Recovery of Ohmic Contacts Formed on C-face 4H-SiC Following High Temperature Post-Processing

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ABSTRACT - This work demonstrates the recovery of ohmic contacts formed on C-face 4H-SiC following high temperature post-processing. After a dielectric anneal in oxygen ambient for 3 minutes at 650 ºC, replacement of the contact metallization is shown to significantly improve ohmic I-V characteristics. In addition we use C-AFM to study the mechanisms responsible for ohmic contact formation, revealing a possible relationship between changes in the SiC crystal orientation and the establishment of ohmic contact behaviour.

INTRODUCTION

The development of high-κ dielectrics on SiC is an enabling technology for next generation MOSFETs and could significantly assist in the creation of selective gas sensor arrays. Such dielectrics often are fabricated by the annealing of metallic films at less than 800 ºC within oxygen ambient [1]. In contrast an ohmic contact is produced using annealing temperatures greater than 1000 ºC within inert ambient. Therefore a compromise is usually necessary when a device requires both an ohmic contact and high-κ dielectric.

RESULTS AND DISCUSSION

- 5 nm titanium/150 nm nickel was deposited onto the prepared C-face of 4H-SiC and patterned. The I-V response in Fig. 1 (curve a) is from a pair of 8×10^{-5} cm^2 contacts.
- Annealing the contacts for 200 seconds at 1050 ºC in an inert ambient produces ohmic I-V characteristics, as given in Fig. 1 (curve b). However following exposure of the contacts to an oxygen ambient for 3 minutes at 650 ºC, the ohmic response degrades, as shown by Fig. 1 (curve c).
- A possible explanation for this, is surface passivation of the contact metal, which has increased the barrier height between contact and probe. Therefore 5 nm chrome/ 50 nm gold was deposited on the contacts to improve their conductivity, however the data in Fig. 1 (curve d) reveals there is no change in I-V response.
- Studies have shown that ohmic contact formation may be due to a modification of SiC at the near interface region [2]. So the contacts were removed and replaced with 5 nm titanium/100 nm aluminium. This is shown by Fig. 1 (curve e) to significantly improve ohmic behaviour, with resulting discrepancy likely due to contact misalignment.
- Surface topology recorded by AFM (shown in Fig. 2a) reveals a major difference between the substrate adjacent to and beneath an ohmic contact. In Fig. 2b it's shown that during contact formation, approximately 75 nm of substrate material is consumed.
- A closer examination of substrate adjacent to and beneath an ohmic contact, made by C-AFM is given in Fig. 3. This reveals surface roughness is 4.5 nm RMS beneath an ohmic contact, with 2.9 nm RMS on the adjacent free surface.
- Fig. 3 also shows that conductance is highest beneath an ohmic contact, particularly on the sharp edges of features. To prove topology is not the cause of this, conductance sweeps taken in opposite directions are given in Fig. 4, which are nearly identical.
- Previous work has demonstrated that substrate crystal orientation can dramatically affect Schottky barrier height [3]. The increased substrate roughness beneath an ohmic contact may produce various crystal orientations, possibly creating regions of low schottky barrier height and establishing the ohmic behaviour.

