Thermally stable ohmic contact to p-type 4H-SiC based on Ti3SiC2 phase

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The high-temperature functionality of SiC devices is useless without ohmic contacts that are also capable of operation under the same conditions. However, during long-term operation at high temperatures, reactions between metal and SiC can continue to evolve, thus leading to an alteration of the interface properties. The aim of this work is to realize an ohmic contact on p-type SiC that is the as stable as possible during a high temperature ageing.

P-Type 4H-SiC has a high work function (around 6-7 eV) and it does not exist any conventional metal that leads to low Schottky barrier height when deposited on P-Type 4H-SiC [1]. Toward this aim, Titanium Silicon Carbide (Ti_3SiC_2) is one of the best candidate materials, because this carbide, of the MAX phase family, has a very interesting combination of metallic and ceramic properties, together with an excellent chemical stability with SiC [2].

In order to form Ti_3SiC_2, 200 nm of $Ti_{50}Al_{50}$ was deposited onto p-type 4H-SiC (0001) 8°off epitaxial layer ($N_A = 2 \times 10^{19}$ cm^{-3}) by magnetron sputtering from pure $Ti_{50}Al_{50}$ targets in an AC450 DC/RF equipment. The deposition was carried out with an Ar constant pressure (5×10^{-3}mbar) at room temperature. The samples were then annealed at 900, 1000, 1100, 1200°C respectively for 10 min under Ar atmosphere in a rapid thermal annealing oven (heating rate of about 20°C/s).

Figure 1, shows X-ray diffraction (XRD) theta-2theta scan of a typical sample annealed in these conditions. As seen, the diffraction peaks unambiguously reveal the formation of the hexagonal Ti_3SiC_2 structure, which is in epitaxial relation with the substrate.

Transmission line method (TLM) structures were fabricated on the mesa in order to characterize electrically the metal/SiC contact. The TLM electrode pattern was 100×500 µm^2 with spacing distances of 3, 6, 10, 20, 40, 80 and 120 µm. An ohmic behavior of the $Ti_{50}Al_{50}$ contacts was found for annealing temperatures of 1000°C and above. For these samples, the Specific Contact Resistance (SCR) ρ_c increased with increasing annealing temperature. The lowest specific contact resistance of 1.1×10^{-4} Ω.cm^2 was obtained when the annealing was performed at 1000 °C for 10 min (see figure 2).

In order to identify the mechanism of the ohmic contact formation and to better understand the electrical behavior of Ti_3SiC_2 at high temperatures, ρ_c and R_{sh} (sheet resistance) were extracted on TLM patterns at different measurement temperatures ranging from 25 to 600°C. These measurements were performed on the sample annealed at 1000 °C for 10 min (see Figures 3 and 4). The SCR and the R_{sh} decreased by increasing the temperature.

Aging tests were performed to examine the stability of the Ti_3SiC_2 contact. This aging has been performed at a constant temperature of 600 °C in an Ar atmosphere. The contact resistivity was monitored before and after the tests. In fixed time intervals (24, 48, 50 and 100 hours), the contacts have been cooled down to the room temperature, and the contact resistivity has been determined. A very good chemical stability between Ti_3SiC_2 and SiC has been observed, because there was no significant change in the contact resistivity after 100 h of aging at 600°C. This chemical stability allows us to obtain a reliable high temperature ohmic contact on SiC.

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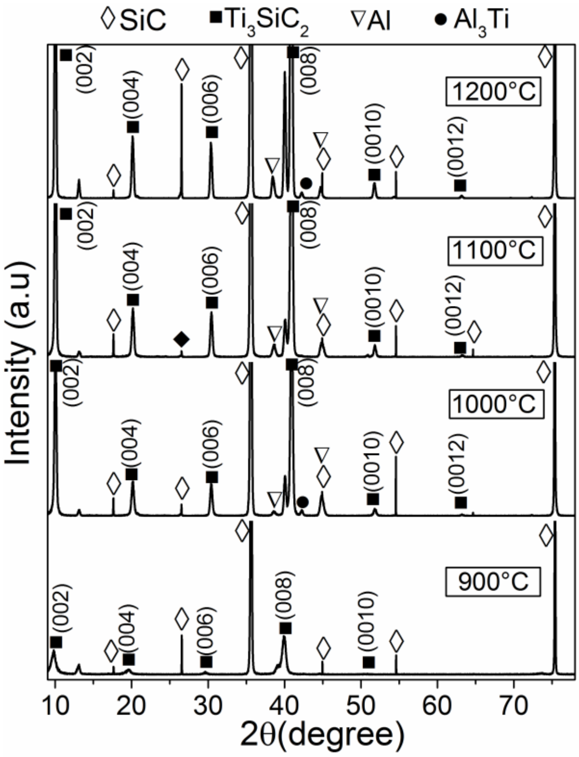

