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IT-11-P-2987 Distribution of electric field and mechanical vibrations of CdS nanocombs during field emission

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CdS comb-like nanostructures (Fig. 1a) were recently shown to have remarkable optical properties and possible applications as waveguides [1]. On the other hand, nano-cone-based field-emission guns (FEGs) have shown a strong improvement of the coherence compared to classical W tips [2] that is of particular interest for electron holography for example. As CdS-based nanostructures are also used in optically-induced field emission [3], it combination with wave guiding properties may allow their use in FEGs, in which the light that triggers the emission of electrons is focused onto a different part of the nanostructure to that from which the electrons are emitted. With this an increase of the local temperature at the electron emission point that results in increase of electron energy spread can be avoided. Here, we study the field emission properties of such nanocombs in situ in the transmission electron microscope (TEM) using off-axis electron holography combined with electrical biasing.

The experiments involved mounting a CdS nanocomb onto a W needle and bringing a movable W probe towards CdS comb in situ in the TEM (Fig. 1b). Bias voltages of between 0 and -140V were applied to the nanocomb. Off-axis electron holograms were acquired before and during field emission from the apex of one of the branches of the comb. The phase shift measured using electron holography is proportional to the projected electrostatic potential. The density of the measured equiphase lines shown in Fig. 2 facilitates identification of the region from which electrons are emitted. This information can be correlated directly with the morphology of the apex. We measured threshold bias voltages for field emission for different electrode configurations. Unexpectedly, the nanocomb was observed to vibrate when field emission was initiated, as shown in Fig. 3.

[1] Liu R. et al., Nano Letters, 2013, 13, 2997−3001

[2] Houdellier F. et al., 15th European Microscopy Congress Manchester Central, 2012

[3] Zhang J. et al., Sci. China Phys. Mech. Astron., 2011, 54 (11), 1963–1966

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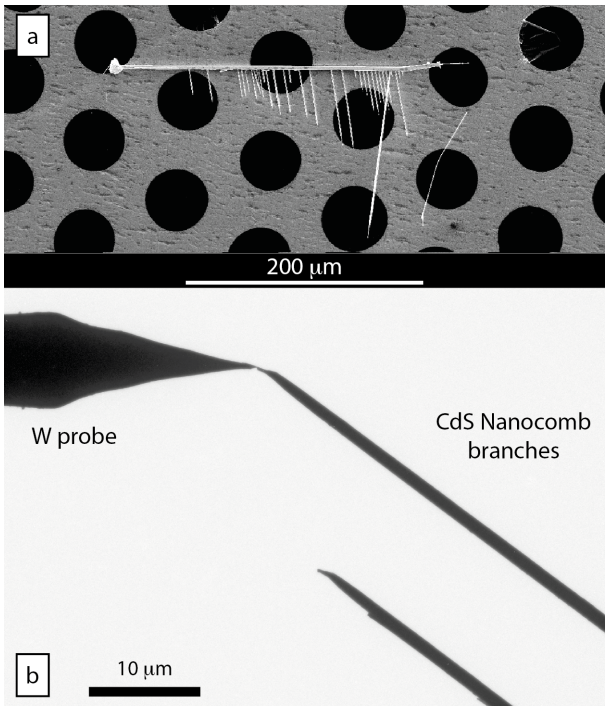

Fig. 1: a) Scanning electron micrograph of a CdS nanocomb deposited on a holy carbon grid. b) Bright-field TEM image showing the geometry of the field emission experiment.