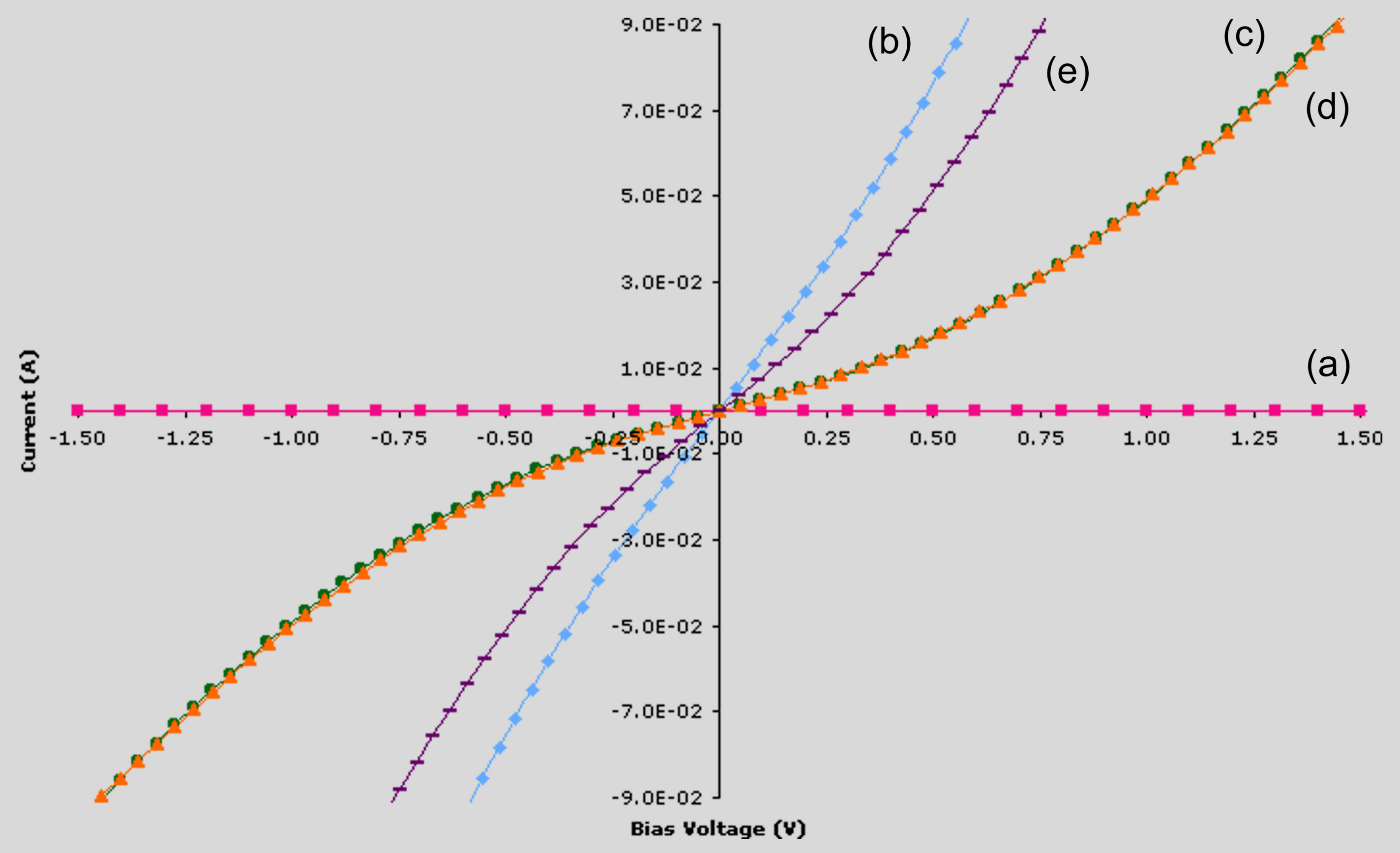

Figure 1: The I-V characteristics from a pair of contacts formed on C-face 4H-SiC following: (a) Ti/Ni deposition; (b) annealing at 1050 °C; (c) Rapid Thermal Processing in O_2 at 650 °C; (d) Cr/Au deposition; (e) complete replacement with Ti/Al

