A Technique to Reduce the Contact Resistance to 4H-Silicon Carbide Using Germanium Implantation

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The effects of implanted Ge on the resistance of nickel-metal contacts to n-type and p-type 4H-SiC are reported. The Ge was implanted with an energy of 346 keV and a dose of 1.7×10^{16} cm^{-2}, and the wafer was annealed up to 1700°C for 30 min. Contact resistance measurements using the transfer length method (TLM) were performed on etched mesas of n-type and p-type 4H-SiC, with and without the Ge. For the annealed-Ni metal contacts, the Ge lowered the specific contact resistivity from 5.3×10^{-4} Ωcm^2 to 6.0×10^{-5} Ωcm^2 for n-type SiC and from 1.2×10^{-3} Ωcm^2 to 8.3×10^{-5} Ωcm^2 for p-type SiC. For the as-deposited (*unannealed*) Ni, the Ge produced ohmic contacts, whereas the contacts without Ge were rectifying. These results suggest that the addition of Ge can be an important process step to reduce the contact resistance for SiC-device applications.

Key words: SiC, contact resistance, Ge, ion implantation, TLM technique

BACKGROUND/INTRODUCTION

Low-resistance ohmic contacts are crucial for silicon-carbide (SiC) electronic devices. Numerical simulations have shown that SiC metal-semiconductor field-effect transistors and impact avalanche and transit time diodes for high-power and high-frequency applications would require specific contact resistivities on the order of 1×10^{-5} Ωcm^2.[1,2] As a large-bandgap semiconductor, SiC does not easily form low-resistance contacts to metals, especially for p-type.[3,4] For example, with metals, such as Ni, quality ohmic contacts to p-SiC have not yet been achieved.[5] By careful preparation, specific contact resistivities near 10^{-5} Ωcm^2 have been obtained with Ni to n-type SiC and Ti/Al to p-type SiC.[6–8] Problems, such as oxidation and electromigration, have been identified as impediments to reliable Al contacts to SiC. Therefore, continued research with ohmic contacts, especially to p-SiC, is vital.

The SiC combined with a few atomic percent of Ge (designated as SiC:Ge) is under investigation as a new material for SiC-device applications.[9] The larger atomic size of Ge is expected to increase the lattice constant of SiC for strain compensation or for matching to larger lattice materials, such as GaN. The lattice structure of Ge in SiC was theoretically investigated using an anharmonic Keating model[10] of the atomic potentials to simulate the interatomic spacings. For the case of cubic 3C-SiC with Ge, this model predicted a lattice constant: a (SiC:Ge) = 0.43593 nm + 0.0337 y, where y is the Ge atomic fraction ($0 < y < 1$). On the other hand, a simple linear interpolation (Vegard's Law) between 3C-SiC and Ge gave a slightly larger lattice constant than the Keating model: a (Vegard) = 0.43596 nm + 0.12994 y. Experimental determinations of the lattice constant of SiC:Ge have not yet been reported.

There have been demonstrations of diode rectifiers and bipolar transistors using SiC: Ge.[11,12] This present study focuses on quantifying the effects of ion-implanted Ge on the properties of nickel-metal contacts to both n- and p-type 4H-SiC. A new process to reduce the resistance of contacts to SiC could be important for applications involving high-power and high-current devices and microelectromechanical systems.

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