3D printed hollow core terahertz Bragg waveguides with defect layers for surface sensing applications

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Abstract: We study a 3D-printed hollow core terahertz (THz) Bragg waveguide for resonant surface sensing applications. We demonstrate experimentally that powder layer thickness variations as small as 3μm can be reliably detected with our sensor.

I. INTRODUCTION

Optical fibers have been extensively studied for biochemical sensing applications due to numerous advantages, such as small footprint, high degree of integration, and continuously quantitative and qualitative analysis [1]. In order to extend the probing depth of the surface waves to longer distances for macromolecular or bacteria detection, one can pursue biosensors operating at longer wavelength, such as THz frequencies [2]. In this work, we proposed a sensor based on a THz Bragg fiber for simultaneously monitoring the layer thickness of α-lactose monohydrate using the anticrossing frequency and the absorption peak strength, respectively.

II. RESULTS

The designed THz Bragg fiber with a defect layer is schematically demonstrated in Fig. 1, where both the resin and air layers in the Bragg reflector have a thickness of 512μm and the core diameter is 4.5mm. The first resin layer in the Bragg reflector is set as the defect layer by increasing its thickness to 812μm. The designed Bragg fiber was fabricated using a commercial stereolithography 3D printer.

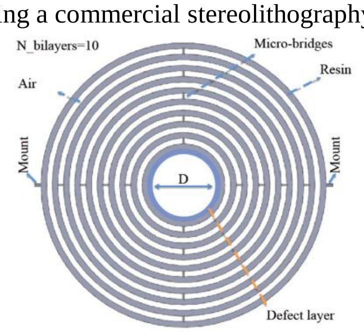

Fig. 1 Schematic of the designed Bragg fiber with a defect layer.

Then, we characterize the transmission spectra of the fabricated waveguides with defect layers using a THz-TDS system. As predicted, the introduction of a defect layer results in pronounced anticrossings between the core-guided mode and the defect modes localized in the vicinity of the defect layer. When the thickness of the defect layer is increased from 200μm to 400μm, the anticrossing frequency shows a blue frequency shift. We note that the two resonant dips in the waveguide transmission spectra correspond to anticrossing of the core-guided mode with the two different defect modes. The experimentally obtained surface sensitivity to changes in the thickness of the first reflector layer is found to be 0.12GHz/μm and 0.115GHz/μm for the resonant dip 1 and dip2, respectively. In what follows, we use the resonant dip 1 with higher sensitivity in order to perform the sensing of different analytes.

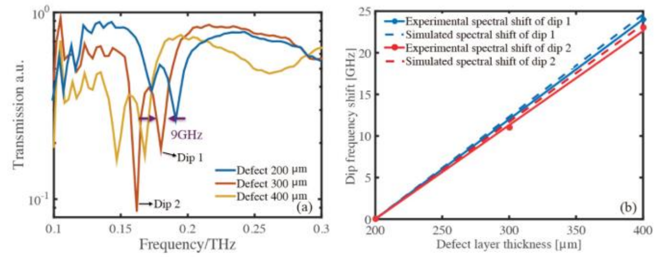

Fig. 2. (a) Measured transmission spectra of the THz Bragg waveguide featuring a defect layer of different thicknesses. (b) Experimental and theoretical spectral shifts of the two transmission dips as a function of the defect layer thickness.

Finally, we apply our waveguide sensor to detect thickness changes in the powder analyte, namely, α-lactose monohydrate. As shown in Fig. 3(a), we find that the increase of lactose powder mass causes a continuous frequency shift in the resonant dip positions. In Fig. 3(b), we plot frequency of the resonant dip found at the right edge of the bandgap as a function of the lactose layer thickness, and a linear dependency is observed. The experimentally achieved surface sensitivity is found to be 0.14GHz/μm. Moreover, in order to theoretically validate the experimental results, we also calculate the surface sensitivity of the HE11 mode. The theoretical surface sensitivity of the Bragg waveguide sensor is shown in Fig. 10(b) and we observe a good agreement between the theoretical and experimental results.

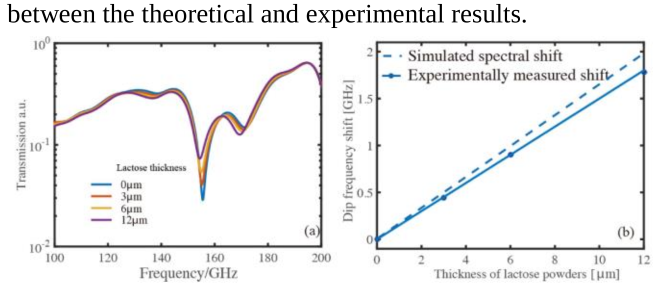

Fig. 3 (a) Measured transmission spectra of the THz Bragg waveguide (with a 300μm defect), when different amounts of lactose powders are loaded into the core. (b) Experimental and theoretical spectral shift of the transmission dip found at the right edge of the bandgap as a function of the layer thickness.

Reference:

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