FY24 R&TD Innovative Spontaneous Concepts (ISC)

A Novel Passivation GaAs Schottky Diode Mixers for 2-5 THz

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Strategic Focus Area: Innovative Spontaneous Concepts

Objectives: The objective is to perform a feasibility study on a novel ALD SiO2 film as a passivation layer for GaAs Schottky diode mixers and, at the same time, as a dielectric layer for Metal-Insulator-Metal (MIM) capacitors. As a case study, we will apply this novel passivation technique to our existing 4.75 THz mixer design to reduce its noise temperature.

Background: Global spatial and temporal observations of spectral lines in the 2-5 THz frequency range with high spectral resolution ($\lambda/\Delta\lambda \geq 5 \times 10^5$) can significantly advance our understanding of Earth's atmospheric dynamics and Sun-Earth interactions, as highlighted in the Heliophysics Science and Technology Roadmap (2014-2033). A key issue in the thermosphere, above ~100 km, is insufficient temporal data coverage, especially during night. Current visible-wavelength observations are limited, but a limb sounder could provide continuous global measurements day and night. Notably, the 2.06 THz and 4.75 THz atomic oxygen (OI) emissions are ideal tracers of wind velocity, temperature, and density in the thermosphere. Our group has been developing 2 THz and 4.75 THz GaAs Schottky diode mixers. While the 2 THz mixer's noise temperature can be reduced to shorten observation time, there is currently no room-temperature 4.75 THz receiver. Hot Electron Bolometer (HEB) mixers, an alternative for 2-5 THz, require heavy, cryogenic operation, posing challenges for long-duration satellite missions. Therefore, room-temperature GaAs Schottky diode mixers beyond 2 THz are crucial to meet scientific needs.

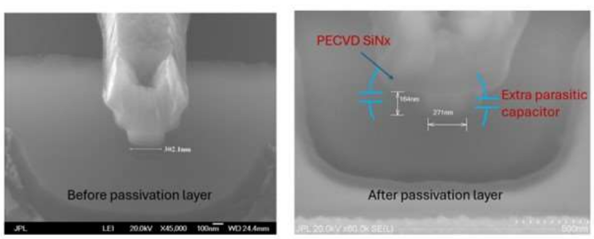

Figure 1. The images show the additional parasitic capacitance caused by the 100 nm thick PECVD SiNx film. By replacing this layer with a 13 nm thick ALD SiO2 layer, we can significantly reduce the unwanted parasitic capacitance.

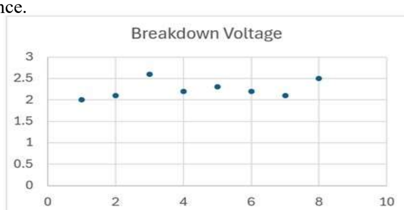

Figure 3. The graph shows the dielectric breakdown voltage of 13 nm thick ALD SiO2 dielectric layers, ranging from 2.0 to 2.6 volts. There is no significant difference in breakdown voltage across the various sizes of MIM capacitors.

Significance/Benefits to JPL and NASA: This project will reduce the noise temperature of 2 THz GaAs mixers, which are scheduled for use in the phase-A DYNAMIC-TLS (D-TLS) mission—a JPL-led terahertz limb sounder instrument as part of the Applied Physics Lab (APL)-led class-D mission. This project demonstrates the effectiveness of the novel passivation technique in reducing the noise temperature of GaAs mixers, while simultaneously enhancing the scientific throughput of the flight D-TLS project, should it receive full funding for flight.

Approach and Results: One of the primary limitations in the RF performance of terahertz Schottky mixers is the parasitic capacitance associated with the anode of the Schottky diode. This parasitic capacitance is largely influenced by the passivation layer, which is crucial for maintaining device stability over time. To address this inherent limitation, we propose removing 90% of the existing passivation layer while retaining sufficient protection for space applications. This will be achieved by implementing a novel, pinhole-free passivation technique: the deposition of a 10 nm-thick SiO2 (silicon dioxide) layer grown at MDL via Atomic Layer Deposition (ALD), replacing the current 100 nm-thick SiNx passivation layer deposited via Plasma Enhanced Chemical Vapor Deposition (PECVD). Additionally, the dielectric constant of SiO2 is approximately 50% lower than that of SiNx, which reduces the parasitic capacitance even further.

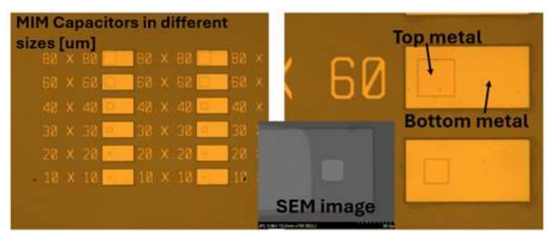

Figure 2. The images show Metal-Insulator-Metal capacitors of varying sizes used to measure the size dependency of the dielectric breakdown voltage, along with a Scanning Electron Microscope (SEM) image.

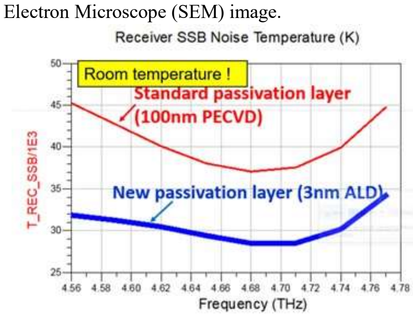

Figure 4. The graph shows a 27% reduction in noise temperature at a 4.75 THz mixer, based on RF simulations using a 3 nm thick SiO2 ALD passivation layer.

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