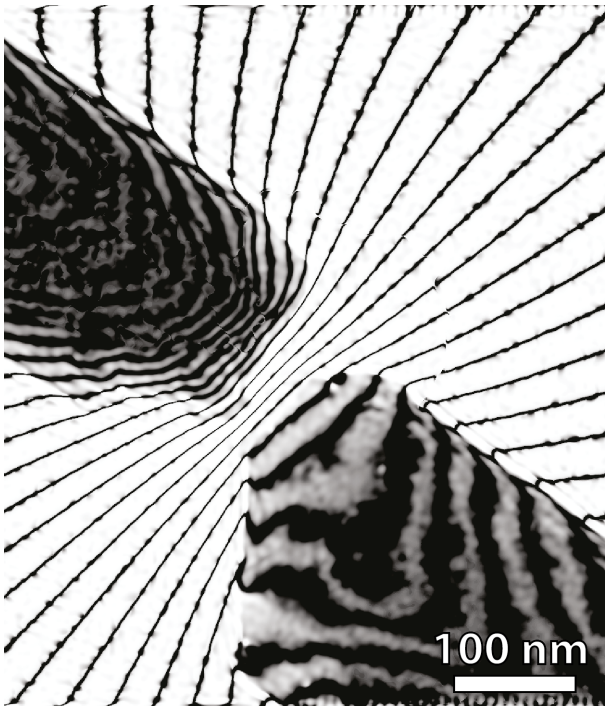

Fig. 2: Equiphase contours recorded using electron holography for a bias voltage of -23 V between the apex of one tooth of the CdS nanocomb (bottom) and the W probe (top).

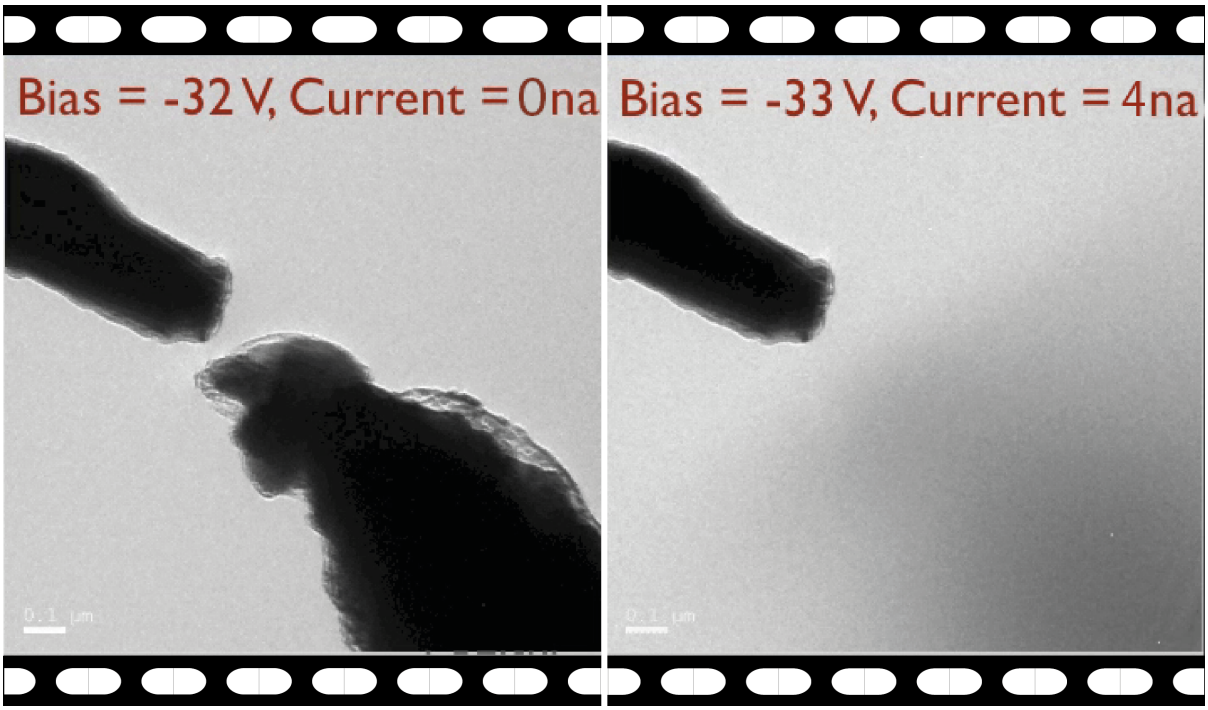

Fig. 3: Frames from a video recorded in a TEM, showing the end of a tooth of the CdS comb (bottom) before the onset of field emission at a bias voltage of -32 V (left) and during field emission at a bias voltage of -33 V with a current of 4 nA (right). The contrast of the tooth is blurred due to the onset of mechanical vibrations with MHz range frequency.