Plasma Technology for Hyperfunctional Surfaces

Food, Biomedical and Textile Applications

Edited by
Hubert Rauscher, Massimo Perucca, and Guy Buyle

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Library of Congress Card No.: applied for

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.d-nb.de.

Typesetting Laserwords Private Limited, Chennai
Printing and Binding betz-druck GmbH, Darmstadt
Cover Design Adam Design, Weinheim

Printed in the Federal Republic of Germany
Printed on acid-free paper

ISBN: 978-3-527-32654-9

Contents

Plasma Technology for Hyperfunctional Surfaces. Food, Biomedical and Textile Applications.
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Preface

The principal aim of this book is the promotion and dissemination of knowledge on plasma technology, underlining its technical applicability, economic sustainability, and minimal environmental impact. This is illustrated via plasma processes that are implemented in traditional or innovative industrial applications in the textile, food packaging and/or processing and biomedical sector. A further objective of this book is to provide selected application examples and case studies deriving from the research, development and technology transfer experienced within ACTECO, a project supported by the European Commission under the 6th Framework Programme. The project provided environmentally friendly, economically sustainable solutions for specific surface functionalities (hyperfunctional surfaces).

This book promotes a broader perspective in the exploitation of plasma technology by thoroughly evaluating the competitive advantages and limitations leading to a new concept of eco-design. In this view, components and products are engineered starting from their functional needs and specifications, rather than from traditional material choice. In this framework, hyperfunctional surfaces, through sustainable dry plasma processing may represent a powerful technique to provide added value via dedicated surface finishing while, at the same time, preserving the beneficial physico-chemical characteristics of the bulk material. Additionally, plasma surface processing can overcome the need for complex composite materials or materials whose specific bulk chemical composition is actually only required at the very surface (e.g., for wear and oxidation resistance of steels).

As a matter of fact, the performance of materials used in major industrial applications in the field of health, food, textile, and environment depends very strongly on the physico-chemical properties of the surfaces. For instance, the very functioning of several biomedical devices is linked to the ability of their surfaces to repel proteins and to avoid biofilm formation. Likewise, textiles for clothing and technical applications are a major target for finishing techniques because imparting, for example, durable hydrophobicity, hydrophilicity, or oleophobicity is a major challenge for several applications. Improved recyclable and/or biodegradable food packaging for a longer shelf life can be realized via more advanced surface barrier properties, while efficient and safe food processing benefits from components whose surfaces are treated against wear, corrosion, and heavy metal migration.

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In general, providing breakthrough competitive and innovative solutions requires a radical new vision for the development of the technological fields involved. Such a new vision should stem from cutting edge scientific knowledge (e.g., from latest progress in nanosciences and nanotechnologies) and be followed by the transfer of exploitable content into up-scalable, industrial solutions. However, the feasibility of a specific surface treatment on the laboratory scale does not necessarily imply its applicability as an industrial process.

For this reason, this book provides a thorough analysis of the developments made for several applications in the form of case studies, thus delivering the stepping stones for wider, more industrial take-up. In particular, the selected examples illustrate that controlling the surface properties has a major impact on the eco-efficiency of the industrial sectors concerned via the reduction of energy and water consumption. Industrial solutions are presented to provide control of adhesion, barrier properties, and wear resistance of materials.

In summary, this book suggests tools and basic knowledge to support the development of novel, knowledge-based added value products and processes, also in traditional industries, less dependent on research and technological development. Its content has been selected to stimulate process design based on eco-innovation and eco-efficiency criteria. Additionally, this book considers modern general demands on novel industrial processes, meaning that the book not only discusses state-of-the-art approaches but also presents a discussion of economic, ecological, and safety issues related to plasma surface processing.

This book consists of three parts. The first part starts with an introduction to plasma technology through plasma fundamentals (Chapter 1) and includes plasma sources (Chapter 2), plasma-surface interactions (Chapter 3), plasma diagnostics (Chapter 4), and surface characterization techniques (Chapter 5).

The second part covers applications studied within ACTECO and, therefore, covers the three domains (food, biomedical, and textile) targeted within the project. These fields currently experience some of the most innovative applications of surface processing by plasma. We will discuss how plasma treatment can be used to tune the surface properties of textiles (Chapter 6), prevent biofilm formation on biomedical surfaces (Chapter 7), provide oxygen barriers for food packaging (Chapter 8) and obtain anti-wear coatings in food processing machines (Chapter 9). A comprehensive theoretical approach is provided to model the interactions of nonthermal atmospheric pressure plasma with surfaces (Chapter 10).

