Polymer-Membrane-Supported Fin-line Frequency Multipliers

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Abstract Two polymer-membrane-supported fin-line frequency multipliers were successfully realized on a 7-micron thick polymer membrane at a temperature below 100 °C, using the previously published polymer-membrane based micromachining technologies [1-6]. The said multipliers can generate from a microwave source a signal well beyond 100 GHz in the absence of any DC bias. Spectral domain measurements have been carried out on these frequency multipliers, and the experimental results suggest that the polymer-membrane based micromachining technologies can be used for realization of circuits operating at G-band frequencies.

I. INTRODUCTION

Membrane-supported circuits are circuits suspended on a substrate of negligible thickness. Normally, the substrate thickness is of an insignificant fraction of the dielectric wavelength. The circuits in this technology have been well known for the negligible dielectric losses and almost free-space electrical wavelengths leading to relaxed dimensional tolerances in millimeter-wave and submillimeter-wave circuit design. Previous work [1-6] has demonstrated several photosensitive-resin based microfabrication techniques [6] that allow a planar circuit to be fabricated on a polymer membrane of thickness less than 10 microns. The polymer-membrane itself is an ultra-thin but slightly elastic layer of polymerized photosensitive resin (e.g. SU-8) that can be either photolithographically patterned or manually cut. This permits direct patterning of windows onto the polymer membrane, resulting in added degree of freedom in circuit optimization. Most of the previously published polymer-membrane-based processes [1-6] can be carried out at a temperature well below the melting point of any indium alloys, and thus will not lead to thermal damage to active microwave components. Polymer-membrane based passive circuits have already been published to some extent in [1-6]. This paper further demonstrates with experimental proof two polymer-membrane based active circuits operating at millimeter wave frequencies ---- two frequency multipliers generating a signal at frequencies beyond 100 GHz from a microwave sources.

II. POLYMER-MEMBRANE-SUPPORTED FREQUENCY MULTIPLIERS

Two membrane-supported frequency multipliers have been successfully realized on 7-micron thick membrane, Figs. 1. The process details have been published in detail in Ref [6]. The focus of this section is on the experimental results.

In both multiplier designs, a single-junction millimeter-wave schottky diode obtained from Alpha Industries ™ was used to perform harmonic multiplication on a microwave signal in the absence of any DC bias. Fig. 1 (a) shows a frequency multiplier that generates a W-band signal from a microwave source pumped at around 15 dbm. The W-band signal generated from the diode was filtered using a high-Q fin-line band-pass filter between the fin-line taper and the diode. The window opened on the membrane further enhanced the Q-factor of this band-pass filter. A best conversion loss (see Fig. 2(a)) of 22.78 dB was measured at 108.21 GHz, corresponding to the eight harmonic of a 13.5 GHz input.

Fig. 1 (b) shows another frequency multiplier that generates a G-band output from a microwave source. Fig. 2 (b) shows the measured spectrum of an output at 180.3 GHz, corresponding to the 10th harmonic of an 18 GHz signal. The G-band multiplier design has not been optimized, and the exact conversion loss cannot be confirmed presently. However, our initial experimental results suggest that the polymer-membrane-based technologies can be used for realization of circuits operating at G-band frequencies.

III. POSSIBLE EXTENSION TO THE EXISTING POLYMER-MEMBRANE BASED TECHNOLOGIES

The existing polymer-membrane micromachining technologies require manual mounting of devices onto a circuit containing one or more active components. It is believed that the way of manually mounting the devices significantly introduced unwanted parasitic burden that contributes negative impact to the conversion efficiency of the frequency multipliers at millimeter wave frequencies. We are now considering a possible extension of the existing polymer-membrane micromachining technologies to minimize these problems. At the time of this writing, the commercially available photosensitive polymers do not favor device-level integration of active devices that operate beyond W-band frequencies. One of the available options is to integrate the device(s) at chip-level. This section proposes an alternative polymer micromachining technique that fulfills this criterion and that was proven working at 30 GHz by the researchers of University of Leeds. What follows outlines the steps involved in this technique:

1. Two sacrificial layers are deposited onto an optically smooth glass slide as illustrated in Fig. 3a, namely sacrificial layer 1 and sacrificial layer 2. Sacrificial layer 1 can be a layer of organic material, while Sacrificial layer 2 needs to be in an inorganic material not soluble in any organic solvent.

2. The required devices are placed upside down to the top surface of sacrificial 1, with the bond pads facing downward and pressing the surface of sacrificial layer 1 (see Fig. 3b).

3. A layer of photosensitive polymer (called polymer-membrane) is spin-coated onto the wafer obtained from step 2, and cured under a suitable radiation source (see Fig. 3c).

4. The polymer membrane together with the devices is lift-off by removing sacrificial layers 1 and 2 (see Fig. 3d).

5. The metalization is photolithographically patterned and deposited onto the bottom surface of the membrane to the required thickness (see Fig. 3e).

IV. DISCUSSION AND CONCLUSIONS

This paper has presented with experimental proof two polymer-membrane-supported fin-line multipliers, both of which successfully generated a signal well above 100 GHz from a microwave source. The multipliers were fabricated on a 7-micron thick polymer membrane at a temperature below 100 °C, using the previously published polymer-membrane based micromachining technologies [1-6]. Our initial experimental results suggest that the polymer-membrane based micromachining technologies can be used for realization of circuits operating at G-band frequencies. It is believed that the performance of the frequency multipliers can be further improved by adopting an alternative fabrication technique that supports integration of device chips onto the polymer membrane.

