Liquid Crystal Polymer (LCP) for Microwave/Millimeter Wave Multi-layer Packaging

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***Abstract* — This paper presents characterization and analysis of liquid crystal polymer materials for microwave and millimeter multi-layer packaging. Processing techniques have been developed to fabricate interconnects on this new LCP material. The experimental results demonstrate that an interconnect on LCP achieves a measured insertion loss of less than 0.1 dB/mm up to 50 GHz. This material is highly suitable for microwave and millimeter wave packaging.**

I. INTRODUCTION

Multi-layer packaging continues to play a critical role in achieving miniaturization, low-cost, and high performance. Although multi-layer organic based packaging has demonstrated its feasibility for microwave and millimeter wave applications [1-4], moisture absorption in polymer films is of great concern. A polyimide film expands when it absorbs water, resulting in curling of the flexible circuit. Moisture absorption will cause significant loss to high frequency interconnects on polymer films. To circumvent these issues, hermetic shielded packages can be used to house multi-layer organic-based modules. However, this technique will increase the final assembly cost of an electronic system.

In this paper, we present the characterization and analysis of microwave and millimeter wave interconnects on liquid crystal polymer substrates. We report the fabrication process that is used to fabricate interconnects on LCP. We demonstrate that coplanar waveguide transmission lines on LCP achieve a measured insertion loss of less than 0.1 dB/mm at 50 GHz. This LCP technology is highly feasible for multi-layer packaging at microwave and millimeter wave frequencies.

II. OVERVIEW OF LIQUID CRYSTAL POLYMERS

Liquid crystal polymer is a high performance material that combines the properties of polymers with those of liquids. LCP has a state of condensed matter between crystalline solids and isotropic liquids. The condensed matter is characterized by a combination of physical properties of a liquid crystalline state and specific polymer properties. LCP's are highly crystalline and are aromatic ring-structured compounds that are very stable after polymerizing. The liquid crystalline material can have its molecules realigned using magnetic or electrical fields, and in the process acquire the properties of both solids and liquids [7-9].

A base LCP film is made by extrusion of thermoplastic LCP resins. Typically, the thermoplastic resins can be classified into three types (I, II, and III) according to their

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heat resistance. Type I LCP resins are aromatic polyesters with rigid-rod molecular structures. They have the highest heat resistance and melting temperature ranging from 300-350°C [7-9].

LCP is commercially available in as a bare film, and as 1-layer or 2-layer copper-clad laminates, in both sheets and roll form. The available thickness of LCP ranges from 25, 50, 75 to 125 μm. The copper thickness can be chosen from 9,12, 18, to 35 μm. Table 1 compares the material properties of Kapton and LCP.

Table 1. Typical Material Properties [5,6]

Property	LCP	Kapton
Dielectric Constant	3.0	3.4-3.5
Dissipation Factor	0.003	0.0025-0.0035
Moisture absorption (%) at 23°C&24 hr soak	0.1	0.4-2.5
Coefficient of hygroscopic expansion (ppm/%)	2	22
Coefficient of thermal expansion (ppm/°C)	16 (23-100°C)	20 (-14-38°C)
Transition Temperature (°C)	335	360-410

II. FABRICATION PROCESS

The fabrication steps begin by cleaning the LCP using Isopropyl Alcohol. The thickness of the LCP is 125 μm for our experiments. In our initial design, the 100Å thick chrome is evaporated onto the LCP using an e-beam system. The chrome layer acts as an adhesion layer between gold and LCP. 2000 Å gold is evaporated onto the chrome layer using the same procedure. The positive photoresist is applied on the LCP and is soft-baked at 110°C for 60 seconds and is exposed under ultra-violet light. The positive photoresist is developed in a MF319 solution to form coplanar waveguide (CPW) patterns. The substrate is then hard-baked at 100°C for 30 minutes. The gold/chrome is etched using KI and chrome etchant. The positive photoresist is stripped using PRS-3000. The CPWs are then electroplated in a gold solution at 60°C. The measured roughness of the LCP and gold is 3000 Å and 8000Å, respectively.

