Terahertz-Bandwidth Transmission Lines on Low-Permittivity Substrates

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Coplanar waveguides and coplanar striplines fabricated on different substrates- including GaAs, quartz, and a 1.4 µm-thick dielectric membrane [1] were characterized up to terahertz using a novel technique. This technique utilizes an *in situ*, laser-driven photoconductive switch to generate a subpicosecond electrical test pulse with a 3-dB bandwidth of over 500 GHz on the transmission line. The photoconductive switch is formed by first lifting-off a 1-µm-thick low-temperature-grown GaAs epi-layer from its original substrate. This thin film, while supported by the wax, is then bonded to the new substrate using a van der Waals force bond [2]. By monitoring the pulse propagation along the transmission line with a non-contacting electro-optic sampling probe [3], the attenuation coefficients have been determined through the Fourier transform of the time-domain wavforms. For the transmission lines fabricated on the dielectric membrane, there is virtually no dispersion observed in pulses after 3 mm propagation (Fig.1), and only a small loss can be seen. In contrast, the pulses on the transmission line with the GaAs substrate suffered huge losses and severe phase distortion after the same propagation distance. The attenuation coefficient shown in figure 2 is calculated from the time-domain waveforms. For the transmission lines on membrane, it can support signal bandwidth over 1 THz, while the lines on GaAs substrate can only support signals bandwidth less than 150 GHz. For quartz substrates, which provide enhanced mechanical support for devices, a moderate 300 GHz bandwidth has been observed. The even and odd modes of the CPW has also been resolved from the experimental time domain waveforms (Fig.3). The results shown that the difference between the phase velocity of even and odd mode is only 5% . Therefore, the circuit on membrane would be less sensitive to circuit asymmetries of comparable size to those typically found on GaAs substrates.

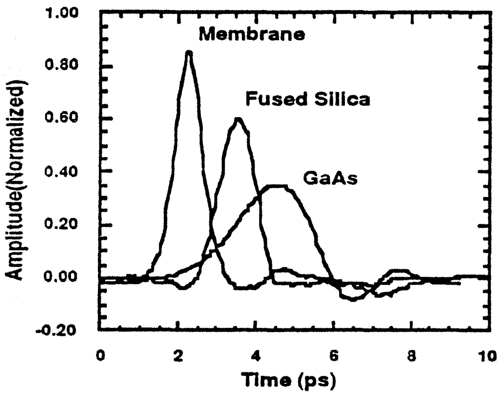

Figure 1. Time domain waveforms of pulses after 3 mm propagation on different substrates. The input pulse has magnitude of 1 and 720 fs FWHM.

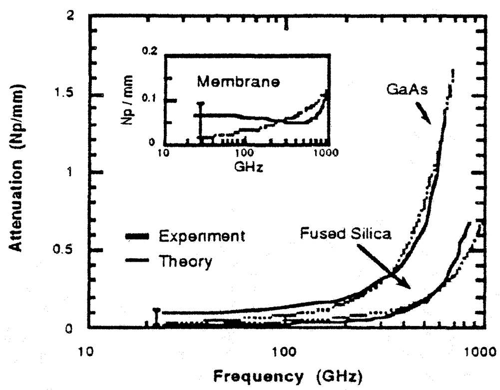

Figure 2. Attenuation coefficients for coplanar stripline on different substrates. The CPS on membrane substrate shows significant lower loss than that of GaAs substrate. At 1 Thz, the CPS on membrane only has loss for about 0.1 Np/mm.

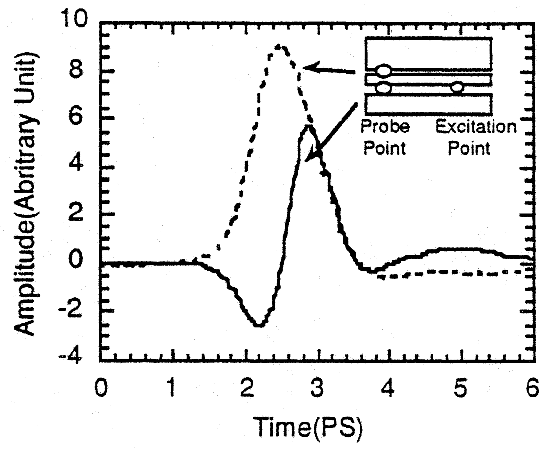

Figure 3. Asymmetrical excitation of Coplanar waveguide to generate both the even and odd modes. The bipolar waveform measured in lower slot shows the opposite direction of electric field of two modes in that slot.

[1] N.I.Dib, W.P. Harokopus, L.P.B. Katehi, C.C.Ling and G.M. Rebeiz,"Study of a novel planar transmission line," 1991 IEEE MTT-S International Symposium Digest.

[2] E. Yablonovitch, D.D. Hwang, T.J. Gmitter, L.T. Flores, and J.P. Harbison, "Van der Walls bonding of GaAs epitaxial liftoff films onto arbtrary substrates," *Appl. Phys. Lett.*, vol. 56, pp. 2419-2421, 1989.

[3] J.A. Valdmanis and G.A. Mourou, "Subpicosecond electrooptic sampling: Principles and applications," *IEEE J. Quantum Electronics.*, vol. 22, pp. 69-78, 1986.