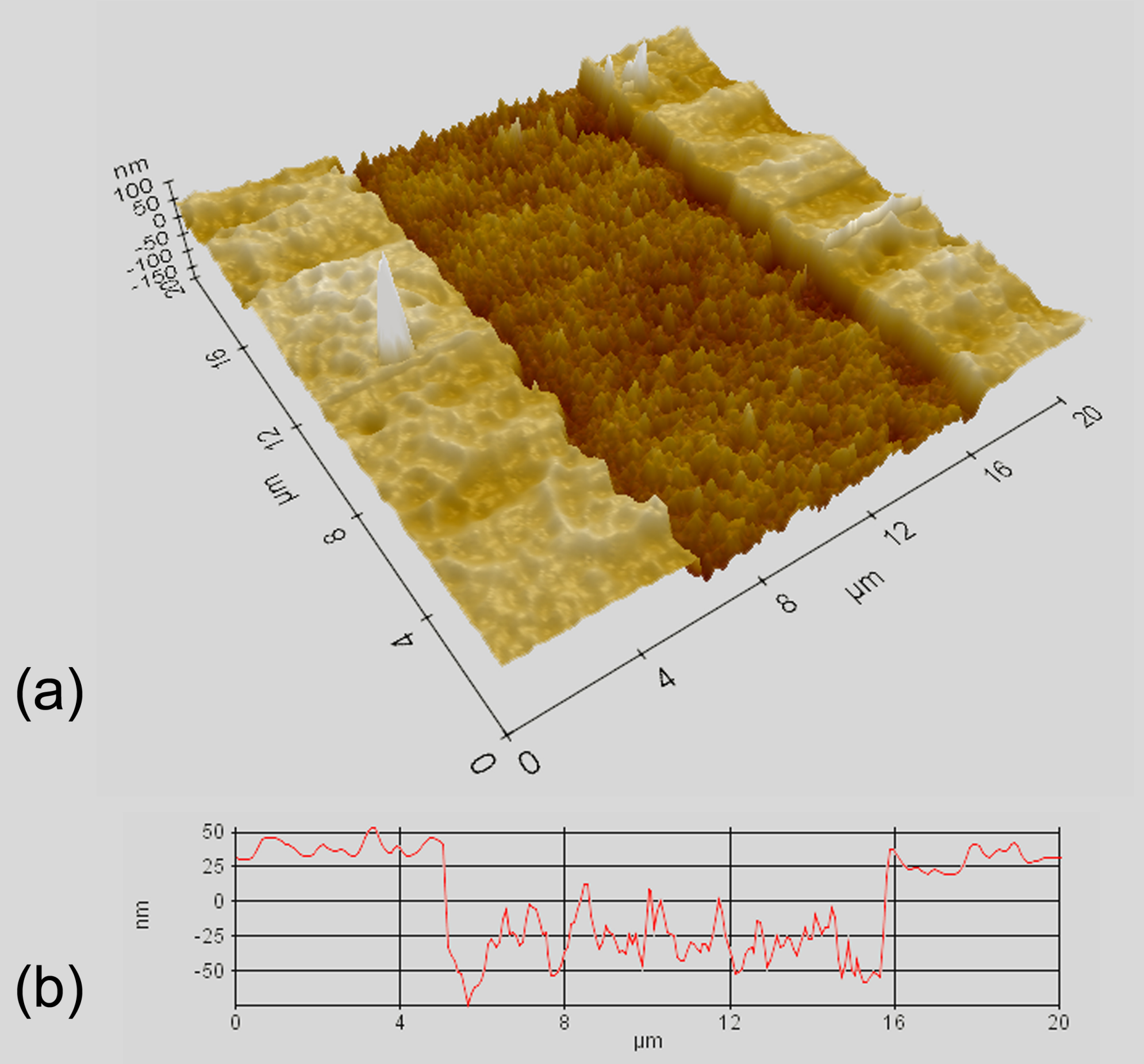

Figure 2: Results of non-contact AFM across the substrate below a 10µm wide ohmic region, displayed as: (a) Topology; (b) Cross-section

