Strain Assisted Self Lift-Off Process for the Fabrication Ultra Low Capacitive Antenna Coupled MIM Tunnel Diodes for the Application of Infrared Detection and Energy Harvesting

F. Yesilkoy, N. Goldsman, M. Dagenais and M. Peckerar
Electrical and Computer Engineering Department, University of Maryland, College Park, MD 20742
filizy@umd.edu

Antenna Coupled Metal-Insulator-Metal Tunnel Diodes (ACMIMTD) are micro-size rectennas that can operate at Infrared (IR) frequencies. The response speed is imposed by the RC time constant of the tunnel junction not the femtosecond-fast tunneling process. Making small junctions reduces capacitance. However, area reduction of the diode increases forward resistance. A new fabrication process called "strain assisted lift-off" has been demonstrated to decrease the junction capacitance while keeping the resistance low. In addition, the tunnel barrier is engineered to provide a substantial nonlinearity by implanting traps during metal oxidation.

An ability to pattern sharply pointed "field emission" tips in two dimensions improves the situation in two ways. First, a sharp tip concentrates field lines, leading to an increase in tunneling current at a given bias voltage, and de-coupling capacitance from forward resistance. Second, diode structure is geometrically asymmetric, leading to asymmetry in the current-voltage response across zero bias, which is essential for energy harvesting.

The fabrication details for the new process are shown in figure 1. This process results in complete planar ACMIM diodes that retain a sharp field-emitting tip surrounded by an electron collecting second electrode. The devices fabricated using strain assisted lift-off method have low forward resistance (improves the rectification efficiency) and low capacitance. In figure 2, the micrographs of the fabricated devices are shown. The total junction area decreases 56% as a result of the removal of the top overlap area on the device shown in figure 2 a).

The rectification efficiency of an MIM tunnel junction is proportional to the nonlinearity of its current-voltage relation (I-V curve). In order to provide an I-V relation with a low forward resistance and a sufficiently high nonlinearity, traps are implanted during the metal oxide barrier formation. This is realized by oxidizing the first Ni-electrode in a saline (NaCl) boiling water for 30 s. According to a preliminary work 25% improvement is observed on the saline water oxidized tunnel junctions compared to the DI boiling water oxidized ones.

In figure 3, DC I-V characterization of a typical device is given. This particular device offers 53kΩ zero bias resistance with a significant asymmetry across the zero bias. The next step of this research will include the testing the performance of these devices under 30THz CO_2 laser radiation.

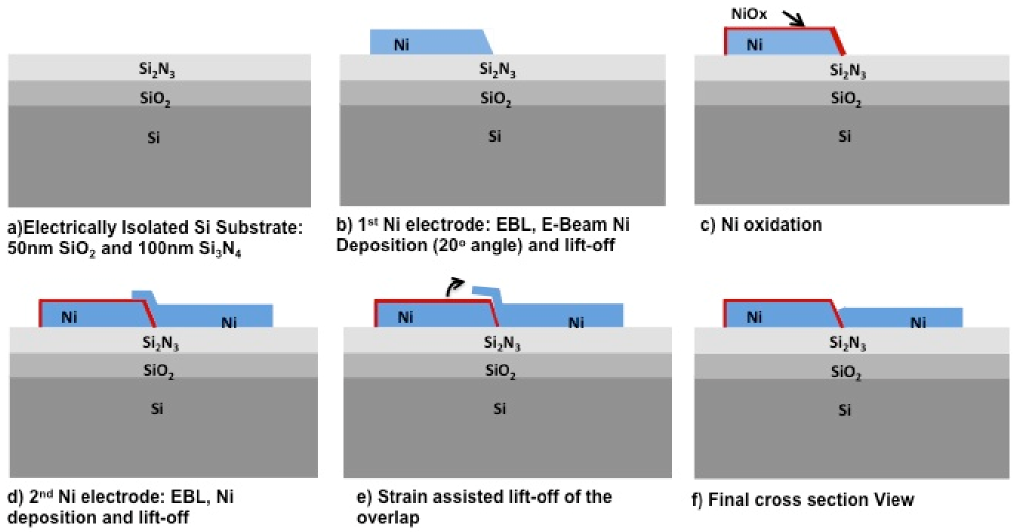

Figure 1: Fabrication steps for the strain assisted lift-off process

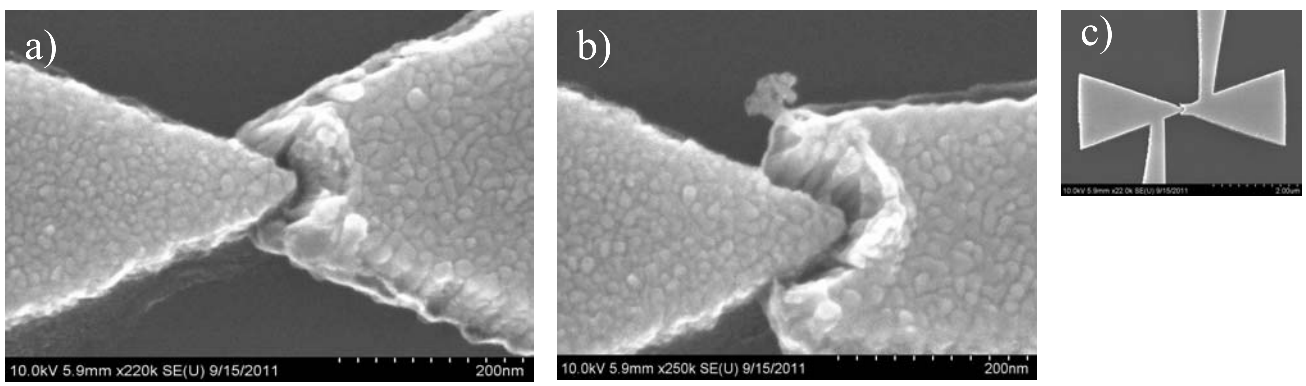

Figure 2: Micrographs of the ACMIMTJ: a) and b) MIM tunnel junction region c) whole rectenna structure

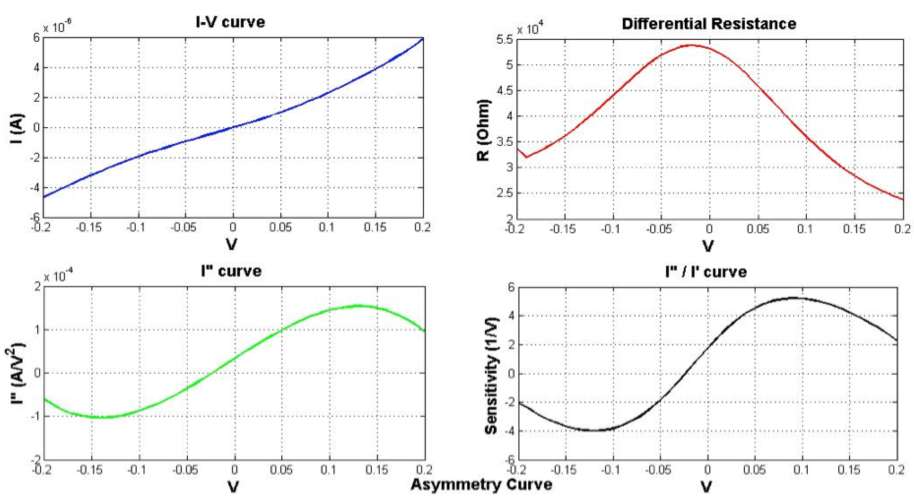

Figure 3: I-V characteristic of the device