

The Effect of Oxidative Environments on the Electrical Characteristics of Pd/SiC Diodes

Chris Anderson, Dr. Kathleen Meehan

The Bradley Department of Electrical and Computer Engineering

In high temperature gas-sensing applications, SiC is often used as a device substrate material because of its excellent high temperature properties and stability. Currently, the effective use of SiC technology in harsh environments is limited due to a certain amount of thermal instability in the sensor structure, as well as defects in the SiC wafers. Through some study of the sensor in various high temperature environments, considerable insight about the thermal instability of these devices can be gained. In particular, these studies can help to uncover the underlying chemical reactions.

This research presents findings concerning the Pd/SiC Schottky diode; which has been tested, repeatedly, as a high temperature gas sensor. The I-V characteristics of a Pd/SiC Schottky diode in dry and wet high-temperature oxidizing environments are presented, and the associated changes in chemical composition are discussed in detail. These discussions address the issues of thermal instability and performance degradation, and explain why more favorable I-V curves result from anneals performed at higher temperatures (325°C range). This experiment ultimately provides further explanation for the results of previous experiments concerning Pd/SiC Schottky diode as a gas sensing device.

The experimental procedure consisted of fabricating Pd/SiC Schottky diodes using SiC 6H substrates that were purchased from Dow Corning. These wafers were cut into 0.75 x 0.75 cm die, and then the die were cleaned using an acetone rinse, Piranha etch, and 10:1 buffer oxide etch cleaning process. In the time just prior to the Pd and Ti/Au depositions on to the SiC substrate, the SiC samples were re-cleaned using a buffered oxide etch, a rinse in de-ionized water, and final blow dry using nitrogen. The Pd and Ti/Au depositions onto the SiC substrate were performed using a Thermionics e-beam system and a shadow masking over the SiC die. The Pd deposition formed the Schottky diode contact, while the Ti/Au deposition on to the opposite side of the SiC die formed the necessary Ohmic contact. Once the samples were prepared, they were exposed to a variety of environments. Specifically, those environments included: atmospheric at 25°C and 325°C, dry oxidizing at 25°C and 325°C, and wet oxidizing at 25°C and 325°C. In each of these cases, the samples were placed on a Quietemp S-1080R heating stage inside a custom-fabricated aluminum gas-containing vessel. The temperatures and dry or wet oxygen were then applied, and the I-V characteristics were taken, as needed, using a Keithley 4200 semiconductor characterization device.

The general procedure given above was used for a number of experiments. In order to uncover the chemical composition of the Pd/SiC samples, Auger emission spectroscopy and ion-scattering spectrometry were required. In these cases, the samples were fabricated with a 25nm Pd thickness and did not include an Ohmic contact; while the Pd/SiC samples used to obtain I-V characteristics were fabricated with a 100nm Pd thickness and included an Ohmic contact.

In completing the I-V characterizations for the atmospheric test, a drift in the electrical characteristics of a Pd/SiC Schottky diode as a function of time was observed at 325°C. The device parameters calculated initially, and after 3 hours at 325°C the I-V characteristics had re-stabilized. These new I-V characteristics were significantly different, with major increases in the built-in and breakdown voltages, as well as reductions in the ideality factor and the reverse saturation currents. Further testing indicated that two different processes are initiated. In the case of the dry oxidative anneal, oxygen in-diffuses to the Pd-SiC interface and reacts with the Pd to form a palladium oxide. This interfacial layer alters the I-V characteristics of the Pd/SiC diode. In the case of the wet oxidative anneal, both oxygen and water in-diffuse to the Pd-SiC interface. The water vapor reacts with Pd at the Pd-SiC interface to form Pd(OH)₂ and to form hydrous palladium oxide during electrical testing. The Pd(OH)₂ attacks the SiC, which allows the out-diffusion of Si from the SiC substrate to the air-Pd surface. The formation of SiO₂ and PdO₂ at this surface impedes the ability for form good electrical contacts to the Pd/SiC. We speculate that the presence of these two oxides along with the palladium hydroxide may account for the observed decrease in sensitivity of Pd/SiC gas sensors.