Graphene-Based Cathode Cold-Field Electron Emission Sources

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Recently, carbon based field emission sources have become a popular area of study owing to their structural robustness and other desirable electrical and mechanical properties.[1,2] Of these carbon based field emission sources, graphene based sources have shown excellent field emission characteristics and are therefore suitable for making high performance field emission devices.[3,4]

Shao *et al*. reported high field emission currents of about 30 μA from a novel graphene ring-cathode (GRC) cold-field emitter design, at relatively low applied electric field in HV conditions,[5]. This is in contrast to conventional single tip cold-field emitters which require high electric field strengths (close to electrical breakdown) and operate in UHV conditions.[6] This ring-cathode emitter is a promising high brightness electron source, especially for lithography applications. This paper shall report further results obtained from the GRC field emitter and its improvements such as the Ni-nanoparticle enriched GRC (Ni-GRC) field emitter (Fig 1), expected to require lower turn-on electric field strength (due to a lower work function[7]) and to be more resistant to damage caused by ion back-bombardment. More results from other graphene based cold-field emitters of different geometries shall also be reported during the presentation.[8]

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1 M. Z. Yusop, G. Kalita, Y. Yaakob, C. Takahashi, and M. Tanemura, Applied Physics Letters **104**, 093501 (2014).

2 N. De Jonge, Y. Lamy, K. Schoots, and T. H. Oosterkamp, Nature **420**, 393 (2002).

3 S. Kumar, G. Duesberg, R. Pratap, and S. Raghavan, Applied Physics Letters **105**, 103107 (2014).

4 Z. S. Wu, S. Pei, W. Ren, D. Tang, L. Gao, B. Liu, F. Li, C. Liu, and H. M. Cheng, Advanced Materials **21**, 1756 (2009).

5 X. Shao, A. Srinivasan, Y. Zhao, and A. Khursheed, Carbon **110**, 378 (2016).

6 L. W. Swanson and G. A. Schwind, in *Advances in Imaging and Electron Physics* (Elsevier, 2009), pp. 63.

7 G. Giovannetti, P. Khomyakov, G. Brocks, V. v. Karpan, J. Van den Brink, and P. Kelly, Physical Review Letters **101**, 026803 (2008).

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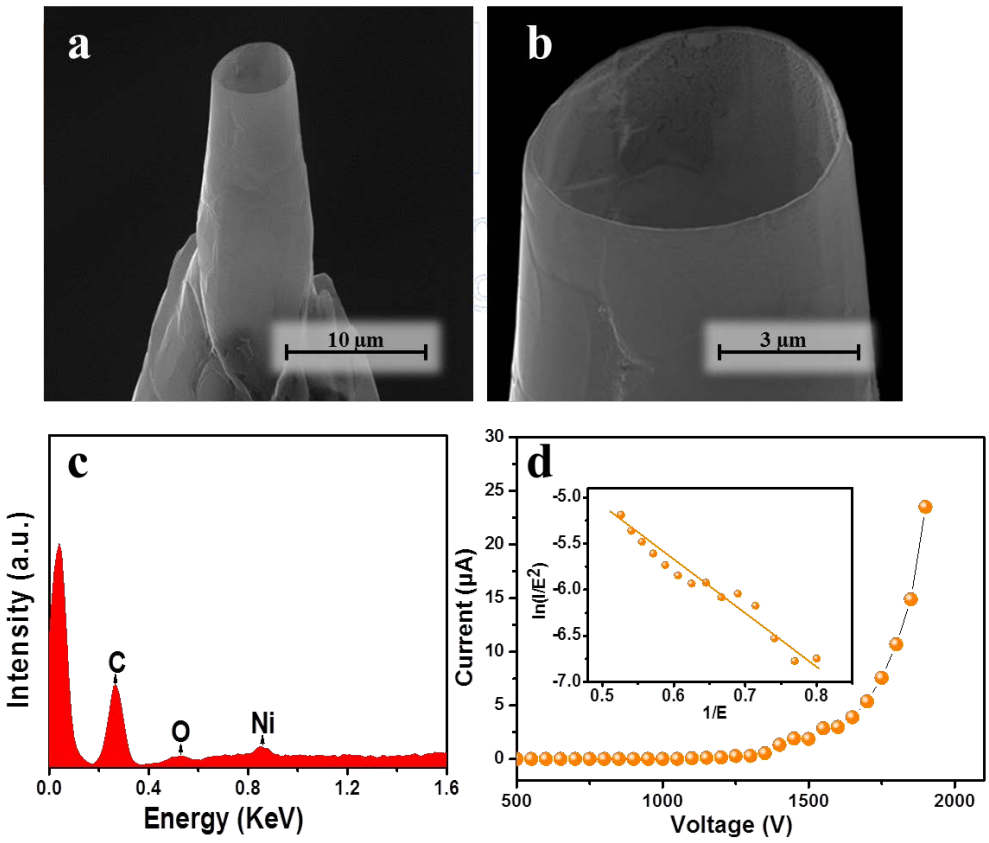

Figure 1: A graphene ring-cathode field emitter (a) SEM image of a Ni-nanoparticle enriched graphene microtube structure. (b) High magnification SEM micrograph of the ring-cathode. (c) EDS spectrum acquired on the surface of the fabricated structure. (d) Field emission I-V curve obtained from the Ni-GRC emitter (inset shows the F-N plot).