the book lies in surface engineering and coatings, aimed at covering recent developments in nanotechnology including nanocoatings and nanostructuring of biomedical devices. The goal of the book is to provide scope for future advances in the field, combining nanomaterials and nanotechnologies with the development of biomedical devices and tools.

Medical devices discussed in this book mainly relate to non-resorbable materials, like titanium based alloys and nanoengineering of their surfaces. Hence, readers looking for information on bioactive, resorbable bone grafts and devices might fall short on expectations. Only a single chapter covers resorbable bone-like grafts.

As the book is a comprehensive overview on a broad variety of topics this review will include only selected chapters related to the reviewer's fields of interest.

Anodisation of Titanium Based Alloys

Chapter 2 by Thomas Webster and Chang Yao (Brown University, USA) describes anodisation and nanostructuring of Ti alloys which is an approach to improve the biocompatibility of Ti-based implant materials. Nanostructured Ti surfaces have been shown to improve the adhesion of relevant cell types involved in osseointegration of metal implants. Anodisation can be used to create nanoscale roughness or nanotubes on Ti surfaces. By controlling the type of electrolyte (for instance sulfuric acid, sodium hydroxide or hydrogen fluoride) and the process parameters like voltage, current density, pH and temperature, the size and morphology of surface nanostructures can be adjusted. The authors give an overview of available studies reporting on nanostructures ranging from nanopores, high aspect ratio nanotubes and regular nano void arrays which can be achieved through tailoring the process parameters and electrolyte type. **Figure 1** shows examples of nanotube morphologies obtained through anodisation of Ti surfaces.

The chapter also provides an overview of selected *in vitro* studies on cell compatibility of nanostructured Ti surfaces. Generally, nanostructured surfaces obtained through anodisation show improved cell adhesion and cell proliferation behaviour which can be attributed to the nano topography corresponding to the exact dimensions for the cell attachment mechanism provided through integrin molecules.

Regarding future directions, the authors suggest that Ti surfaces should have roughness and structuring on all scales ranging from macro to nano which could be achieved through a combination of mechanical grinding and anodisation steps. Furthermore, anodisation could be used as a tool for incorporating drug delivery capabilities into Ti based surfaces by using the nano topography as a reservoir for chemical signalling molecules like bone morphogenetic proteins (BMPs) to stimulate bone regeneration.

Corrosion Behaviour of Nitinol

Chapter 4 by Frank Placido *et al.* (University of Paisley, Scotland, UK) describes a particular study on the influence of surface finish on corrosion behaviour of nitinol. Beside concerns on biocompatibility which is a basic requirement of biomaterials, metals bear the additional risk of corrosion when exposed to the physiological environment. The authors evaluated the influence of different surface finishes, for example those created by chemical etching and mechanical polishing, on the corrosion of nitinol. The corrosion test was performed in 0.9% saline solution and was evaluated in terms of electrochemical potential, open circuit potential (OCP), corrosion pits and current density measurements. The authors showed that chemically etched nitinol wires were most stable (compared to untreated reference and mechanically etched wires) with the highest corrosion potential, a low corrosion rate and a low corrosion current. Additionally, pitting corrosion behaviour was evaluated based on anodic polarisation treatment of the differently treated wires and a ‘pitting potential’ as well as a ‘passivation potential’ were determined. It has been shown that the values for the ‘pitting potential’ and the ‘passivation behaviour’ were closer for the chemically etched wires indicating lower susceptibility to pitting

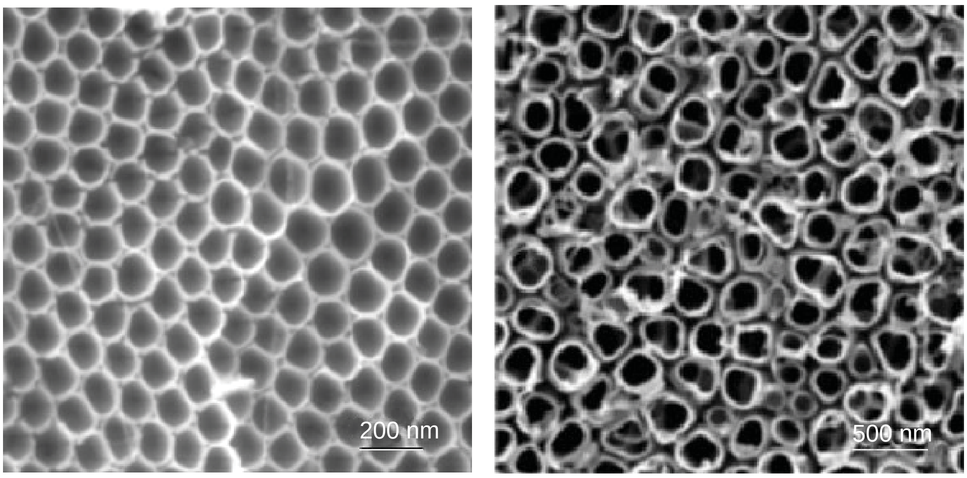


Fig. 1. Examples of nanotube morphologies formed on Ti using anodisation under different process conditions varying the electrolyte type (1)

corrosion. This observation was confirmed through electron microscopic evaluation showing severe pitting corrosion attack accompanied by crack formation on the mechanically treated sample while the chemically etched sampled seemed to be almost unaffected by the anodic treatment. Overall, the authors concluded chemical etching to be a suitable technique to provide enhanced corrosion protection to nitinol materials exposed to corrosive saline environments.

