Conductive atomic force microscopy study of self-assembled silicon nanostructures

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Understanding the electrical transport properties of nanostructures and metal-nanostructure contacts is important before these can be fabricated into electronic devices. Both issues can be adequately addressed in conductive atomic force microscopy (C-AFM) measurements. This paper reports C-AFM investigations of self-assembled silicon nanostructures fabricated using electron-beam rapid thermal annealing (EB-RTA),[1] a process that has been shown to produce field-emission devices using CMOS-compatible technology.[2]

For this study self-assembled nanostructures were formed on p-type silicon (100) using EB-RTA at 1000 ± 0.1˚C for 15 s, with ± 5˚C/s heating and cooling rates. The topographic and C-AFM measurements were carried out simultaneously using a Veeco Instrument's Dimension 3100 AFM [Fig. 1] with Pt/Ir coated Si cantilevers. Figures 2 and 3 demonstrate for the first time an unambiguous correlation that exists between the topography and current flow on these nanostructured surfaces, with ±1.0 V biases applied to the sample respectively. Current on the nanostructures is typically ~10× that on the surrounding silicon, which is in the noise level of the instrument (low pA range); this low current level is typical of unstructured silicon samples due to the presence of the native oxide acting as a tunnel barrier. Average electrical current-voltage (I-V) readings for substrate dc bias sweep from -1.0 V to +1.0 V of five representative nanostructures of height of ~8 nm are shown in Fig. 4. An asymmetric I-V relationship is observed, with an offset voltage of approximately 150 mV.

Higher currents at the nanostructures indicate either a lowering of the tip-surface potential barrier height from the presence of surface states in the different facets[3] or tunnelling from the enhanced field emission of the nanostructures. A combined effect of the both can also be a possibility. Through this C-AFM imaging a deeper understanding of the effects of surface states and field emission on the transport properties of these and other nanostructures will therefore be possible.

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[1] S. Johnson, A. Markwitz, M. Rudolphi, and H. Baumann, J. Appl. Phys. **96**, 605 (2004).
[2] S. P. Lansley *et al*., Proc. 2006 ICONN, Brisbane, Australia, IEEE Press (06EX1411C), pp. 332-335.
[3] G. Cheng *et al*., Appl. Phys. Lett. **92**, 223116, (2008).

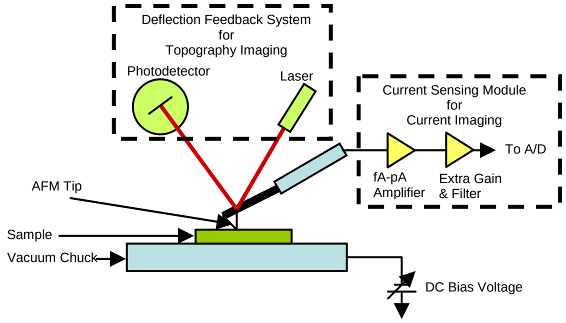
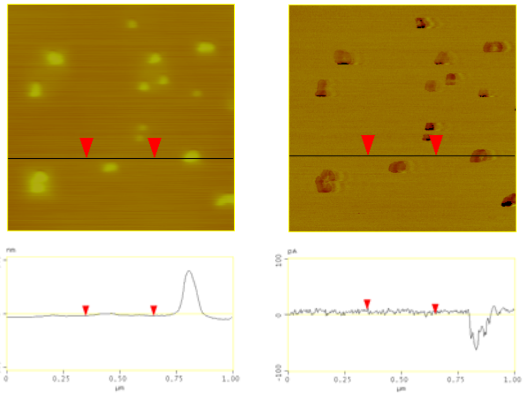
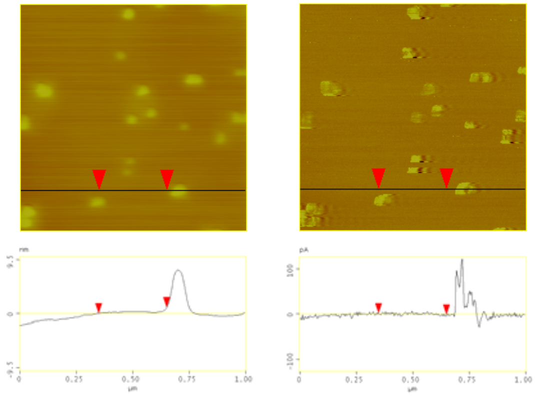


Fig. 1. Schematic for conductive and tunnelling AFM. The tip is in contact with the sample surface.



(a) (b)

Fig. 2. Sample biased -1.0 V DC.
(a) Topographic, and (b) Current image.



(a) (b)

Fig. 3. Sample biased +1.0 V DC.
(a) Topographic, and (b) Current image.

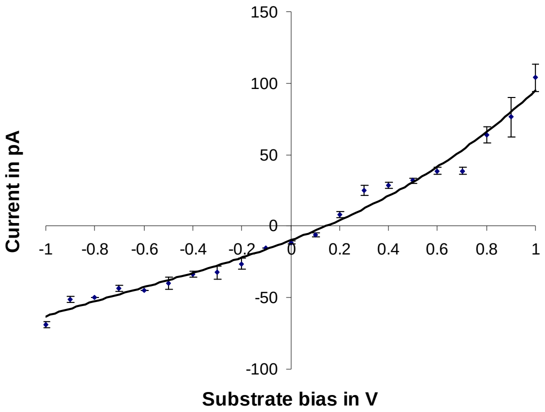


Fig. 4. I-V characteristics of nanostructures.
(DC sweep from -1.0 V to +1.0 V)