UNIVERSITY OF SOUTH FLORIDA

Beyond Photovoltaics: Productionizing of Rectenna Technology for Conversion of Solar Radiation to Electrical Energy

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Description: The main objective of the proposal is to commercialize and scale up a new technology, rectenna to convert waste heat energy to electricity. Although the prediction of highly efficient (~85%) solar rectennas was published almost 30 years ago, serious technological challenges have prevented such devices from becoming a reality. Since the ultimate goal of a direct optical frequency rectenna photovoltaic power converter is still likely a decade away, we plan to convert optical solar radiation to thermal radiation (~30 THz regime) using an innovative blackbody source. Leveraging the research efforts of the world-class team members, we plan to further develop the rectenna technology that is within reach of efficient radiation conversion at 30 THz. A fully integrated, blackbody converter and 30 THz rectenna system will be capable of converting at least 50% of solar and thermal energy into usable electrical power, clearly demonstrating a truly transformational new technology in the renewable energy technology sector.

Budget: $598,500

Universities: USF

External Collaborators: Sandia National Laboratory

Progress Summary

Summary of Progress: The main research objectives for the current reporting period include development of a MIM tunnel junction based on self-assembled monolayers (SAM), testing and characterizing of the solid-state insulator layer, and design/optimization of novel dipole fed slot antenna.

Progress Made Toward Objectives During Reporting Period: High frequency MIM junctions have been typically developed using solid-state materials. In this research task, MIM junctions have been developed with SAM films. Several alkanethiols were procured and a thiol with smallest chain length was used for junction development. Specifically, 1-dodecanethiol (DDT) was used as the organic dielectric. The devices have been fabricated on a silicon substrate through photolithography and E-beam lithography (EBL). Fig. 1 shows the schematic of the SAM MIM junction design. Initially, a ground plane metal (gold) was deposited and patterned to form the bottom electrode as well as the contact pad for electrical testing. Then a window was patterned using EBL to deposit the thiol. A 1 mM solution of 1-Dodecanethiol was created in ethanol and the sample was immersion coated in the pre-opened window. A metal layer was deposited on top of the SAM layer to form a MIM structure.

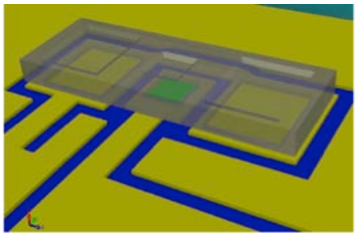

Figure 1: A schematic of the SAM MIM design

Fig. 2 shows an optical micrograph of the fabricated SAM array. The device will be developed for IR detection in collaboration with Sandia National Laboratories.

In order to develop stable MIM junctions with inorganic dielectric, the nickel oxide dielectric was characterized by varying the oxygen content during the deposition process. The dielectric layer deposited with low oxygen (1:3 O_2:Ar) content yielded a smoother film. However, the phase of the crystal structure was modified. It was also determined that the devices fabricated with 1:1 O_2:Ar ratio yielded a higher tunneling current of the order of 10^{-4}A. However, these devices were unstable over a period. Upon further analysis, Nickel oxide deposited with 1:2 O_2:Ar ratio was determined to be the most stable dielectric suited for the MIM fabrication. Later, the NiO samples were subjected to annealing to determine the charge dissipation. NiO was annealed at temperature of 900°C for 3 different soak intervals 30s, 1min & 1min 30s. When compared to un-annealed samples, the annealed samples showed conduction at a faster rate due to the increased crystallinity of the films. Furthermore, to improve the reliability of the tunnel junctions the sidewall of the bottom electrodes were passivated using a thick SiO_2 layer. This increased the breakdown voltage of the tunnel junction. Fig. 3 shows the schematic of the MIM junction with a passivation layer.

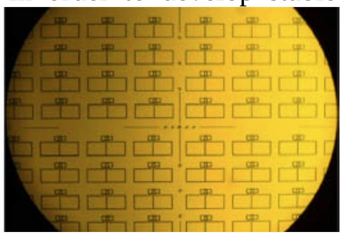

Figure 2: Rectifier array fabricated on silicon substrate

Previously a 94 GHz slot antenna was designed and fabricated. In order to develop a THz antenna, design and simulation needs to be performed using HFSS. As a preliminary step, the 94 GHz antenna was optimized to be coupled with a dipole fed slot configuration. The return loss of the antenna was determined to be -36dB as shown in Fig 4. Research activities for the next reporting period will focus on making extensive measurements on the SAM based as well as the inorganic MIM junction and scale-up the operating frequency of the device. The antenna structure will also be scaled and fabricated to operate at 1 THz.

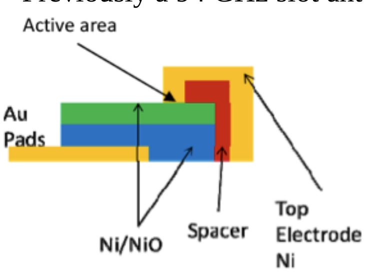

Figure 3: A schematic of the MIM with passivation layer

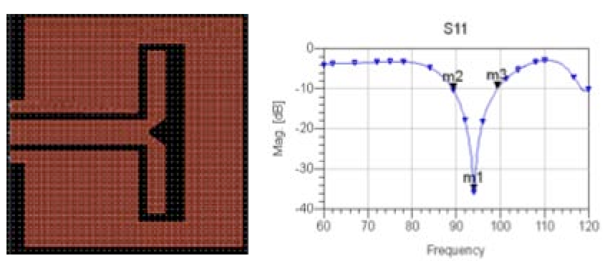

Figure 4: A schematic of the dipole antenna and return loss at 94 GHz