Impact of Metal-Pad Placement on Waveguide Loss and Modulation Performance in Graphene-Integrated SiN Ring Modulator

Pawan Kumar Dubey[1]
Ashraful Islam Raju[1], R. Lukose[1], C. Wenger[1,2], M. Lukosius[1]
1IHP- Leibniz Institut für innovative Mikroelektronik, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany
2BTU Cottbus Senftenberg, Platz der Deutschen Einheit 1, 03046 Cottbus, Germany
Dubey@ihp-microelectronics.com

Chip-scale electro-absorption graphene ring modulators can outperform straight-geometry modulators in terms of modulation depth and speed. However, their design is more complex, demanding precise control of parameters such as bus–ring coupling efficiency, resonator circumference, and waveguide loss, all of which strongly influence the device's resonance [1,2]. Additionally, metallic contacts for biasing graphene can cause parasitic propagation loss in the waveguide affecting the critical coupling and output bus transmission of the modulator. Here, we systematically investigate metal-pad placement in graphene-based electro-absorption modulators integrated with silicon nitride (SiN) ring resonators, focusing on how the pad–waveguide gap affects waveguide excess loss. Finite-difference time-domain (FDTD) simulations reveal that these excess losses—beyond intrinsic propagation loss—drop exponentially with increasing pad-to-waveguide distance. For a 10 µm graphene region on an 80 µm ring circumference, lowering the additional loss from 1 dB to 0 dB improves the modulation depth from −15 dB to −35 dB. This underscores the critical role of precise metallization in optimizing optical confinement and graphene–light interaction, offering a route to higher modulation depths and potentially faster operating speeds in compact, energy-efficient photonic integrated circuits.

References

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Figures

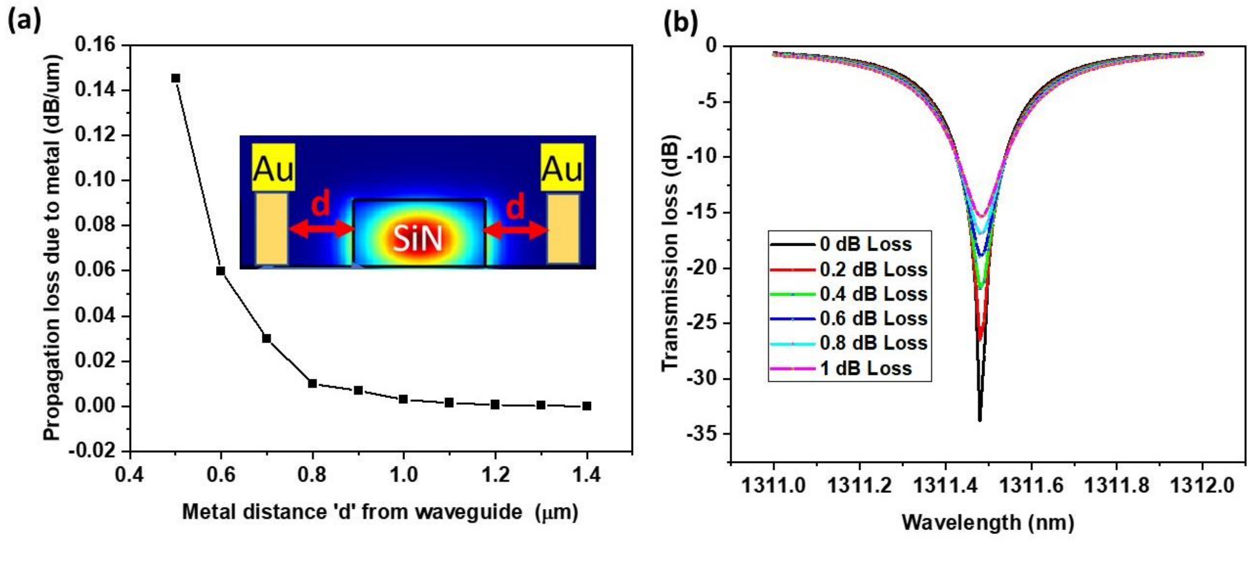

Figure 1: (a) Loss vs. metal distance, with insets showing the TE mode propagation in the waveguide. (b) Transmission loss for different metal-induced excess losses.

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