University of South Florida

Beyond Photovoltaics: Nanoscale Rectenna for Conversion of Solar and Thermal Energy to Electricity

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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: Bhabha Atomic Research Center, India

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period includes; (a) testing and characterizing of an organic MIM tunnel junction using Gallium as a liquid contact, (b) characterizing the solid-state MIM junction using tunneling AFM technique, and (c) fabrication of a dipole fed slot antenna.

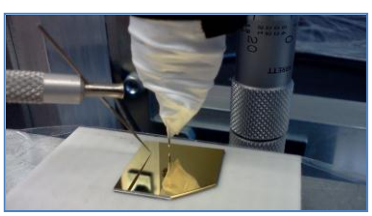

Figure 1: Test set-up for measuring SAM with Ga

Progress Made Toward Objectives During Reporting Period: (a) In this research task, MIM junctions have been developed with SAM films. One of the main challenges in fabricating a SAM based tunnel junction is the inability to deposit a top electrode. In order to overcome this challenge, a liquid metal contact is used to form a top contact, which was suspended from a needle probe. The test set-up used for measuring the I-V characteristics of the tunnel junction is shown in Figure 1. The I-V characteristic was measured using a Keithley 2400 source meter. The bias voltage was swept from -1V to +1V and the corresponding current was measured. Figure 2 shows the I-V characteristics of the SAM junction. As shown in the

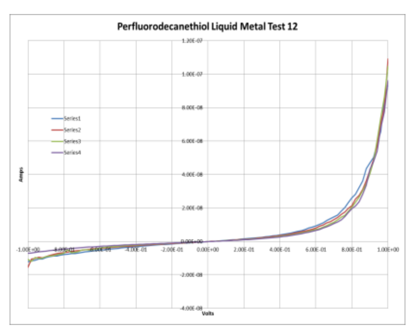

Figure 2: I-V response of SAM junction

figure, the tunnel junctions exhibited a high degree of asymmetry. The rectification ratio of the organic tunnel junctions was 1:19, suggesting a better performing rectifier.

(b) In this task, thin film dielectric was characterized using tunneling AFM technique. Ni and NiO were deposited on a silicon substrate and AFM tip was used as the top electrode to measure the tunneling current. Figure 3 shows an optical image of the AFM probe on NiO film. A sample bias voltage of -3V was applied and the tunneling current was measured. Figure 4 shows the I-V characteristics of the Ni/NiO/AFM probe. The I-V response exhibited an asymmetric curve with 1:7 rectification ratio. However, the current was in the order of few uA. This is due to the film thickness. The current can be improved by reducing the NiO thickness. Based on the above experimentation, the NiO is being characterized for use in MIM stack.

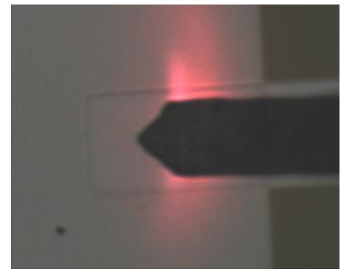

Figure 3: Optical image of MIM with AFM probe

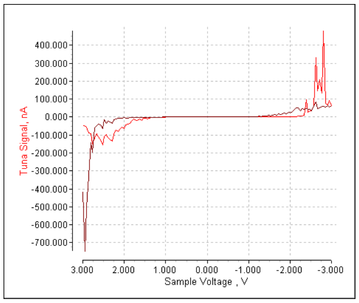

Figure 4: I-V measurement using AFM probe passivation

(c) In this task the modeling, simulation and fabrication of a single element antenna operating at 60GHz was accomplished. The modeling and simulation was done using Agilent Technologies' Momentum Electromagnetic Simulator. This software uses an efficient meshing approach and adaptive frequency sampling to reduce simulation time. The single element antenna design was modeled in the software using a substrate thickness of 50um. Based on the design, a 60 GHz antenna was fabricated on a 50um silicon diaphragm using bulk micromachining technique. Figure 5 shows the fabricated antenna and the simulated return loss. Currently, the antenna is being measured experimentally to determine the radiation pattern and the reflection co-efficient using a network analyzer.

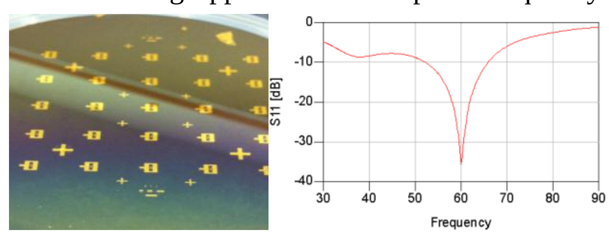

Figure 5: Optical image of fabricated dipole antenna and simulated return loss

New collaborations		
Partner name	**Title or short description of the collaboration**	**Funding**
Bhabha Atomic Research Center, Mumbai, India	Provide guidance and expertise on developing an organic tunnel junction to improve the rectification ratio	None at this time

Proposals						
Title	**Agency**	**Ref #**	**Investigators/ Collaborators**	**Funding requested**	**Duration**	**Date submitted**
Development of an Automated Engineering Test Bed to Evaluate Terahertz Devices	NSF	1126700	Yogi Goswami Shekhar Bhansali Subbu Krishnan Susan Allen Lee Stefanakos	$504,365	3 years	Jan 27, 2011
Nanoscale Organic Dielectric based Planar Tunnel Junctions as High Frequency Rectifiers	NSF	1128604	Shekhar Bhansali Lee Stefanakos Subbu Krishnan	$394,790	3 years	Feb 7, 2011
Development of Plasmon Emitter for High Efficiency Solar Energy Conversion	NSF	1134342	Yogi Goswami Lee Stefanakos Subbu Krishnan	$296,057	3 years	Mar 3, 2011