Low Loss Silicon Waveguides for the Terahertz Spectral Region

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***Abstract*— Chip scale terahertz dielectric waveguides, consisting out of high resistivity silicon as a core material have been fabricated. The waveguide loss is measured to be ~1dB/cm at both 1 THz and 2.5 THz.**

I. INTRODUCTION

The terahertz frequency band (ranging from 0.3 THz to 3 THz) in between the microwave frequency band and the optical frequency band has proven to be a frequency range were it is technologically difficult to develop building blocks. \ One component that is missing is a low loss waveguide. Such waveguides are a critical building block for more complex terahertz systems such as for example chip scale Terahertz gas sensors. It is the lack of highly transparent materials in the terahertz wavelength range which makes the fabrication of terahertz waveguides challenging. High-resistivity float zone silicon (High Res Si) has been proposed as the material of choice for making integrated waveguides [1]. Indeed the high refractive index of silicon (3.42 ~at 1 THz) combined with the low loss in the 0-4 THz range (<1 dB/cm) [2] makes the platform an ideal candidate for the integration of terahertz components on a chip. Here we show the experimental realization of high resistivity silicon waveguides at terahertz frequencies. The waveguide loss is measured to be less than 1dB/cm.

II. FABRICATION

The fabrication process of the waveguides is shown in Fig 1(a). The fabrication starts with depositing silicon nitride on both sides of an oxidized silicon wafer (1). Photoresist is then spin coated on the wafer, patterned and developed, after which the silicon nitride and silicon oxide layer is etched using reactive ion etching (RIE) (2). In the next step (3), trenches are etched 150 µm deep by wet-etching the silicon in a KOH solution. A high-resistivity SOI wafer is bonded on top of the processed handle wafer by using a benzocyclobutene (BCB) polymer as a bonding agent (4,5). The SOI wafer consists out of a 100 µm thick high resistivity (>10 kΩcm) silicon layer on top of a 2 µm oxide layer on a 350 µm silicon handle wafer. The substrate wafer is removed in two steps. The substrate is first partially removed in a grinding step (6) after which the remaining silicon is removed in a KOH wet-etching step (7). The remaining silicon-oxide layer is removed by HF wet etching the oxide. The waveguides are patterned in the bonded high resistivity silicon layer with the help of a thick photoresist (8) and deep reactive ion etching (9) (DRIE). In Figure 1 (b) a top view of the silicon waveguides can be seen. The rib waveguides are 70 µm wide and are etched 80 µm deep. By wrapping the waveguides in a small spiral-coil, long waveguides with lengths of 2, 7.5 and 14 cm were fabricated on a small footprint (<2.5 cm2).

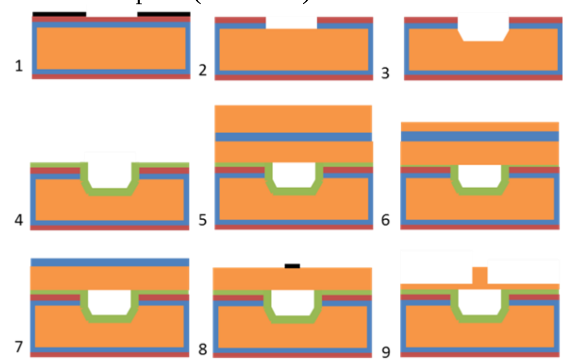

Figure 1: Fabrication processing steps

III. LOSS MEASUREMENT

The waveguides were characterized in a cut back measurement. A terahertz continuous wave methanol gas laser pumped by a CO2 laser is used as a source. The light is coupled in and out of the chip using polymer lenses with a focal length of 2.5 cm. A bolometer is used to measure the output power. The terahertz gas laser is first tuned to 2.5 THz and the horizontal polarization of the emitted light excites the quasi TE-mode of the waveguide. In a next experiment the gas laser is tuned to 1 THz, where the vertical polarization excites the quasi TM mode of the waveguide. In both the experiments the insertion loss of waveguides with a length of 2, 7.5 and 14 cm are measured. The loss was found to be less than 1 dB/cm at both wavelengths.

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