Direct observation and mechanism for enhanced electron emission sites in Pt ion implanted/post-annealed ultra nanocrystalline diamond films

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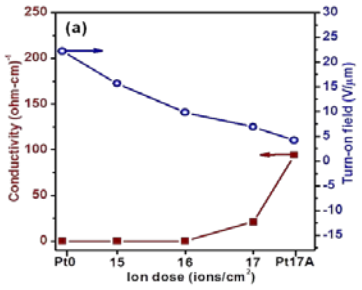
Ultra nanocrystalline diamond (UNCD) films have recently caught great attention from researchers due to their unique granular structure and immense potential to be employed as cold cathode materials in flat panel displays and other field emitting devices [1]. The properties of nanostructured diamond films depend on the grain size while the structure of the grain boundaries determine the electrical and optical characteristics [1]. On the other hand, ion implantation has been a long practice to modify the properties of carbon materials through controlled doping of variety of dopants [2]. Here, we report the mechanism for enhancement in electron field emission (EFE) properties of UNCD films upon Pt ion implantation and subsequent post-annealing process. The Pt ion implanted/post-annealed films exhibit higher conductivity and best EFE properties (Fig. 1(a) & 1(b)) respectively, with a turn on field of E_0=4.17 V/μm and current density of J_e=5.08 mA/cm^2 at 7.2 V/μm. TEM analysis indicates the mechanism for enhanced EFE properties is due to the formation of nanographitic phase around the diamond grains. Moreover, a UHV STM system is used to directly detect the emission sites and the mechanism for enhanced EFE properties from a microscopic viewpoint [3]. Role of the nanographitic phase in improving the emission properties is directly revealed by the current imaging tunneling spectroscopy (CITS) mapping which indicates better electron emission in Pt implanted/post-annealed films than the pristine ones. Interestingly, the electron emission sites are mostly seen around the diamond grain boundaries, as confirmed from high resolution CITS mapping. Fig. 2(a) shows the HRSTM image of Pt implanted/post-annealed UNCD (Pt17A) with the corresponding CITS image in 2(b). Bright contrast in the CITS image shows better electron emission [3].



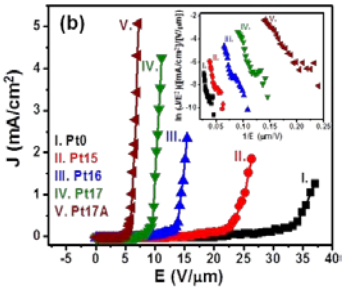


Fig.1 Variation in the electrical conductivity (solid squares) and turn-on field (open circles) and (b) the electron field emission properties of various dosage of Pt-ion implanted and annealed UNCD films. The inset of (b) shows the corresponding Fowler Nordheim (FN) plot.

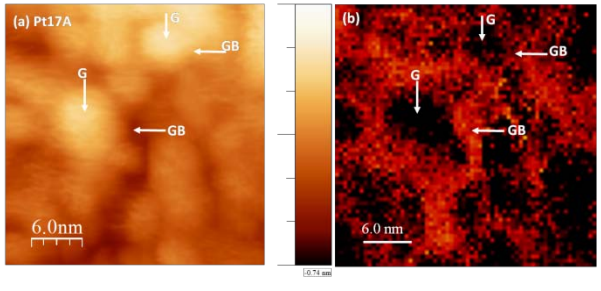


Fig. 2 STM image of Pt implanted/post-annealed UNCD Pt17A film (a) with corresponding CITS image in (b).

[1] W. Zhu et al., *Science* **282**, 1471 (1998).
[2] K. Panda et al., *Appl. Phys. Lett* **105**, 163109 (2014).
[3] K. Panda et al., *ACS Appl. Mater. Interfaces* **6**, 8531(2014).