Interventional and Implantable Devices

Chapter 5 by Michael Whitt (California State Polytechnic University, USA) *et al.* gives an overview of generic materials requirements for cardiovascular applications and gives examples of currently used materials and devices. For interventional devices (typically guiding catheters and guiding wires) two most critical parameters are 'track ability' (ease of tracking the device up to the target lesion) and 'push ability' (ability to advance the device across the lesion) which are challenging to measure *in vitro*. Friction can be improved by using hydrophilic coatings as well as hydrophobic coatings like silicon or polytetrafluoroethylene (PTFE) which act as lubricants.

Implantable devices include mechanical (stents) and electrical devices (pacemakers). The main concerns for permanently implanted devices are related to potential thrombus formation (clogging) and blood compatibility (haemocompatibility). Hence, for implantable devices surface properties are key for minimising thrombose risk targeting reduced coagulation, platelet adhesion and platelet activation. In this chapter the reader will find fundamental aspects of thrombus formation and blood cell physiology. For example, a relationship between the haemocompatibility of a material and its electronic structure has been proposed which is based on the theory that fibrinogen denatures (which initiates the cascade reaction leading to thrombus formation) upon electron exchange with an artificial material surface. Hence, the scope for development of haemocompatible implants is targeting materials with semiconducting properties with a band gap of greater than 1.8 eV which is associated with the band gap of fibrinogen (which can be described as a semiconducting material).

Nature's most haemocompatible surface is the endothelium, a thin layer of flat cells lining the interior of blood vessels which, under normal circumstances, prevent blood clogging and allow smooth blood flow. Consequently, a logical and promising approach to increase a material's haemocompatibility is to seed the graft material with endothelial cells prior to implantation. In this context, the compatibility of a graft material with endothelial cells, affecting properties such as their adhesion and proliferation, is essential for adequate performance of cardiovascular device materials. Endothelial cell adhesion on an artificial surface involves distinct molecular interactions which need to be carefully controlled in order to enable confluent cell layer formation, avoiding shear stress and possible complications.

Surface properties of biomaterials are essential for the performance of biomedical devices since the outermost surface (a few atomic layers) are crucial for their interfacial interaction *in vivo*. Surface modifications are widely proposed in order to improve the biocompatibility of material surfaces used for cardiovascular applications.

Surface Engineering of Cardiovascular Devices using Diamond Like Carbon (DLC)

Chapter 6 by Nasar Ali (University of Aveiro, Portugal) *et al.* elaborates on surface compatibility of cardiovascular device materials, describing surface engineering approaches for improving materials biocompatibility based on DLC. DLC coatings are used on prosthetic heart valves since they are chemically inert, hard, wear resistant and biocompatible. It has been shown that DLC reduces platelet adhesion compared to Ti surfaces hence being more haemocompatible. *In vitro* studies have shown reduced platelet adhesion on DLC compared to Ti, TiN and TiC. Typically, no platelet activation, clotting of platelets or thrombus formation are observed on DLC coatings which can be related to a higher ratio of albumin and fibrinogen observed on the DLC coatings.

DLC coatings can also be modified through doping with chromium or silicon. Doping of DLC with silicon has been shown to improve the vitality of endothelial cells and it has been shown that Cr-doped DLC coatings yielded higher endothelial cell attachment. Based on Raman spectroscopy and evaluation of intensities for the D and G graphitic bands, the authors suggest that disordered graphitic phases present in the DLC are responsible for improved endothelial cell viability on Cr-doped DLC coatings.

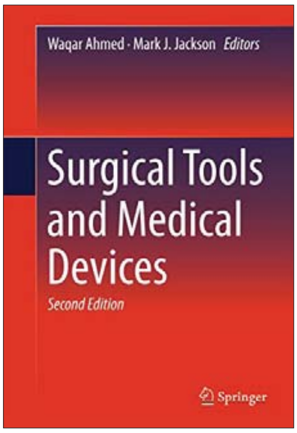
The interactions of biological entities, for example cells and proteins, with artificial surfaces is key for understanding the performance of biomedical devices.

The book includes a chapter (Chapter 11) dedicated to this topic, exploring the fundamentals of interaction between cell biology and materials which can be greatly appreciated by the reader with an engineering background. The chapter provides a comprehensive overview on material cell interactions in surface engineered carbon based biomedical materials, describing the key aspects dictating the biological response to artificial material surfaces including interactions with proteins, various human cell types and bacteria. As such, this chapter gives scope for the development of suitable materials specifically for cardiovascular applications.

Despite significant advances in the mechanical properties of stents and in implant techniques and antithrombotic therapies, the use of stents and heart valves is still complicated by substantial cases of thrombotic occlusions, stenosis and restenosis. Beyond that mechanical failure, wear or debris, oxidation and corrosion can cause failure of biomedical devices.

Conclusion

Overall, the book is a good overview on materials and surface engineering technologies used for biomedical devices and surgical tools. While it is a comprehensive compilation, as a consequence it remains somewhat superficial regarding technical discussion of specific technologies and materials. However, the book will provide a high level introduction to biomedical devices, biomaterials and biomedical surface engineering. Hence, the book is particularly recommended for (bio) materials researchers and technologists who are interested in an overview and an introduction into the field of biomedical devices, especially in the field of cardiovascular applications. Specialists in biomedical device manufacturing might find less of interest, although they may find use in the comprehensive overview and detailed up to date reference content which will provide scope for expanded research on each topic.



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