Figure 1. X-ray diffraction patterns of the $Ti_{50}Al_{50}$ contacts onto (0001)Si-face 4H-SiC, after annealing at different Temperature.

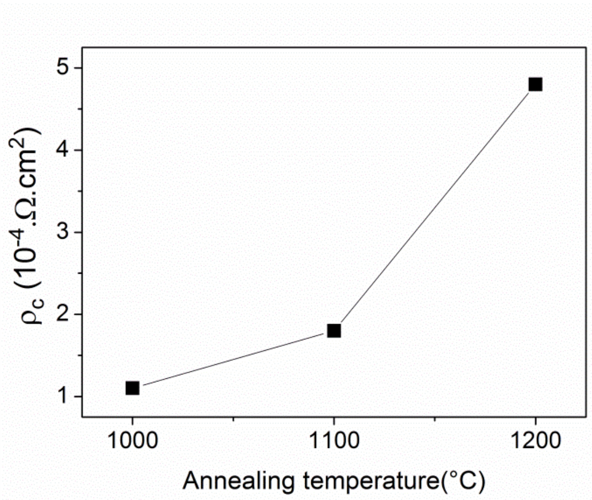

Figure 2. SCR of the $Ti_{50}Al_{50}$ ohmic contacts on p-type 4H-SiC as a function of annealing temperature.

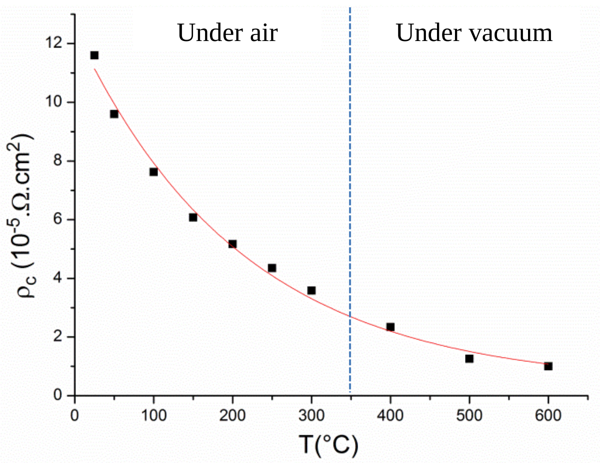

Figure 3. Temperature dependence of the SCR on the p-type 4H-SiC.

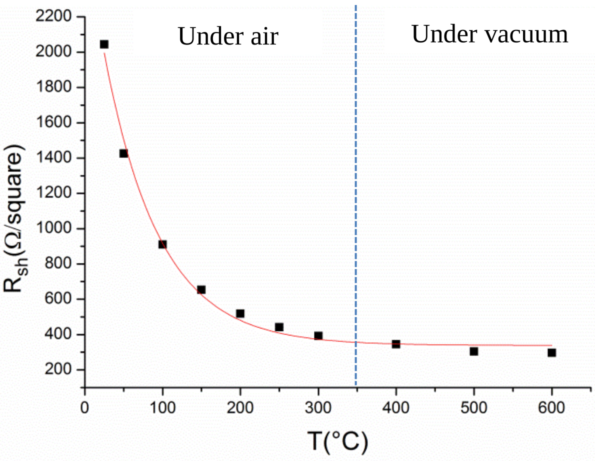

Figure 4. Temperature dependence of the sheet resistance of the p-type 4H-SiC.