Characterization of transmission lines using low loss polymers up to 320 GHz

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***Abstract*— Thin film grounded coplanar waveguides using Parylene-C and Cyclic-Olefin-Copolymer (COC) as low loss thin film have been fabricated and characterized up to 320 GHz. Attenuation around 1.75 dB/mm has been measured at 300 GHz with ~5-µm-thick Parylene-C film, close to the attenuation obtained with Cyclo-Olefin Copolymer film of similar thickness.**

I. INTRODUCTION

Low loss interconnects is a key issue for the development of integrated circuits working in the millimeter wave and in the sub-millimeter wave range. Integrated circuits working at frequency above 0.3 THz use microstrip lines on thin substrate, thin film microstrip lines (TFMSL) or grounded coplanar waveguides (GCPW), which are both located on top of the substrate. Due to their low dielectric constant, polymers are good candidates to be used in TFMSL or GCPW.

Here we present the characterization up to 320 GHz of thin film GCPW based on Cyclic-Olefin Copolymer (ε_r=2.35 at 10 GHz) and Parylene-C (ε_r=2.95 at 1 MHz [1], ε_r =2.62 at 450 GHz [2]). COC is an amorphous non-polar polymer presenting a very low dielectric loss tangent (tan δ=1x10^{-4} at 10 GHz and 7x10^{-4} at 1 THz [3]). Low stress COC layers can be deposited by spin coating and short bake at low temperature (between 140 °C and 200°C) [4]. Parylene is a conformal polymer coater based on poly-para-xylylene. It is a linear and highly crystalline polymer deposited at room-temperature, avoiding thermal stress and damage of active devices. Parylene-C (C for Chlorine) has a high deposition rate (~0.3 µm/min), better mechanical and thermal properties than COC, which is an important issue as far as concerned fabrication aspects, and rather low dielectric losses (tan δ=1.3x10^{-2} at 450 GHz [2]).

II. RESULTS

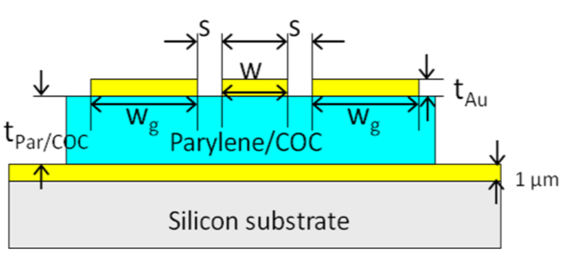

Fig. 1. Geometry of the grounded coplanar waveguide

GCPW transmission lines (see Fig. 1) are designed in order to present a characteristic-impedance (Zc) close to 50 Ω, by means of closed-form expressions based on quasi-TEM and lossless approximations [5],[6]. We present in Table 1 the dimensions of the lines characterized in this study calculated with the dielectric constant of the COC (ε_r=2.35).

	GCPW		
t (µm)	w (µm)	s (µm)	w_g(µm)
5.8/5.2 µm	16	9	100
8.4	24	10.5	100
22	40	5	100

On-wafer measurements have been performed in the 0.5-110-GHz, 140-220-GHz and 220-325 GHz frequency bands by means of vector network analyzers (VNA), coplanar probes and Line-Reflect-Reflect-Match calibration kit. Thanks to negligible return loss, lower than -10 dB in the entire frequency range, the attenuation coefficient (α) and effective refractive index (n_{eff}) of a transmission line at a frequency (f) can be calculated from the transmission scattering parameter (S_{12}=S_{21}) measured on a structure of length (L) considering that:

$$S_{12} \approx e^{-(\alpha + j n_{eff} \frac{2\pi f}{c})L}$$

Attenuation coefficients measured from 4-mm-long GCPW with several COC film thicknesses (t_{COC}=5.8, 8.4 and 22 µm) and with 5.2 µm thick Parylene-C film are shown Fig. 2. In addition, the effect of the conductor-loss is shown by decreasing the Au-strip-thickness from 1 µm to 0.5 µm.

Attenuation clearly decreases with the film thickness. The values obtained on Parylene-C films are comparable to those obtained on COC thin film structures, because dielectric losses in Parylene-C are low enough to be dominated by conductor losses in this frequency range.

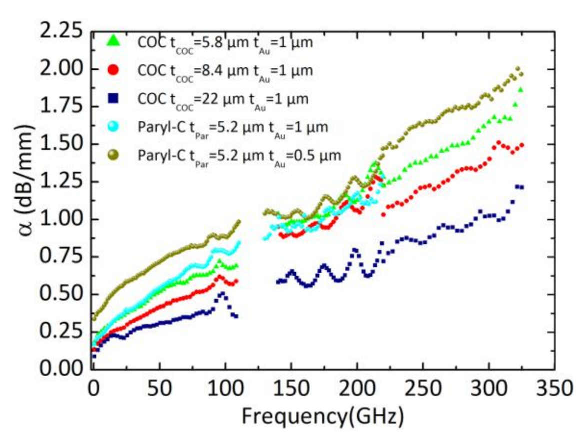

Fig. 2. Attenuation coefficients of grounded coplanar waveguides (GCPW) made on Cyclo-Olefin Copolymer and Parylene-C as a function of the frequency for several films and gold waveguide stripes thicknesses.

In Fig. 3 are shown the effective refractive indexes of the GCPW using both polymers extracted from measurements. We have also drawn the calculated ones obtained by means of closed-form expressions based on quasi-TEM and lossless approximations.

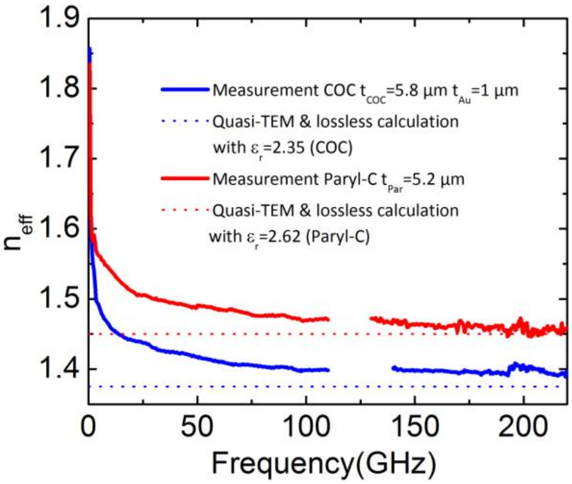

Fig. 3. Effective refractive index of grounded coplanar waveguides (GCPW) made on Cyclo-Olefin Copolymer and Parylene-C as a function of the frequency.

As expected, the GCPW shows dispersive properties in the lowest frequency range because of the frequency dependence of the penetration depth of the electrical currents related to the propagating wave. Beyond 100 GHz, the effective refractive index are quite constant and are close to the calculated ones.

III. SUMMARY

It has been shown that Parylene-C can be used as low loss substrate for thin film transmission line. Losses of 1.75 dB/mm at 320 GHz have been measured on a 5.2-µm thick film close to those obtained with a low-dielectric-loss COC film of same thickness [4].

ACKOWLEDGMENTS

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