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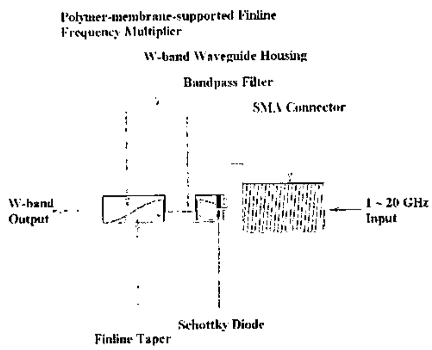
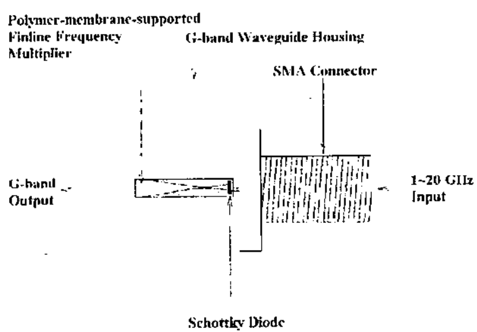
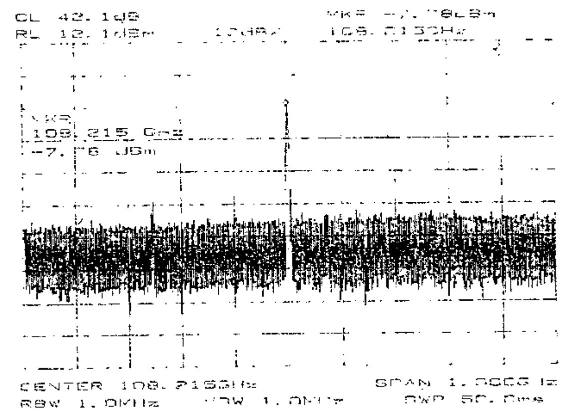


(a)

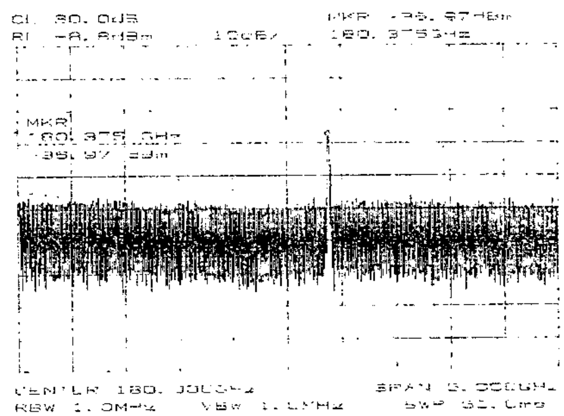


(b)

Fig. 1. Polymer-membrane-supported Fin-line Frequency Multipliers (a) Output at W-band; (b) Output at G-band

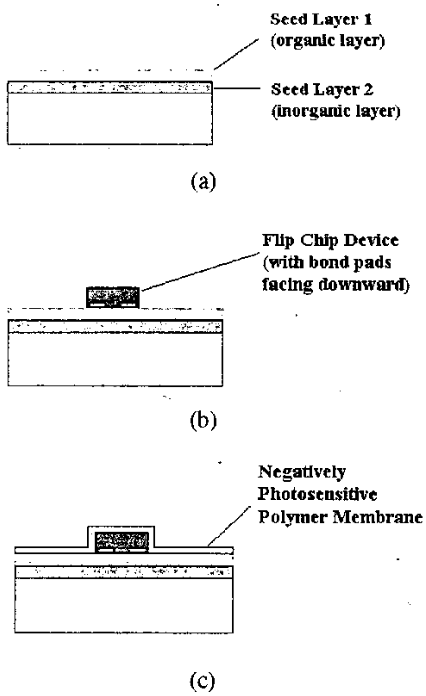


(a)



(b)

Fig. 2. (a) Output spectrum of the Fin-line Frequency Multiplier shown in Fig. 1a, when the input was pumped at 13.5 GHz, 15 dbm; (b) Output spectrum of the Fin-line Frequency Multiplier shown in Fig. 2b, when the input was pumped at 18 GHz, 15 dbm.



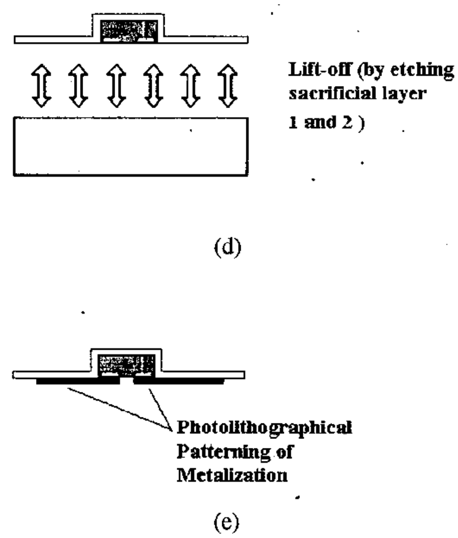


Fig. 3. Process flow of polymer micromachining technique that supports chip-level integration