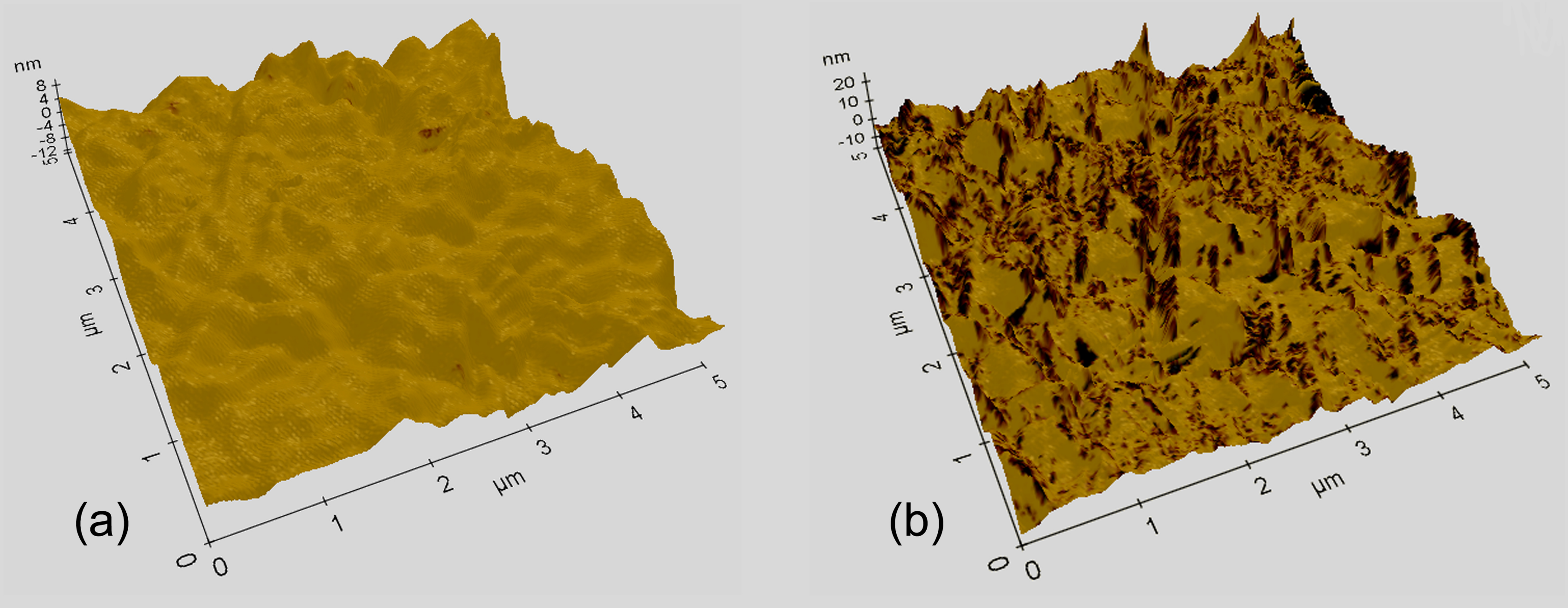

Figure 3: Surface topology overlaid with conductance, recorded by C-AFM at -2 V substrate bias, for areas of substrate: (a) adjacent to an ohmic contact; (b) beneath an ohmic contact

