Preface

Metamaterials, first known as left-handed materials (LHMs) or negative-index materials (NIMs), are artificially constructed *effective materials* using periodic structures that are a fraction of the wavelength of the incident electromagnetic wave, resulting in effective electric and magnetic properties (permittivity and permeability) that are unavailable in natural materials. The ability to design effective materials with deterministic electromagnetic properties makes them very attractive for terahertz applications since natural materials do not respond well to this frequency regime.

Since the discovery and experimental demonstration of artificial material with negative permittivity and negative permeability by Sir Pendry et al. in 1996 and 1999, the research interest in metamaterials has significantly increased. In spite of the intense research activities in the last two decades, application of metamaterials to terahertz frequencies is a recent phenomenon. And, terahertz metamaterials embedded with active devices are even a smaller portion of this research landscape. Moreover, the transition from research to real-world application of terahertz metamaterials is still years behind because of numerous implementation challenges.

This book intends to close that gap by providing theoretical background and experimental and fabrication methods in one comprehensive text. This is well suited for engineers and physicists to be able to design, fabricate, and characterize terahertz metamaterial devices in commercial planar semiconductor processes.

Three case studies are covered in detail involving terahertz modulator and detector implemented in commercial gallium arsenide (GaAs) and complementary metal-oxide semiconductor (CMOS) process for imaging and communication applications.

The first three chapters provide the introduction, background theory, and experimental methods which give the reader the motivation and basic background to understand terahertz metamaterials. The last three chapters provide the three case studies of active metamaterials fabricated in planar semiconductor process for terahertz imaging and communication applications.

Chapter 1 begins by providing the motivation for working in the terahertz frequency regime for its numerous important applications and showing, with quantitative reasoning, why metamaterials are a suitable technology for that regime. An overview of technologies for terahertz wave modulators is presented, which is the primary structure underlying all of the designs in this text.

Chapter 2 reviews some of the basic electromagnetic principles for a basic understanding of metamaterials. One of the key contributions of this text is the analysis of terahertz wave modulators using the Drude–Lorentz model.

Chapter 3 covers the experimental methods for modeling, simulating, and characterizing terahertz metamaterials. A section on CMOS fabrication is introduced with few metamaterial case studies for readers to get familiar with a very accessible process that can be used for limited terahertz metamaterial applications. For metamaterial characterization, terahertz time-domain spectroscopy (THz-TDS) and continuous-wave terahertz spectroscopy (cw-THz) are covered in detail. A section is also dedicated to the alignment of off-axis parabolic mirrors, which is found in most terahertz test setups and should be a valuable resource for anyone doing experiments in this field.

Chapter 4 covers a case study of metamaterial-based terahertz modulator using embedded HEMT devices which is one of the main contributions to the scientific literature by the authors. Design principle of HEMT-controlled metamaterial is covered in detail based on the modulator principle introduced in Chap. 2. Design, fabrication, experimental setup, and test results are also covered in this chapter.

Chapter 5 covers another case study of an all solid-state metamaterial-based terahertz spatial light modulator (SLM) using the HEMT-based modulator described in Chap. 4. The principle behind single-pixel imaging is presented in this chapter followed by design, fabrication, and test of the SLM.

Chapter 6 presents the last case study of a terahertz focal plane array (FPA) using metamaterials in a 0.18 μm CMOS process. The principle of resistive self-fixing detection is covered followed by the design and simulation of the FPA.

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http://www.springer.com/978-3-319-52218-0

Active Metamaterials
Terahertz Modulators and Detectors
Rout, S.; Sonkusale, S.
2017, XIII, 118 p. 67 illus., 59 illus. in color., Hardcover
ISBN: 978-3-319-52218-0