The third part is dedicated to the technical and economic aspects of plasma technology. It includes an analysis of the market potential as well as the economic impact arising from the introduction of plasma technology into the textile, food, and biomedical sectors (Chapter 11). This part concludes with a discussion of environmental and safety issues related to plasma surface treatments (Chapter 12). This includes a comparative life cycle analysis to assess the eco-efficiency of surface plasma functionalization with respect to traditional surface treatment and an assessment of plasma processing safety in terms of process reliability for environmental working conditions as well as the potential local impact due to emissions.

Within this book we have tried to achieve a sufficient cohesion and self consistency. Internal referencing among chapters, although written by different authors, is provided to enable the reader to browse through the content via different pathways, even starting from different points, according to different interests, needs, and background.

This philosophy was followed when putting the manuscript together. Clearly, we cannot list all these chapter interconnections in the preface but we want to highlight an example as a possible suggestion for a path through the book. One of the applications mentioned in the book regards tuning of the surface energy of textiles by plasma treatment. Starting from the specific application discussed in Chapter 6 the reader may move up-stream to Chapter 2 in order to find out details related to plasma systems used for textile processing. Further on the reader may explore the related economic and ecological aspects connected to these processes by visiting Chapters 11 and 12, respectively. Furthermore, additional information can be found in Chapter 5, which illustrates some of the surface characterization techniques employed to assess the physico-chemical changes induced by plasma treatment. A similar approach may be followed for the other main applications dealt with in this book. Nevertheless, the reader may follow a more orthodox approach by sequentially going through each chapter, which provides a more general perspective of the topics treated. The sequential approach is particularly recommended to readers completely new to plasma surface functionalization.

This work has been partially funded by the European Commission in the 6th Research Framework programme through the integrated project ACTECO for small and medium enterprises (IP 515859-2), contract number NMP-CT-2005-515859, launched on 1 May 2005 and ended on 30 April 2009. The full project title is: 'Eco efficient activation for hyperfunctional surfaces'; this highlights its main focus: addressing the use of plasma technology for efficient and effective surface functionalization and activation (*http://www.acteco.org/*).

The consortium, whose composition evolved during the course of the project, consisted of several partners that can be grouped into different categories. The first are end-users within the different application areas: food related (Diad s.r.l., Tops Foods), biomedical applications (PlasMATec, Covidien-Sofradim), and textile companies (Jovertex, Creat-Chargeurs, Luxilon). Another group of companies were the plasma technology providers related to atmospheric as well as low pressure plasma (Muegge, CPI, AcXys, Dow Corning Plasma Solutions, Environment Park, and Europlasma, the project coordinator). Also high-tech SME companies dedicated to surface analysis formed part of the project (CSMA, Biophy, Biomatech). Further, several research centers and universities supported the R&D activities (UPMC, TRINITI, USTUTT-IPF, IFTH, EC-JRC, Centexbel). ACTECO also included a partner to perform market studies (Nodal) and sector associations covering the three targeted domains via IVLV, Clubtex, and Eucomed. A full list with the contact details of the project partners, according to the situation at the end of the project, can be found at the end of the preface.

We would like to thank all ACTECO partners, whose valuable contributions throughout the project created a synergy that made ACTECO a success story. Without them, their precious work carried out within the project and their input during the writing of the manuscript, this book could not have been written.

We tried our best to design and write a book that is useful for people already working in plasma technology as well as for those whose focus is more on one of the application fields discussed. Moreover, suggestions may be found for the application of plasma technology in industrial sectors not explicitly treated here.

Plasma Technology for Hyperfunctional Surfaces: Food, Biomedical and Textile Applications addresses industry professionals, researchers, academic teachers and PhD students specializing in the field of plasma physics and chemistry, as well as people entering the field of plasma surface treatments and technical staff involved in economic sustainability and ecology. Our intention is that also policy makers in the field of clean, environmentally friendly, and economically efficient technological innovations will find useful information here on trends and potentials of plasma surface engineering.

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ISBN: 978-3-527-32654-9

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ISBN: 978-3-527-32654-9

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ISBN: 978-3-527-32654-9