# Low Specific Contact Resistance TiNb Ohmic Contacts to 4H-SiC with Laser Annealing for Harsh Environment Applications

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**Introduction:** SiC with large bandgap, high electric field strength, high thermal conductivity, and high mobility of charge carriers, etc., has been the potential candidate for high-power, high-temperature, high frequency, and hard radiation device applications [1]. Jennings et al. reported that low specific contact resistance is critical problem for minimizing power lossless in the high power devices as well as improvement high switching speed in the high frequency devices [2]. Recently, Ti has been reported to be one of the best candidates to form ohmic contact to 4H-SiC. It has been reported that laser annealing has many advantages over rapid thermal annealing (RTA) to form ohmic contact to SiC. Milantha et al. fabricated Ti/4H-SiC ohmic contact with laser annealing with the lowest specific contact resistivity of 4.0 x $10^{-4}$ $\Omega cm^2$. However, TEM images showed that the carbon agglomeration was still observed, which was believed to cause the degradation of the contacts when operating in high power and high temperature environments [3]. It has been indicated that Nb is a good candidate to collect the excess carbon atoms and thus improve the quality of the contacts.

**Experimental:** n-type 4H-SiC substrates with nitrogen doping $N_D \approx 1x10^{18}$ $cm^{-3}$ were used for the experiments. Prior to metal deposition, the surface substrate was chemically cleaned. After photolithography process, Ti(75 nm)Nb(x nm) (where x = 15, 25, 50 nm) were deposited on C-face of the SiC substrates by using RF magnetron sputtering. The photoresist and excess metal deposited on the photoresist layer was removed by lift off process. The contacts were annealed by ultraviolet laser with the energy density was varied from 1.9 to 2.8 J/$cm^2$ at wavelength of 355 nm. After the annealing, Al film was deposited with a vacuum evaporation system, and was patterned as top electrodes.

**Results and Discussions:** The smallest specific contact resistivity was 1.56 x $10^{-4}$ $\Omega cm^2$ in the case of Ti(75)Nb(15) at the laser energy density of 1.9 J/$cm^2$ extracted from I-V curves (Fig. 1). This value is almost three times smaller than the value that Milantha et al. reported (4 x $10^{-4}$ $\Omega cm^2$). The dependence of the specific contact resistance on the laser energy density was illustrated in Fig. 2. The results showed that with the appropriate thickness of Nb, not only the excess carbon atoms were collected by the formation of $Nb_xC_y$ but also low specific contact resistivity was ensured. This explains for the Ti(75)Nb(25) sample has specific contact resistivity maintained at small value when changing the laser power. This also means that Ti(75)Nb(25) can be a potential candidate to operate stably in high temperature as well as high power environments.

[1] T. Kimoto et al., John Wiley & Sons, Singapore (2014).
[2]. M. R. Jennings et al., Physics of Semiconductor Devices, Springer (2014), pp 929-932.
[3]. Milantha et al., Appl. Phys. Lett. 110, 252108 (2017).

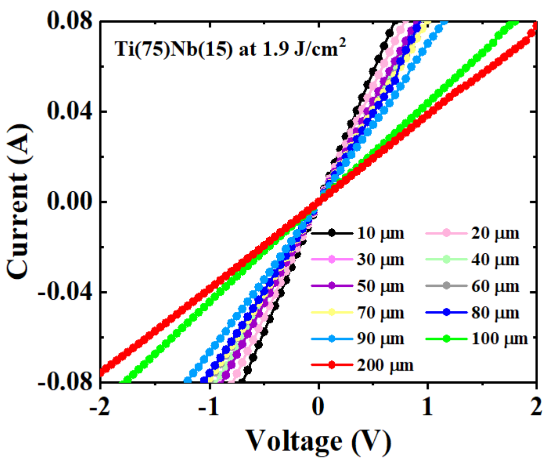


Fig.1 I-V Characteristics of Ti(75)Nb(15)4H-SiC after annealing at laser energy density of 1.9 J/$cm^2$ with contact spacing varying from 10 to 200 µm.

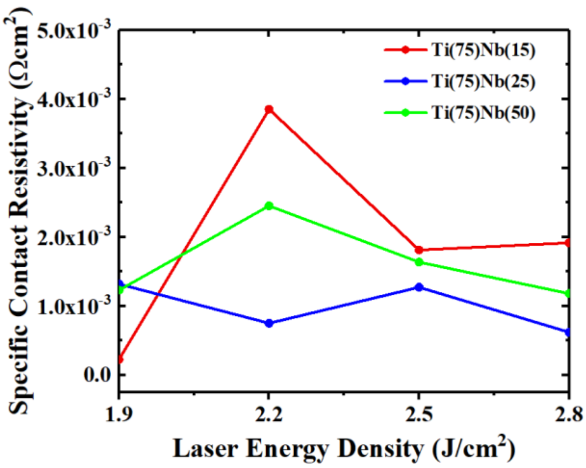


Fig. 2 Dependence of the specific contact resistance of the Ti(75 nm)Nb(x nm) (where x = 15, 25, 50 nm) samples on laser power annealing.