Plasmonic Nanoelectronics and Sensing

Plasmonic nanostructures provide new ways of manipulating the flow of light, with nanostructures and nanoparticles exhibiting optical properties never before seen in the macro-world. Covering plasmonic technology from fundamental theory to real-world applications, this work provides a comprehensive overview of the field.

- Discusses the fundamental theory of plasmonics, enabling a deeper understanding of plasmonic technology
- Details numerical methods for modeling, design, and optimization of plasmonic nanostructures
- Includes step-by-step design guidelines for active and passive plasmonic devices, demonstrating the implementation of real devices in the standard CMOS nanoscale electronic–photonic integrated circuit to help cut design, fabrication, and characterization time and cost
- Includes real-world case studies of plasmonic devices and sensors, explaining the benefits and downsides of different nanophotonic integrated circuits and sensing platforms.

Ideal for researchers, engineers, and graduate students in the fields of nanophotonics and nanoelectronics as well as optical biosensing.

Er-Ping Li is a Principal Scientist and Director of Nanophotonics and Electronics at the Institute of High Performance Computing, A*STAR, Singapore. He is a Fellow of the IEEE and of the Electromagnetics Academy, USA.

Hong-Son Chu is a Scientist at the Nanophotonics and Electronics Department of the Institute of High Performance Computing, A*STAR, Singapore. He is a member of the Optical Society of America, the IEEE, and the Materials Research Society.

EuMA High Frequency Technologies Series

Series Editor
Peter Russer, Technical University of Munich

Homayoun Nikookar, *Wavelet Radio*
Thomas Zwick, Werner Wiesbeck, Jens Timmermann, and Grzegorz Adamiuk (Eds), *Ultra-wideband RF System Engineering*
Er-Ping Li and Hong-Son Chu, *Plasmonic Nanoelectronics and Sensing*

Forthcoming

Peter Russer, Johannes Russer, Uwe Siart, and Andreas Cangellaris, *Interference and Noise in Electromagnetics*
Maurizio Bozzi, Apostolos Georgiadis, and Ke Wu, *Substrate Integrated Waveguides*
Luca Roselli (Ed.), *Green RFID Systems*
George Deligeorgis, *Graphene Device Engineering*
Luca Pierantoni and Fabio Coccetti, *Radiofrequency Nanoelectronics Engineering*
Alexander Yarovoy, *Introduction to UWB Wireless Technology and Applications*

Plasmonic Nanoelectronics and Sensing

ER-PING LI and HONG-SON CHU
A*STAR Institute of High Performance Computing, Singapore

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107027022

First published 2014

A catalogue record for this publication is available from the British Library

ISBN 978-1-107-02702-2 Hardback

Contents

Cambridge University Press & Assessment
978-1-107-02702-2 — Plasmonic Nanoelectronics and Sensing
Er-Ping Li , Hong-Son Chu
Frontmatter
More Information

Contributors

1 Fundamentals of plasmonics and
2 Plasmonic properties of metal nanostructures
Yuriy A. Akimov
*A*STAR Institute of High Performance Computing, Singapore*

3 Frequency-domain methods for modeling plasmonics
Zhengtong Liu
*A*STAR Institute of High Performance Computing, Singapore*

4 Time-domain simulation for plasmonic devices
Iftikhar Ahmed and Eng Huat Khoo
*A*STAR Institute of High Performance Computing, Singapore*

6 Silicon-based active plasmonic devices for on-chip integration
Dim-Lee Kwong, Guo-Qiang Lo, and Shiyang Zhu
*A*STAR Institute of Microelectronics, Singapore*

7 Plasmonic biosensing devices and systems
Lin Wu and Ping Bai
*A*STAR Institute of High Performance Computing, Singapore*

Preface

Data communication and information processing are driving the rapid development of ultra-high speed and ultra-compactness in nano-photo-electronic integration. Plasmonics technology has in recent years demonstrated the promise to overcome the size mismatch between microscale photonic and nanoscale electronic integration, and it likely will be crucial for the next generation of on-chip optical nano-interconnects, enabling the deployment of small-footprint and low-energy integrated circuitry.

The phenomenon of surface plasmons was first observed in the Lycurgus cup, which is a Roman glass cage cup in the British Museum, London, UK. This special cup is made of a dichroic glass that shows a different color depending on the condition of illumination. Specifically, in daylight, the cup appears to have a green color, which means that light is being reflected from the cup; however, when a light is shone into the cup and transmitted through the glass, it appears to have a red color. Today, we know that this fascinating behavior is due to nanoscopic-scale gold and silver particles embedded in the glass. However, it took 1500 years and doubtless countless fantastic interpretations for a plausible explanation to emerge. In the last few decades, the phenomenon of surface plasmons has been extensively studied both theoretically and experimentally, and there have been attempts to use it for various applications ranging from solar-cell energy and sensing to nanophotonic devices.

This book presents the results from many years of our collective research in the fields of nanoplasmonics and its applications. It presents state-of-the-art plasmonics device modeling and design techniques, with novel developments in particular in CMOS-compatible integrated circuits and sensing technologies. We hope this book can serve as a good basis for further progress in this field, both in academic research and for industrial applications. The book consists of seven chapters, contributed by Yuriy Akimov, Zhengtong Liu, Iftikhar Ahmed, Eng Huat Khoo, Er-Ping Li, Hong-Son Chu, Wu Lin, and Bai Ping, from the Department of Electronics and Photonics, Institute of High Performance Computing, Singapore, and Shiyang Zhu, Patrick Guo-Qiang Lo, and Dim-Lee Kwong from the Institute of Microelectronics, Agency for Science Technology and Research, Singapore.

Chapter 1 introduces the fundamentals of plasmonics associated with Maxwell's theory and applications in plasmonics. Chapter 2 provides an introduction to the plasmonic properties of metal nanostructures. Chapter 3 presents the modeling and simulation of plasmonics associated with plasmonic devices by implementation of frequency-domain numerical methods. In Chapter 4, time-domain simulation methods, in particular the finite-difference time-domain method, are introduced for passive and active plasmonic device design. Chapter 5 describes the development of various passive plasmonic waveguides, in particular CMOS-compatible devices for on-chip nanoelectronic integration, and Chapter 6 presents CMOS-compatible active plasmonic devices for on-chip nanoelectronic integration. Both theoretical studies and experimental results are presented in these two chapters. The recent development of plasmonics for biosensing applications is presented in Chapter 7.

We gratefully acknowledge the research support from the Agency for Science Technology and Research, Singapore. Also acknowledged are the contributors to the book, Drs. Yuriy Akmov, Zhengtong Liu, Iftikhar Ahmed, Eng Huat Khoo, Wu Lin, Bai Ping, Shiyang Zhu, and Patrick Guo-Qiang Lo and Professor Dim-Lee Kwong, who did the really hard work. We also wish to express our gratitude to Mia Balashova and Julie Lancashire from Cambridge University Press for their great assistance in keeping us on schedule. Finally, we are grateful to all the contributors' families, without whose continuing support and understanding this book would never have been published.

We hope that this book will serve as a valuable reference for engineers, researchers, and post-graduate students in the fields of nanophotonics and nanoelectronics as well as optical biosensing. Even though much has been accomplished in these fields, we predict that many more exciting challenges will arise in these areas.

Er-Ping LI and Hong-Son CHU