Fabrication and Characterization of 6H-SiC Photovoltaic Devices

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Abstract-- Silicon Carbide (SiC) photovoltaic (PV) devices have caught the interest for extra terrestrial endeavors. This is due to the excellent resistance to radiation, good thermal conductivity, and high quantum efficiency of such devices. Also the large band gap (of 2.9eV) makes it ideal for gathering high-energy UV photons thus creating a large power density.

Using 1cm^2 6H-SiC diode samples, photovoltaic cells were produced. Both P-on-N and N-on-P were examined for this study. There are two samples for each type with varying doping concentrations. For the n-side of each sample, a multilayer of Ti/Ni/Al metals was deposited to have ohmic contact to the substrate. For the p-side, Al metal was deposited. A spectral response will be studied on these devices in the 200-400nm range and quantum efficiency will be determined for an AM0 (atmosphere in space) spectral output. The devices will also be tested over a range of temperatures to see how efficiency changes. Other responses that will be characterized are maximum power output, fill factor, built-in forward bias voltage, breakdown voltage, and the dark leakage current. Combining all of the above responses will help in optimizing photovoltaic devices to best serve the needs of power and efficiency.

1. INTRODUCTION

Silicon Carbide (SiC) has caught the interest of using photovoltaic (PV) devices for extraterrestrial endeavors. This is due to the excellent resistance to radiation and good thermal conductivity of such devices. Also the large band gap (of 2.9eV) makes it ideal for gathering high-energy UV photons. Along with high quantum efficiency, a large power density is created.

SiC is an excellent choice due to high radiation resistance. This is very important factor when dealing with extraterrestrial applications since there is no protection from undesired radiation in space that could damage the devices.

Since there is no protection from radiation, there is radiation through the full electromagnetic spectrum. SiC photovoltaic devices have a high quantum efficiency (that is producing the electricity from the amount of radiation impinged upon the device) in the UV range of 200-400nm. Utilizing the large 2.9eV band-gap of SiC, high-energy UV radiation can be gathered by the SiC photovoltaic device to produce a large power output from devices.

However the lower energy radiation (such as visible and infrared) may cause heat in the device since they are not energetic enough to produce electricity across the diode. Also the heat generated from the sun will also heat the device. As photovoltaic devices heat up, they tend not to be quite as efficient. Good thermal conductivity is essential, especially in space, to help reduce the effect of heat on a device. SiC devices show good thermal conductivity.

For this study, 1 cm^2 SiC samples were used with various doping concentrations and different device type (P-on-N or N-on-P). Using these devices, the I-V characteristics will be studied. This will produce a good knowledge base and further studies on how to optimize SiC photovoltaic devices.

2. EXPERIMENTAL PROCEDURE

Four existing 1cm^2 doped 6-H SiC samples were obtained. The characteristics of these cells are as follows in Table 1. A quartz mask was designed and made for the imaging of a top contact for the photovoltaic devices.

Table 1: Cell Characteristics for study

Sample #	1	2	3	4
Type	P-on-N	P-on-N	N-on-P	N-on-P
Bottom Doping (cm^{-3})	3.5E+17	3.0E+17	8.0E+17	6.5E+17
Top Doping (cm^{-3})	2.1E+18	3.0E+18	1.3E+18	1.7E+18
Junction Depth (um)	0.4	0.4	0.4	0.4

(1)

A. Processing

Samples were first adhered to 4" silicon wafers with the N-side up. For creating contacts on the N-side, a CVC 601 sputtering tool was used to deposit a Ti/Ni/Al contact with the thicknesses at 200Å/750Å/100Å. When annealed the nickel will start to form a silicide with the SiC substrate. However, this would leave a build up of carbon at the interface, which would create high resistance at the interface. By having the titanium, it combines with the carbon to create TiC and reduces the interface contact resistance. The aluminum is used as a capping layer so an oxide is avoided when annealing.

The samples are then removed from the wafers, cleaned, and adhered back onto the silicon wafers, this time with the P-side up. Using the CVC601 Sputter tool again, a 1000Å Al metal contact was sputtered.

Next, the N-on-P samples were removed from the silicon wafers turned around to the top side of the device and adhered back on to the silicon wafers. A photolithography step was done to create an image in resist for the top contact.

For the N-on-P samples, etching was done. Using aluminum etch the Al and Ni layers were etched. Next the Ti was etched using diluted HF (HF/Water 1:50). Once the etches were done, the line width of the contacts were measured to makes sure they were the right length. For the P-on-N samples, etching was done by using aluminum etch to the Al.

The next thing to do was to anneal the wafers to create a better contact between the substrate and the metal contacts. After this the samples were ready to be tested.

B. Testing

First, an AM0 flood exposure is done to obtain an I-V curve. From the I-V curve the open circuit voltage, short circuit current, and maximum power output can be measured. Fill factor can be calculated as follows.

$$FF = \frac{P_{\max}}{Voc * Isc} \quad (1)$$

Next without any exposure, an I-V curve will be generated to determine the dark leakage current.

Also, a spectral response will be measured. This will show what the quantum efficiency is over discrete wavelengths. The quantum efficiency, η, will be calculated as follows.

$$\eta = \frac{P_{output}}{P_{input}} \quad (2)$$

Looking over all of these factors per sample the best sample will be determined by which has highest quantum efficiency, highest power output, and largest fill factor.

3. RESULTS

Results are yet to be determined. This paper will be revised once results are produced.

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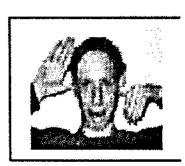

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