金属被覆誘電体平行平板導波路の TE モードにおける伝播損失

Propagation loss of metal-coated dielectric parallel-plate waveguide in transverse-electric (TE) mode

東大院工 [1]，東大院理 [2]，〇黄　昱源 [1]，小西　邦昭 [2]，出浦　桃子 [1]，下山　裕介 [1]，湯本　潤司 [2]，五神　真 2，霜垣　幸浩 1，百瀬　健 1

The Univ. of Tokyo, ◦Yuyuan Huang, Kuniaki Konishi, Momoko Deura, Yusuke Shimoyama, Junji Yumoto, Makoto Kuwata-Gonokami, Yukihiro Shimogaki, and Takeshi Momose

E-mail: yyhuang@dpe.mm.t.u-tokyo.ac.jp

Introduction

Terahertz (THz) waveguide is an essential component for propagating THz waves. However, it is challenging for fabricating THz waveguides owing to their sub-millimeter sized aperture and high-aspect-ratio feature. Thus, three-dimensional (3D) printing technology combined with the metal coating is developed to fabricate metal-coated dielectric THz waveguides. [1] For coating metal film on 3D printed substrate, electroless plating followed by electroplating has commonly been adopted, yet its low film quality and poor step coverage confine application on THz waveguides. Therefore, we proposed to apply supercritical fluid deposition (SCFD), which enables high-quality film onto high-aspect-ratio structures for fabricating THz devices. [2] In the development of metal-coated dielectric waveguides, the required film thickness and suitable material are essential. Thus, we conducted material selection and derived a model for evaluating the required film thickness. [3,4] However, the previous study concentrated on transverse-magnetic (TM) mode only. Considering high loss in TM_1 mode and incomplete confinement in TM_0 mode, the lowest transverse electric (TE_1) mode is attracted to low-loss propagation. [5] This study investigated the required film thickness by evaluating the propagation loss in the silicon-based parallel-plate waveguides (PPWG) with different length and different coated Au film thicknesses. The model to estimate propagation loss was expressed in TE mode.

Methodology

Au films were coated by magnetron sputtering on both sides of 280-μm silicon substrates and then stacked for ten times with 280-μm intervals to form PPWG. Au film thickness ranged from 20 to 450 nm, and waveguide length were 2.5 and 5 mm. The transmittance was measured in TE mode by using conventional THz time-domain spectroscopy (THz-TDS). Propagation loss was calculated from transmittance obtained from 2.5- and 5-mm-long waveguides. The theoretical model to estimate propagation loss of THz PPWG was developed by incorporating reflection of THz waves at interfaces of Au/Si into loss calculation model for metallic PPWG [5, 6]. The metallic property of Au was described by the Drude model. The regression line of measured resistivity on film thickness was applied to the model for loss calculation.

Results and Discussion

Figure 1(a) shows experimental and theoretical propagation loss in the 20 nm-thick Au-coated PPWG. Experimental result has good agreement with simulated propagation loss. Propagation loss decreases with an increasing frequency above the cutoff (0.53 THz). Figure 1(b) shows the film thickness dependence of propagation loss in the Au-coated waveguides at 0.72 THz. Good matching of experiments and calculation also validated our methodology in TE mode. It is observed that there is less than 2% extra loss (0.07 dB) when the film thickness (168 nm) is more than twice its skin depth (84 nm). Furthermore, loss in TE_1 mode (0.50 dB) was found to be lower than that in TM_1 mode (0.90 dB) in same condition (168 nm Au, not shown) based on our calculation. In brief, our developed model is confirmed to evaluate propagation loss in TE mode, which makes the possibility for designing low-loss metal-coated dielectric PPWG.

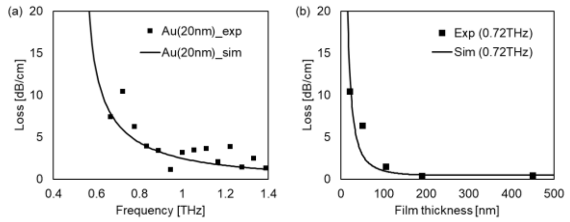

Fig. 1. (a) Propagation loss of 20 nm-thick Au coated PPWG. (b) Film thickness dependence on loss of Au-coated PPWG at 0.72 THz. Simulation lines is calculated from proposed model.

References

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