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21.2: Enhanced Field Emission Properties from Carbon Nanotube Emitters Grown on NiCr Alloy Surfaces with Grain Boundary Effect

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Carbon nanotubes (CNTs) are known to have exceptional field emission properties such as low turn-on voltage and high current density. Nilsson et al. reported that field emission properties depend highly on the density of the CNT films [1]. The CNTs must have low density in order to minimize electrostatic field screening from neighboring nanotubes. At the same time, the CNT films must have a high number of emitting sites to achieve a desirable current density. Recently, the direct growth of CNTs on metal alloys containing Ni, Cr, and Fe has been shown to be an attractive alternative for fabrication of CNT emitters without requiring a metal catalyst deposition step [2]. Herein, we report the field emission properties of multi-walled carbon nanotube (MWNT) films grown on polished smooth 80/20 and 70/30 NiCr surfaces by thermal chemical vapor deposition. We show that 80/20 NiCr surfaces prohibit growth of MWNTs at the grain boundaries [3], resulting in a lower turn-on field in comparison to a continuous MWNT film obtained with 70/30 NiCr substrates.

We reported previously on the field emission properties of MWNT films grown as pillars with 50 μm diameter based on a micropatterning technique [4]. Figure 1a shows the I-V curves for MWNT films grown on 80/20 and 70/30 NiCr alloys, which exhibit very distinct turn-on fields of 1.3 V/ μm and 3.6 V/ μm , respectively. The 80/20 NiCr alloy reveals a discontinuous film with MWNT islands, where MWNTs are not observed in areas around the grain boundary. In contrast, the 70/30 NiCr alloy shows a continuous film and a higher turn-on field (SEM image in Figure 1c). We attribute the lower turn-on field for the 80/20 NiCr sample to less field screening effects from lower density films, with a higher number of emission sites at the edge of MWNT islands close to the grain boundaries.

We utilize Auger electron spectroscopy (AES) elemental mapping and depth-profiling techniques to investigate the influence of the NiCr substrates on growth behavior. AES elemental mapping of the NiCr surface of both compositions reveal high Ni content at the inner grain surface and segregation of Cr and O to the grain boundary after a high temperature annealing process at 750°C, similar to the growth conditions for MWNTs. Less segregation of Cr and

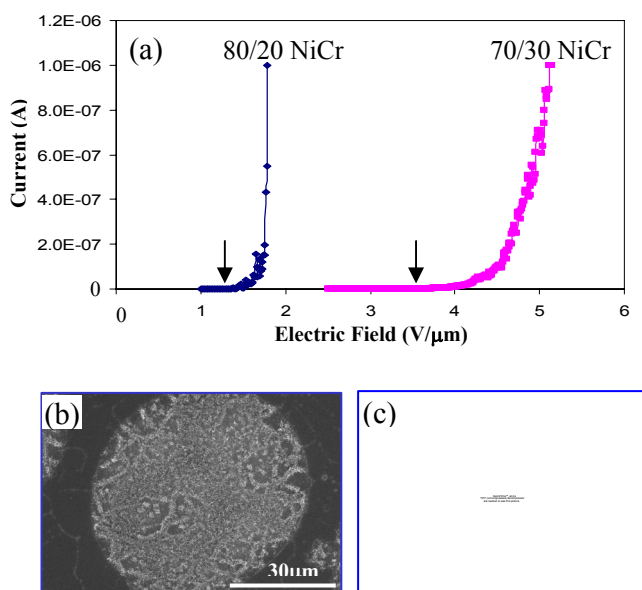


Figure 1. (a) Field emission I-V curves of 80/20 and 70/30 NiCr alloys, (b) SEM image of 80/20 alloys with grain boundary effect, (c) SEM image of 70/30 alloys showing a continuous film, without grain boundary effect. The turn-on field is defined at an emission current of 1 nA.

O, with grain boundary width of about 1 μm , is observed in the 70/30 alloys. In comparison, the 80/20 alloys reveal much larger areas of Cr oxide segregation at grain boundaries (Figure 2). The Ni-rich regions at the interior of the grains are directly correlated to areas of MWNT growth, as evidenced in the 80/20 NiCr alloy shown in Figure 3, whereas Cr oxide surface areas at the grain boundary appear to inhibit MWNT growth. It is interesting to point out that AES depth profiles of both 80/20 and 70/30 NiCr alloys reveal that the Ni-regions at the inner grains have a subsurface Cr and O enrichment.

