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Exploring Backside Contact Formation on SmartSiC™ Engineered Substrates Using Nanosecond Laser Anneal

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Recently, several studies have discussed the various advantages of **bilayer SiC engineered substrates**. Composed of a thin monocrystalline 4H-SiC layer bonded on a low-resistivity polycrystalline SiC handle wafer [1], these substrates have proven to offer higher energy conversion yield [2] and improved ruggedness to bipolar degradation [3] as compared to industry standards. Other studies report that the backside anode contact can also be fabricated with lower thermal budget than that required for conventional monocrystalline 4H-SiC substrates, while still ensuring both low contact resistivity and reliable device performance [4].

In the frame of this research, we sought to investigate the formation of **backside ohmic contact** on such polycrystalline wafers [5] through morphological and electrical characterizations. Two 150 mm wafers of bulk monocrystal 4H-SiC (monoSiC) and bulk polycrystal 3C-SiC (polySiC) were thinned down to 180 μm using two successive steps of rough and then fine grinding. An 80 nm-thick Ni film was deposited by PVD on the backside of the wafers, prior to nanosecond laser anneal (NLA) using Sumitomo Heavy Industries LT-3100 tool [6]. The Ni-covered surfaces were then treated by juxtaposing 15×15 mm² fields of five 160 ns-long pulses at $\lambda = 308$ nm (excimer XeCl) with laser energy densities (ED) of 2, 3 and 4 J/cm².

Fig. 1 shows the surface morphologies observed by optical interferometer before and after NLA at 2, 3 and 4 J/cm² on both monoSiC and polySiC substrates. Both samples present similar surface roughness before Ni deposition and NLA. However, a significant increase of R_q and R_{max} parameters is observed at 4 J/cm² ED for both samples, characterized by the onset of **micrometer-scale bumps and filament-like structures** on the surface. Moreover, the surface of the monoSiC sample remains smooth after exposure to ED of 2 and 3 J/cm², while the Ni layer deposited on the polySiC wafer seems to have dewetted on the surface starting from ED = 2 J/cm², forming filament structures or decorating grain boundaries. Further EDX analysis, shown on **Fig. 2** (polySiC sample, NLA at ED = 4 J/cm²), indicates that the **Ni has segregated in the filament structures**, whereas only few of it remains on major part of the surface. Raman scattering evidences the presence of crystalline Si, graphite and Ni₂Si silicide on the surface of both wafers after NLA at ED = 4 J/cm². The mappings of the former three phases are given in **Fig. 3** for both samples. For polySiC, the Ni₂Si alloy is detected only in **localized clusters** within the filament structure. In contrast, for the monoSiC sample, Ni₂Si is found to be formed on a wider part of the surface, accompanied by quenching of Si longitudinal optic (LO) mode. This suggests that the SiC **either decomposes in Si + C or chemically reacts with the Ni film** upon high ED laser anneal. Raman signature of carbon phases is present on major part of the surface with varying intensities, evidencing a reduced crystallinity inside the bumps or filament-like structures – consistent with previous studies [6]. One can also note that samples annealed at 2 J/cm² do not exhibit any Raman signature (will be included in the extended paper), suggesting that no chemical reaction occurred between Ni and SiC.

These observations highlight **distinct mechanisms** of silicide formation upon nanosecond laser anneal on polySiC wafer surface versus the (000 $\bar{1}$) surface of monocrystalline 4H-SiC. Notably, the Ni₂Si silicide seems to form on major parts of the monoSiC surface, but is almost totally absent from the polySiC sample. The varying thermal conductivities or chemical potentials – due to changes in polytype, grain orientations and other structural factors – may play an important role in the **dewetting of the Ni film** before it reacts with SiC upon laser annealing, **influencing the amount and possibly the stoichiometry of the Ni silicide formed during the process**. Further XRD characterizations will allow us to assess the formation of any other nickel silicide (such as NiSi₂, which exhibits a very weak Raman signature [6]). Ultimately, **electrical measurements** of contact resistivity will be used to evaluate the effectiveness of NLA backside contact formation considering the use of SmartSiC™ bilayer substrates.

