Electrical and Chemical Effects of Metal Contacts to β-Ga_2O_3 Surfaces

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Abstract:

Over the last decade significant progress has been demonstrated for β-Ga_2O_3, with its ultrawide bandgap of 4.6-4.8 eV, controllable range of n-type, shallow dopants (Sn, Si, Ge), and a scalable melt-growth process allowing the production of large-area, native substrates this material has garnered strong interest for applications as UV photodetectors and high-power electronics. A critical piece of development for ultrawide bandgap materials is the optimization of the metal-semiconductor interface for high-power applications. This talk focuses on the electrical properties of various metallizations to differently oriented β-Ga_2O_3 crystals and focuses on the resulting chemistry of certain metal-semiconductor interfaces.

The Schottky barriers of Ti/Au, Mo, Co, Ni, Pd, and Au on (100) β-Ga_2O_3 substrates were analyzed using a combination of current-voltage (J-V), capacitance-voltage (C-V), and current-voltage-temperature (J-V-T) measurements. The ideality factors and Schottky barrier heights from J-V and C-V methods are documented and discussed. J-V-T measurements of Ti/Au, Co, and Pd diodes reveal inhomogeneity of the Schottky energy barrier. These combined results reveal a strong positive correlation between the calculated Schottky barrier heights and the metal work functions: the index of interface behavior, S, for J-V and C-V data. Additionally, Ti and Au metallizations reveal peculiar electrical properties (higher ideality factors, different J-V and C-V Schottky barrier heights, etc) and further characterizations are pursued.

Au contacts to (100) β-Ga_2O_3 were subsequently examined with transmission electron microscopy (TEM) due to the electrical properties exhibited via J-V and C-V measurements. The contacts exhibited a chemical reaction with void formation 5-20 nm below the Au/β-Ga_2O_3 interface, a reacted region at the interface that is structurally dissimilar to the bulk β-Ga_2O_3 structure, the presence of Ga interstitials diffusing to the metal-semiconductor interface, and EDS mapping reveals Ga diffusion into the Au overlayer.

Chemical measurements of Ti/(010) and Ti/(001) β-Ga_2O_3 contacts were examined with x-ray photoelectron spectroscopy (XPS). XPS revealed partial Ti oxidation at both interfaces in the as-deposited condition, with more Ti oxidation on the (001) β-Ga_2O_3 epilayer surface than the (010) β-Ga_2O_3 substrate surface. The amount of oxidized Ti increased with annealing temperature. J-V and C-V measurements of contacts made from these devices reveal a strong orientation dependence of the electrical properties of Ti/β-Ga_2O_3 diodes.