LCP for Microwave Packages and Modules

This comprehensive overview of electrical design using liquid crystal polymer (LCP) gives you everything you need to know to get up to speed on the subject. It describes successful design and development techniques for high-performance microwave and millimeter-wave packages and modules in an organic platform. These were specifically developed to make the most of LCP's inert, hermetic, low-cost, high-frequency (DC to 110+ GHz) properties.

First-hand accounts show you how to avoid various pitfalls during design and development. Extensive electrical design details are given in the areas of broadband circuit design for low-loss interconnects, couplers, splitter–combiners, baluns, phase shifters, time-delay units, power amplifier modules, receiver modules, phased-array antennas, flexible electronics, surface mounted packages, microelectromechanical systems (MEMS), and reliability. Ideal for engineers in the fields of RF, microwave, signal integrity, advanced packaging, material science, optical, and biomedical engineering.

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Contents

Cambridge University Press
978-1-107-00378-1 - LCP for Microwave Packages and Modules
Anh-Vu H. Pham, Morgan J. Chen and Kunia Aihara
Frontmatter
More information

Cambridge University Press
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Frontmatter
More information

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Frontmatter
More information

Preface

Package design and fabrication techniques are critical to the high-frequency community. In building improved products, packaging developments are driven by economics, performance, and reliability. For example, the telecom industry as a whole is currently pushing to improve electrical performance and lower cost by replacing the current transceiver designs with new surface mount solutions. This book is intended for electrical engineers involved in designing microwave circuits. As operating frequencies rise with the emergence of high-speed products, engineers will increasingly need a good understanding of RF/microwave packaging.

This book presents engineering breakthroughs in liquid crystal polymer (LCP) applications to microwave-frequency electronics. It appears that LCP is a highly attractive platform to achieve low-cost hermetic devices that offer mechanical flexibility. These benefits are attractive for applications in gigabit wireless communication, radar and imaging systems. Liquid crystal polymer research is currently a very hot topic in microwave engineering, with contributions from several research groups and organizations on a global level.

As we will discuss, using LCP can be challenging at times. The inert chemistry of LCP, which provides its attractive electrical and mechanical properties, can also act to hinder actual circuit build. The book gives brief descriptions of the theory and provides deep insights into the practical issues of design and realization with LCP. Numerous real-world examples with expanded explanations of previously published works are included to create a comprehensive and cohesive volume. We hope to share tips and tricks that we have found for successfully processing LCP for microwave packages and circuit modules. We describe successful techniques in using LCP and how to avoid pitfalls.

In general, very few books on microwave packaging form an interdisciplinary bridge between electrical, mechanical, and chemical expertise. This will be the first book to discuss LCP packaging at the package, component, and system levels. The authors are perhaps uniquely positioned to describe and discuss novel LCP packaging techniques for microwave circuits, since they come from academia, government, and industrial research. All three authors have conducted research from 2003 to the present on advanced microwave packaging using liquid crystal polymer.

Book organization

The book is organized bottom-up, beginning with the basics of packaging and a description of LCP's fundamental material properties. Next, techniques for physically processing this new material and LCP packaging techniques for devices are discussed. The book gradually progresses into increasingly complex electrical circuits and designs. Numerous specific examples are provided to cover the wide range of microwave packages and circuits. Specific chapter focuses are described below.

Chapter 1 provides an overview of packaging. It includes a discussion of existing electronic packages, package requirements, and general package design process flow. This chapter is intended to provide a sufficiently broad overview of packaging and high-frequency topics.

In Chapter 2 we describe LCP material properties in terms of chemical, electrical, physical, and environmental properties. The chemistry of LCP is discussed in order to offer the reader a comprehensive material property overview. Then LCP materials are electrically characterized to show their excellent low-loss performance and stable operation under humidity. LCP packages are demonstrated to provide a fine-leak rate of less than 5×10^{8} atm cm^3/s, which passes the hermetic requirements set by method 1014, Mil-Std-883 [3]. Hence LCP is a viable low-cost option to replace many traditional ceramic packages.