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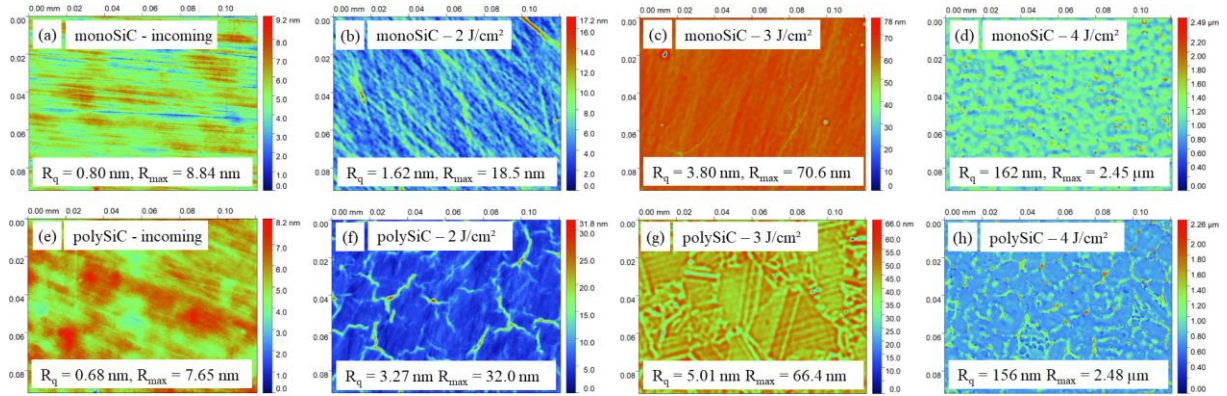


Fig. 1: Optical interferometer micrographs of sample surfaces after NLA (scale $121 \times 92 \mu\text{m}^2$). Substrates: (a-d) **monoSiC** and (e-h) **polySiC**. Laser anneal conditions: (a), (e) initial surface prior to Ni deposition; (b), (f) NLA at ED = 2 J/cm^2 ; (c), (g) ED = 3 J/cm^2 and (d), (h) ED = 4 J/cm^2 .

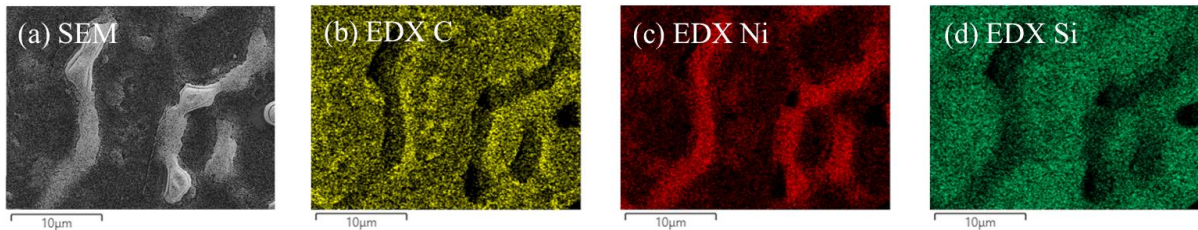


Fig. 2: SEM/EDX maps of polySiC surface after NLA exposure at 4 J/cm^2 . (a) Secondary electron image; (b), (c) and (d) EDX maps of C, Ni and Si elements, respectively, on same location.

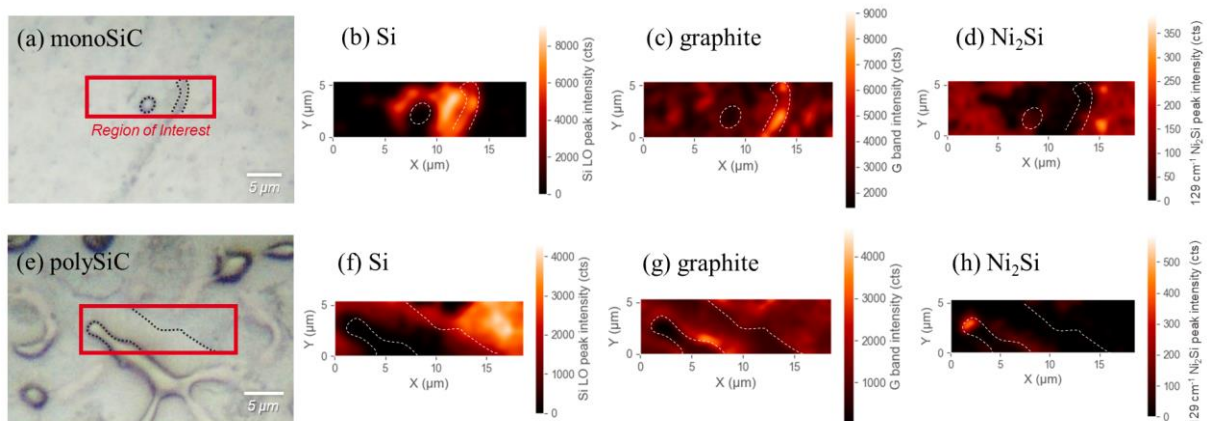


Fig. 3: (a), (e) Optical microscopy images and maps of Raman peaks intensities of (b), (f) Si; (c), (g) graphite and (d), (h) Ni₂Si obtained from a fitting procedure. Substrates: (a-d) monocrystal 4H-SiC and (e-h) polySiC samples after NLA (both after exposure at 4 J/cm^2).