Fabrication and RF Evaluations of 5G Antennas on Flexible Substrates

CNF Project Number: 3038-22
Principal Investigator(s): Mark D. Poliks
User(s): Dylan Richmond

Affiliation(s): Materials Science and Engineering, Binghamton University

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Contact: mpoliks@binghamton.edu, drichmo2@binghamton.edu

Primary CNF Tools Used: Electron beam evaporator (odd & even hour), Heidelberg Mask Writer - DWL2000, DISCO dicing saw

Abstract:

Internet-of-things (IoT) implementations are becoming increasingly popular as real-time sensing and edge computing aim to improve efficiency, safety, and wellness. To enable communication among IoT devices, such as self-driving cars, mobile, and wearable devices, they must be networked and are often reliant on rapid signal transmission and processing. Flexible glass and flexible ceramic have emerged as two primary candidates for the fabrication of high-quality roll-to-roll (R2R) antennas at low cost. We have previously demonstrated a fully additive technique for fabricating double-sided 5G Vivaldi antennas using aluminum on flexible glass [1]. This work continues and expands the scope of substrates, metallizations, and RF devices to develop wafer-level processes that can be ported to R2R. Herein, we demonstrate fabrication of double-sided 5G mm-wave RF devices on flexible glass and ceramic operating at 28 and 39 GHz. Devices are designed and simulated using ANSYS high-frequency structure simulator (HFSS). Validation of the designs is conducted by measuring the return loss and 3D radiation patterns using a Rohde and Schwarz ZNB-40 Vector Network Analyzer (VNA) and comparing operational performance to simulated results. While a R2R manufacturing process is developed in tandem, the wafer scale prototypes have been made using standard materials, processes, and facilities to allow a facile translation to R2R.

Summary of Research:

RF devices were fabricated on flexible glass and ceramic wafers using both conventional photolithography and depositions with shadow masks to define features. First, metals were evaporated onto both sides of the wafer substrates using the electron beam evaporators available in the CNF. Blank photomasks were purchased from the CNF store and designs were exposed using the direct-write expose tool to define mask patterns. Photolithography was performed at Binghamton University's clean room on the wafers metallized at the CNF. Once metal patterns were defined onto the wafer, a subsequent via filling process was done to make electrical connections from one side of the wafer to the other. Wafers were then coated in a dry film photoresist and brought back to the CNF for dicing. The DISCO dicing saw was used (with the all-purpose blade) to singulate the devices from the wafer. Finally, devices were evaluated for their RF performance using a vector network analyzer to obtain S-parameters and radiation patterns in an anechoic chamber.

Conclusions and Future Steps:

This work was meant to prototype and evaluate processes that can be used to fabricate these devices on webs of flexible materials on a larger scale, roll-to-roll (R2R) manufacturing level. The initial trails of fabricating these devices were successful in that the devices operated as expected. The next steps consist of testing the compatibility of these webs of flexible materials with our tool set at Binghamton University and begin to carry out preliminary experiments on the R2R platform towards high-volume manufacturing these devices. The final step will eventually be the manufacturing of these devices.

References:

[1] M. D. Poliks, et al., "Transparent antennas for wireless systems based on patterned indium tin oxide and flexible glass," in 2017 IEEE 67th Electronic Components and Technology Conference (ECTC), 2017, pp. 1443-1448.

[2] J. P. Lombardi, et al., "Copper transparent antennas on flexible glass by subtractive and semi-additive fabrication for automotive applications," in 2018 IEEE 68th Electronic Components and Technology Conference (ECTC), 2018, pp. 2107-2115.

[3] D. Richmond, et al. "Additive Fabrication of Aluminum Antennas on Flexible Glass," New York State Nanotechnology Network (NNN) Symposium, May 2022.

[4] D. Richmond, et al. "Fabrication and RF evaluations of 5G Antennas on Flexible Substrates," New York State Nanotechnology Network (NNN) Symposium, April 2023.

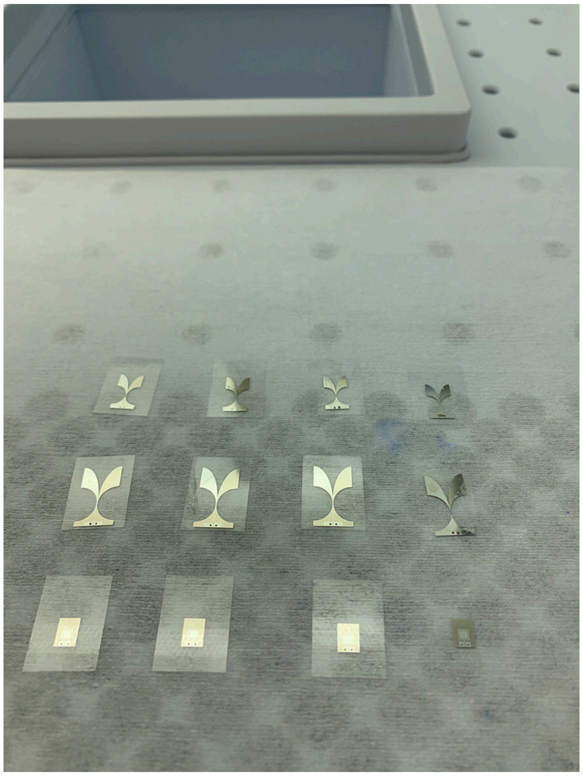

Figure 1: RF devices on 100 µm flexible glass, diced using DISCO dicing saw.