In Chapter 3 we discuss fabrication techniques for processing LCP, including in-depth detail on novel techniques. We hope to provide insight and to share techniques that we have used to process LCP. Material formats are introduced, and methods for metallizing laminates are presented. Standard PCB processes compatible with LCP are discussed. Detailed descriptions are also provided for flex laminate PCB processes, including metallization, etching, mechanical and laser via processes, and multilayer lamination. Further, novel processes for LCP are presented. These topics include special handling techniques, bulk LCP machining, selective sealing, and molding processes.

In Chapter 4 we show novel implementations for using LCP in MEMS chip-scale packages (CSPs). We explain how, using new packaging processes, we designed and implemented a two-bit phase shifter with RF MEMS switches in a multilayer organic module. This build employing LCP allows MEMS devices to be hermetically sealed with a Si base, LCP walls, and a Cu roof. Blind vias through LCP form first-level interconnects in this package. An application for these MEMS devices in a two-bit phase shifter circuit is shown as an extension of chip-on-flex (CoF) technology.

In Chapter 5 we describe a variety of feed-through designs for air-cavity surface mount technology (SMT) packages. A return loss greater than 20 dB is demonstrated at Ka-band frequencies for these feed-throughs. Air-cavity SMT packages are characterized using a low-noise amplifier (LNA). Further, a multilayer LCP implementation to create a multi-chip module (MCM-L) receiver front end in an air-cavity SMT package is shown. Novel bandpass filter feed-throughs are also

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Anh-Vu H. Pham, Morgan J. Chen and Kunia Aihara
Frontmatter
More information

developed. Bandpass filter designs are presented that give excellent high-frequency interconnection with minimal loss, which allows a DC block to be built directly into the packaging. These research efforts show that it is possible to use low-cost organic hermetic surface mount packages for millimeter-wave frequencies.

Chapter 6 presents LCP for passive components, including implementations for novel wide-band baluns, Wilkinson power combiner–dividers, and hybrid couplers. Many of these devices take advantage of multilayers and thin physical dimensions to achieve breakthrough performance. Our wideband multilayer balun structures make evident how LCP packaging provides an ideal high-density organic module technology with an embedded passive. The balun achieves less than 0.5 dB insertion loss, 0.5 dB amplitude imbalance, and 5° phase imbalance over 6–18 GHz. The broadband Wilkinson offers performance on LCP over 2–18 GHz with 1.6 dB excess insertion loss and 12 dB isolation. A novel, compact, hybrid coupler is demonstrated on multilayer LCP that offers a less than 7° phase imbalance and 15 dB isolation over 2–17 GHz.

In Chapter 7 we discuss LCP packaging for system integration and provide a design for package integration of a true-time delay (TTD) circuit, push–pull power amplifiers (PAs), and a full receiver module with phased-array antennas. Our DC-10 GHz broadband long-time-delay (LTD) circuit provides amplitude compensation over long time variation control from 0 to 600 ps delay in 200 ps increments (two-bit). The LTD is implemented with MEMS switches to provide less than ±0.5 dB amplitude imbalance over all frequencies. Using the broadband LCP baluns described in Chapter 6, a Ku-band push–pull amplifier is presented that achieves 20 dB second-order harmonics reduction over 6–18 GHz. Lastly, a design for a full receiver module that has an integrated phased-array antenna and active devices packaged into a novel LCP platform is given. In this antenna design, LCP is an ideal low-loss material with dimensions suited for microwave propagation.

In Chapter 8 we consider reliability aspects for LCP packaging. Qualification tests and results are provided to demonstrate a high level of robustness under proper process conditions. Typical reliability tests are derived from military and JEDEC standards. Since it passes these stringent life and stress tests, LCP packaging is clearly able to meet the required standards under varying heat, moisture, and temperature conditions.

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Anh-Vu H. Pham, Morgan J. Chen and Kunia Aihara
Frontmatter
More information

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