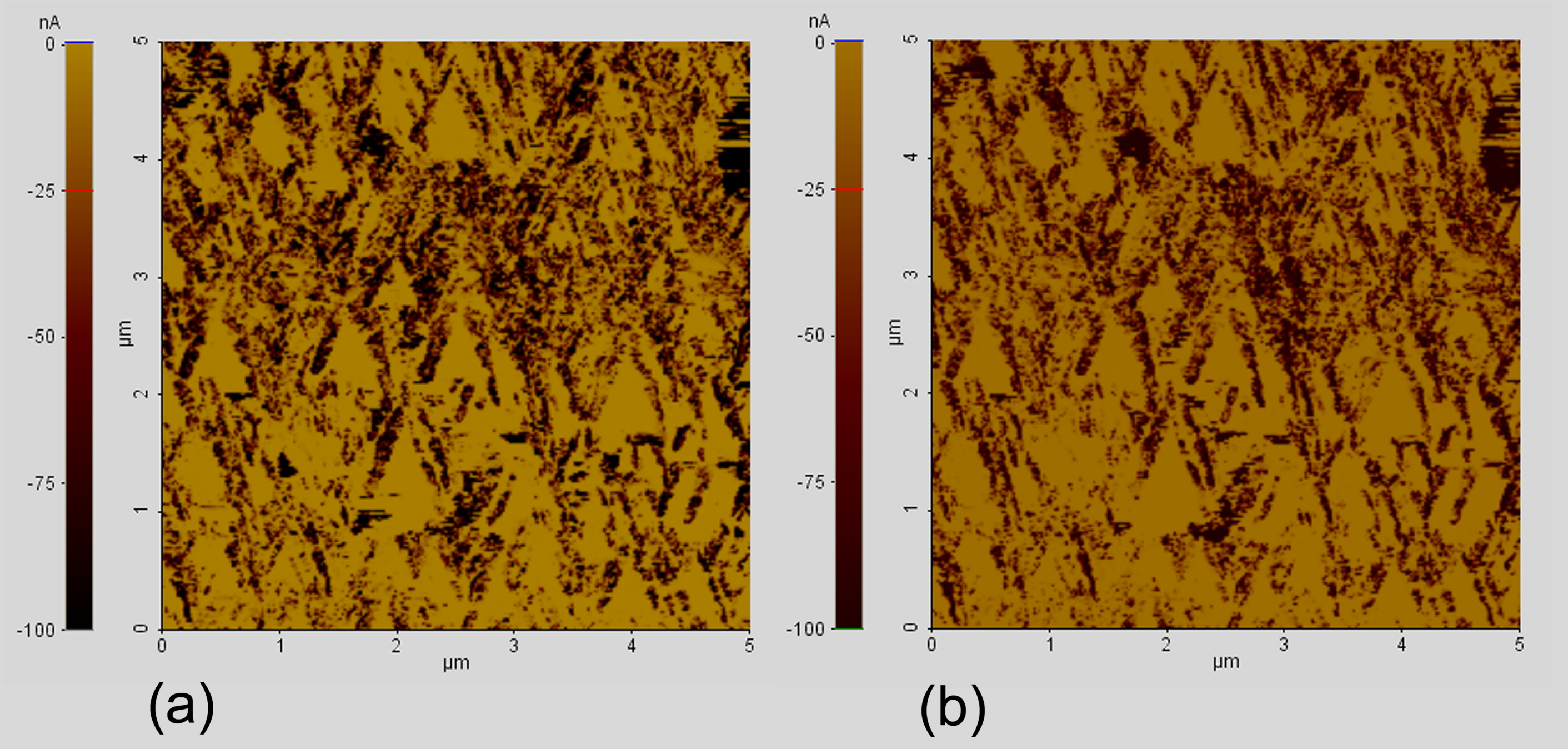

Figure 4: Conductance recorded by C-AFM at -2 V substrate bias, for an area of substrate beneath an ohmic contact, with a sweep direction of : (a) left to right; (b) right to left

SUMMARY

This work reports on a technique for recovering ohmic contacts formed on C-face 4H-SiC after high temperature post-processing. Ohmic contacts are exposed to oxygen ambient for 3 minutes at 650 ºC, then by contact replacement the damage caused to ohmic I-V characteristics is largely corrected. This supports previous work proposing that ohmic behavior is related to a modification within the near interface region of silicon carbide. To validate such a mechanism further, the results of AFM were used to demonstrate the surface roughness beneath an ohmic contact is much greater than adjacent substrate. Then comparison of this with C-AFM reveals that conductivity is highest on the steep features of the rougher surface. With the support of literature it's concluded that changes in SiC crystal orientation may create a reduction in barrier height that assists in ohmic contact behavior.

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