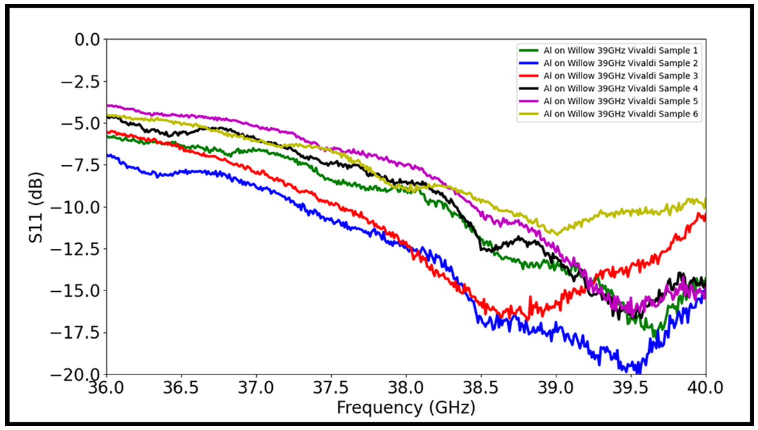

Figure 2: Return loss (S11) of Vivaldi antennas on 100 µm flexible glass.

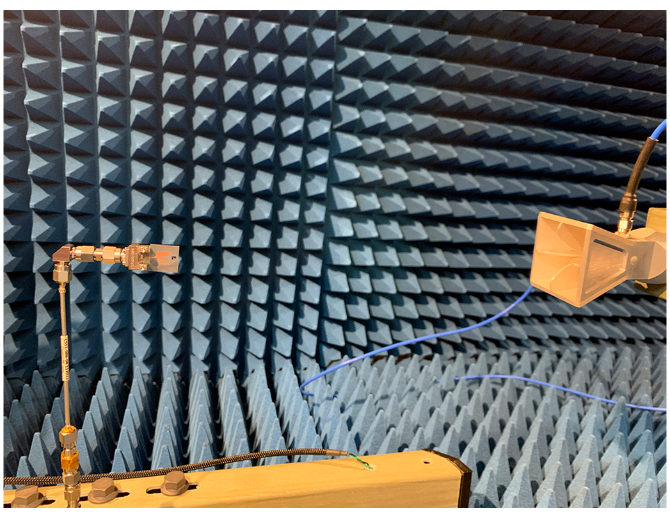

Figure 3: Anechoic chamber radiation measurement setup.

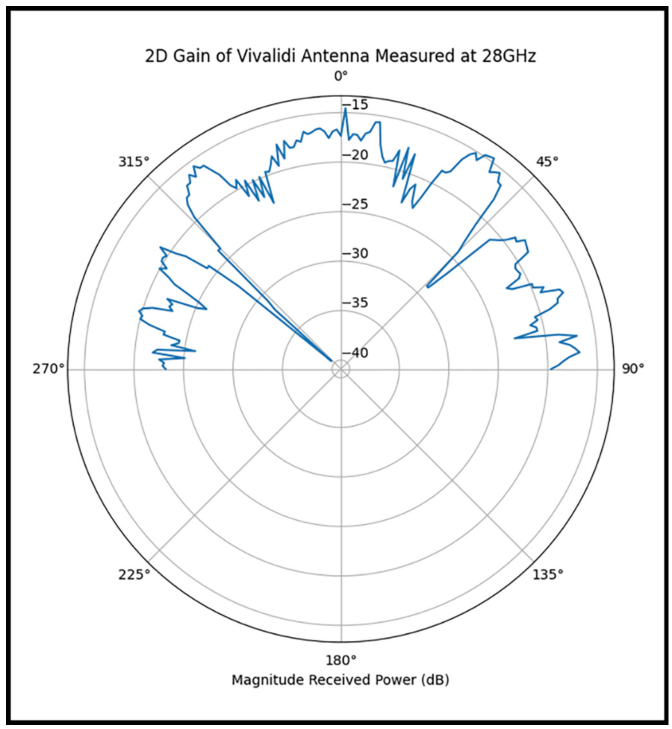

Figure 4: 2D gain of Vivaldi antenna on 40 µm flexible ceramic measured at 28 GHz.

PROCESS & CHARACTERIZATION