In this paper, we demonstrate enhanced field emission properties from MWNT emitters grown directly on the 80/20 NiCr alloy surface due to the grain boundary effect. The elemental segregation was clearly demonstrated by AES elemental mapping, where Cr and O surface segregation inhibited MWNT growth. The potential for this simple process is that it may be employed for fabricating CNT emitters without

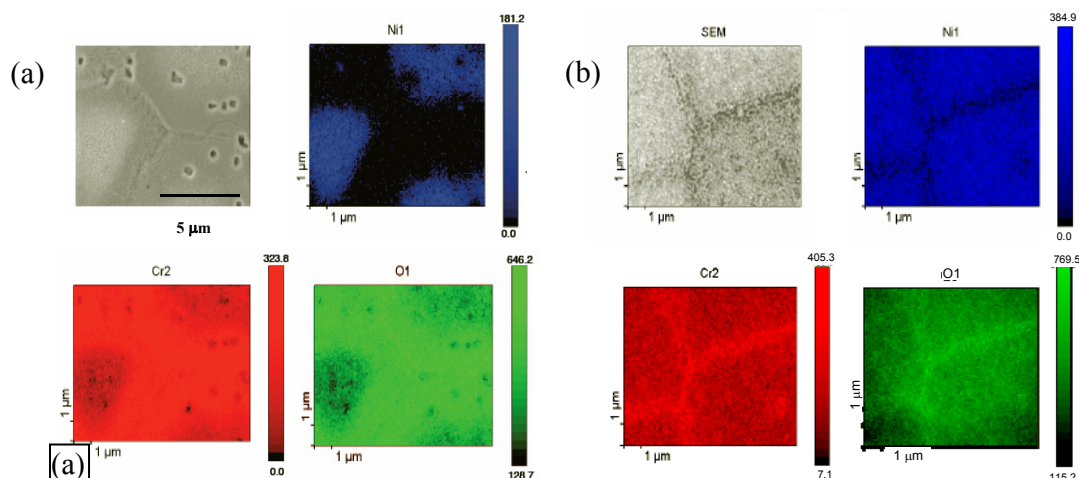


Figure 2. AES elemental mapping of thermally annealed (a) 80/20 and (b) 70/30 NiCr alloys.

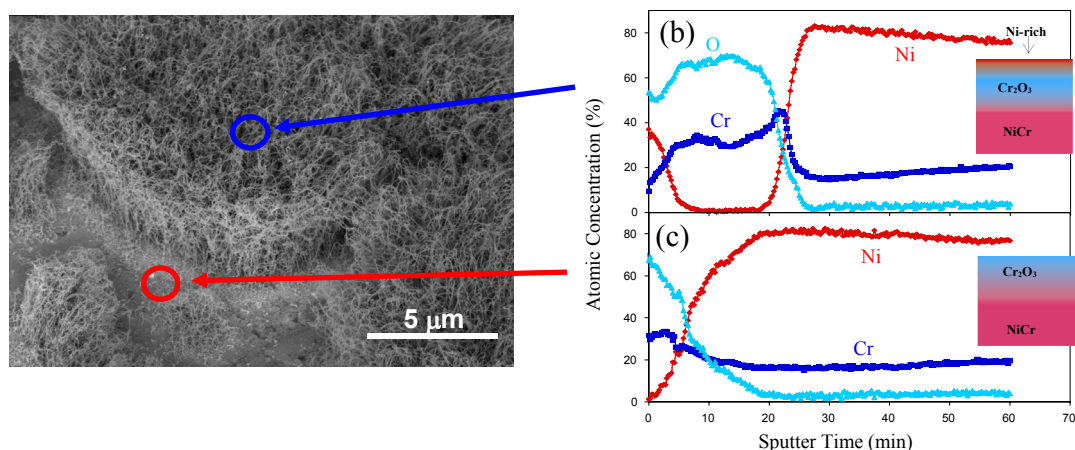


Figure 3. (a) SEM micrograph of selective growth of MWNTs on 80/20 alloy surface, (b) AES depth profile at Ni-rich grain interior region, and (c) at the grain boundary.

requiring any metal deposition step nor microlithography process in order to minimize the field screening effect.

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