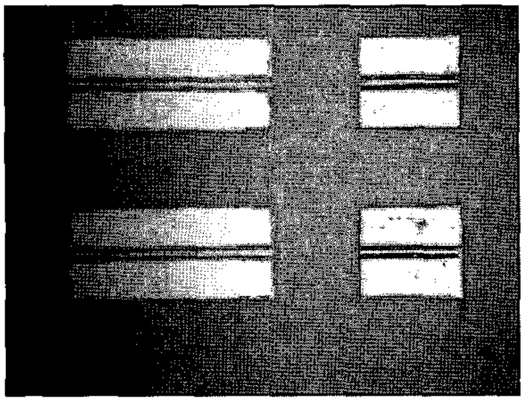

Fig. 1. Prototypes of coplanar waveguide transmission lines on 125 μm-thick LCP. The signal width and gap of the CPW are 230.5 μm and 50 μm, respectively.

III. MICROWAVE AND MILLIMETER WAVE CHARACTERIZATION

A Cascade probe station, an Agilent PNA E8364 Network Analyzer and coplanar waveguid probes were used for two-port S-parameter measurements. Prior to measurements, a line-reflect-match (LRM) calibration was performed to establish reference planes at probe tips. Figures 2 and 3 demonstrate the measured S-parameters of the coplanar waveguide transmission line on the LCP. The CPW on LCP achieves a measured insertion loss of less than 0.1 dB/mm at 50 GHz. This measurement demonstrates the feasibility of developing low-loss structures on multi-layer LCP for millimeter wave applications. In addition, the CPW was designed to achieve 50-Ω characteristic impedance. The measured return loss of less than 20-dB over 50 GHz bandwidth indicates that the material properties of LCP is stable with respect to frequency.

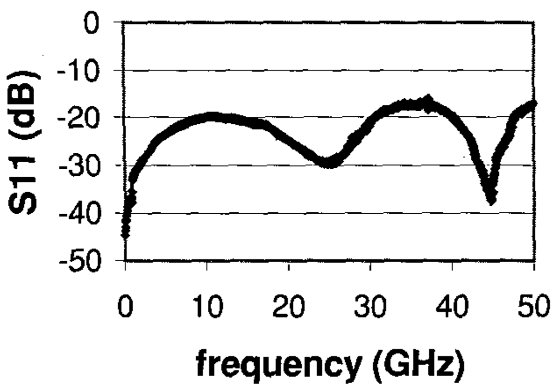

Fig. 2. Measured return loss of a coplanar waveguide transmission line on 125-μm thick LCP (width = 235.5 μm gap = 50 μm)

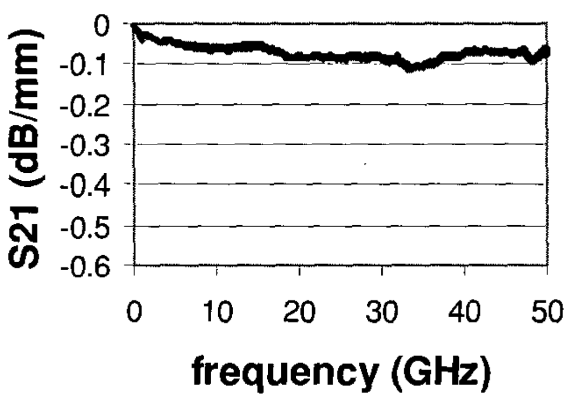

Fig. 3. Measured insertion loss of the CPW on 125-μm thick LCP(width = 235.5 μm gap = 50 μm).

IV. CONCLUSION

This paper presents the fabrication and characterization of interconnects on LCP. The experimental results demonstrate that a coplanar waveguide transmission line on LCP achieves a measured insertion loss of less than 0.1 dB/mm at 50 GHz. This polymer material system is highly suitable for multi-layer organic based packaging. At the meeting, we will present detailed analysis and characterization of a number of passive devices including filters on LCP.

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