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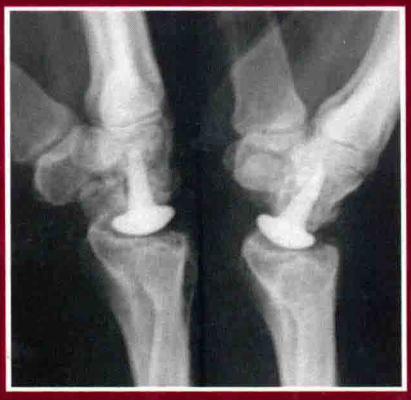

# Coatings for biomedical applications

Edited by Mike Driver

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Coatings for biomedical applications

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# Preface

Coatings are used in a multitude of applications, and invariably when a substrate material does not provide all of the required properties in a particular application. The coating may provide an obvious decorative or protective function, as in many household and industrial applications, or it may provide a much more fundamental change in performance or function by, for example, improving the clinical performance of a medical device. The purpose of this book is to explore some of the types of coating and other surface modification technologies developed for use in biomedical applications and how they have been used to improve performance characteristics.

The book is divided into two parts; the first is focused on different types of coatings and their general applications and the second presents case studies, with a more in-depth look at specific application areas.

Part I starts with a detailed look at hydrophilic coatings, giving consideration to the types of polymers used to make the coatings, including polyethylene glycol (PEG), polyvinyl pyrrolidone (PVP), hyaluronic acid and phosphorylcholine-containing materials, their attachment to surfaces and their properties. An important point is made; hydrophilicity *per se* must not be regarded as the only major consideration when designing an effective biocompatible coating. Chapter 2 looks at mineral coatings developed for use in orthopaedic applications, methods of making and applying them, and their clinical performance. Chapter 3 is focused on the uses of pyrolytic carbon coatings, particularly in orthopaedic and cardiovascular applications. The electrochemical surface modification of titanium is the subject of chapter 4, providing details of the various processes that may be used to modify surfaces with complex inorganic species and more recent research directed towards the development of hybrid organic–inorganic surface treatments. Chapter 5 looks at the methods used to prepare a surface (cleaning, polishing, etching and priming) prior to further treatment, while chapter 6 describes some of the methods employed for characterising surfaces and coatings.

Part II of the book looks in more detail at specific application areas where the use of surface treatments has resulted in medical devices with better performance characteristics. Chapter 7 focuses on the development of coronary stents incorporating drug-eluting coatings and how this approach has dramatically improved clinical outcomes. Chapter 8 looks at the use of coatings to improve the blood compatibility of extracorporeal circuits that are used during open-heart surgical procedures such as cardiopulmonary bypass. In a similar vein, chapter 9 discusses surface modifications designed to reduce complications resulting from blood activation of ventricular assist devices (VADs). Chapter 10 describes the development of joint-replacement prostheses, in particular total hip replacements, with modified surface composition and topography, intended to integrate better with bone. Biofilm formation and mineral encrustation are two related issues affecting the function of urological devices and chapter 11 reviews the use of coatings, including those incorporating antimicrobial compositions, to combat this. Finally, chapter 12 looks at the development of soft contact lenses and other ocular devices, and the use of performance-enhancing surface treatments.

It is not the aim of this book to provide a comprehensive review of every coating system ever reported, but rather to provide an insight into the process that starts with the identification of an unmet need in the clinic, which then leads to scientists providing design, materials science and engineering input, all of which, after many iterative loops and much evaluation (and the support of marketing and regulatory colleagues), can lead to the development of improved medical devices.

*Mike Driver*

# Contents

# Part I

## Coating types and applications

# 1

# Hydrophilic coatings for biomedical applications *in* and *ex vivo*

P. WYMAN, DSM Biomedical Materials, the Netherlands

**Abstract**: Hydrophilic coatings are applied to a wide range of surfaces of biomaterials. This chapter addresses the need for coatings in both *in-* and *ex-vivo* settings for both blood-contacting and non-blood-contacting applications, with illustrations of the coating chemistry used in each setting. Applications for non-fouling surfaces in diagnostics, lubricious surfaces on cardiovascular devices, and both lubricious and antimicrobial hydrophilic surfaces for urological applications are presented. Processes using both photochemical grafting and addition cure technologies to generate hydrophilic surfaces are outlined, and a selection of polymers commonly employed in commercially available coating systems are considered and discussed in the context of the application area.

**Key words**: hydrophilic polymer coatings, non-fouling surfaces, medical devices, *in-vitro* diagnostics, blood contact.

## 1.1 Introduction

Hydrophilic coatings for biomedical application, and more specifically for medical devices, serve numerous purposes. This chapter focuses on applications relevant to medical and medical-related devices, with occasional reference to other applications.

The features and chemistry of common polymers are explored, including covalently and non-covalently bound layers and interpenetrating networks. The relative merits of each approach, along with the advantages and disadvantages of a particular polymer, are illustrated. The chapter covers the application areas relevant to hydrophilic coatings and provides some background and highlights of the favoured chemistries in each of these areas; they are split into *in-vivo* blood contact and non-blood contacting and *ex-vivo*, the division reflecting the regulatory requirements in each application area.

Section 1.2 explores the polymers and chemistries used to generate hydrophilic surfaces and considers the most commonly used materials. Section 1.3 on *ex-vivo* coatings evaluates the use of polyethylene glycol (PEG), and especially PEG functional colloidal particles, for non-fouling