Improvement Field Emission Uniformity in Carbon Nanotube Composite using Zinc Nano-Fillers

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Abstract

The improvement in the field emission parameters, luminescent uniformity, degradation rate and half life has been observed for the thin–multi wall carbon nanotube (t–MWCNT) composite, after incorporating the Zn nanoparticles. The Zn nanoparticles (diameter ~ 100 ±15 nm) has been incorporated to synthesize the Zn–t–MWCNT composite.

1. Introduction

Due their potential application as the cold cathode layers, the field electron emission parameters of the carbon nanotubes (CNTs) have been the focus of several recent investigations. As a field emitter, CNTs have lower turn–on field due to the high mean–field enhancement factor, γ_m, originated form the high geometric aspect ratio and small diameter, *d*, of the tips [1]. In this paper, Zn is incorporated in the thin–multiwall carbon nanotube composite. Due to the low exothermic (melting) point, the Zn nanoparticles melt in the composite during the curing process. The presence of melted Zn clusters improves the connectivity between nanotubes and cathode substrate, which in turn influences the field emission parameters, luminescent uniformity, and half life of the composite. The incorporation of Zn nanoparticles to improve the field emission characteristics of carbon nanotube composite is rarely reported in the literature. This is the topic of the communication. The details are presented.

2. Experimental

To prepare CNT-composite, we premixed 1.0 wt% t-MWNT, 10 wt% Zinc nano-particles and organic vehicles. The prepared CNT-composite was printed onto an indium tin oxide (ITO) coated soda lime glass by the screen-printing method which could be efficiently adapted to a large screen size. Two types of CNT-composite were prepared to compare raw CNT-composite with CNT-composite using zinc nano-particles. In order to remove the organic vehicles, CNT-composite film was annealed at a temperature 450 °C during 10 min under N_2 atmosphere. However, the CNT-composite with zinc nano-particles was annealed at a temperature 500 °C during 30 min to sinter zinc. The zinc nano-particles could help attach with CNT on ITO glass during melting in the furnace.

3. Results and discussion

Figure 1 is the recorded SEM micrograph (cross view) for the (a) raw composite (b) corresponding detailed morphology, (c) Zn–t–MWCNT–composite and (d) its detailed morphology. Because the nanoparticles have been sintered during the composite synthesis then Zn may assist in improving the adhesion between the carbon nanotubes and the substrate [2]. Furthermore, from Figure 1 (a) and (c) one can see that average height of the nanotubes in the t–MWCNTs composite is reduced as compared with the nanotubes in the raw–composite.

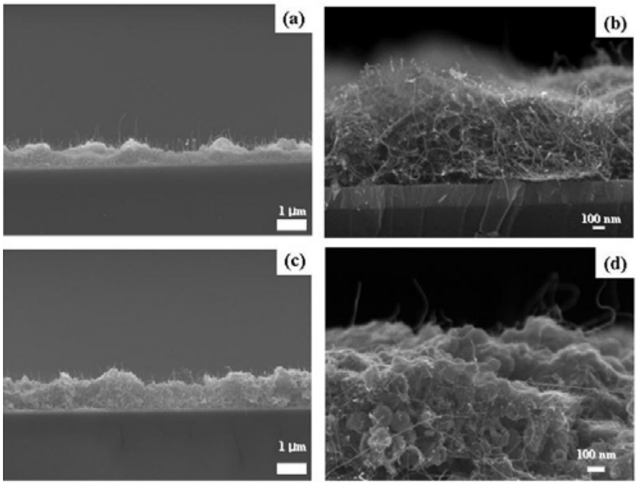

Figure 1: Recorded SEM micrographs for (a) raw-composite, (b) corresponding detailed view, (c) Zn-t-MWCNT-composite and (d) corresponding detailed view.

Figure 2 is the plot of variation in the measured current density (mA/cm^2) as a function of applied electric field (V/μm) for the composites prepared by (a) pristine t-MWCNTs and (b) Zn–t–MWCNTs. Each plot is the average of five recorded profiles. Inset shows the corresponding Fowler–Nordheim plot for log (I/V^2) as a function of 1/V [3,4]. From Figure 2 one can see that, the magnitude of the current density monotonically increases with increase in the applied electric field, however, no major variations in the current density has been observed upto ~ 1.4 V/μm, for the plots (a)-(b).

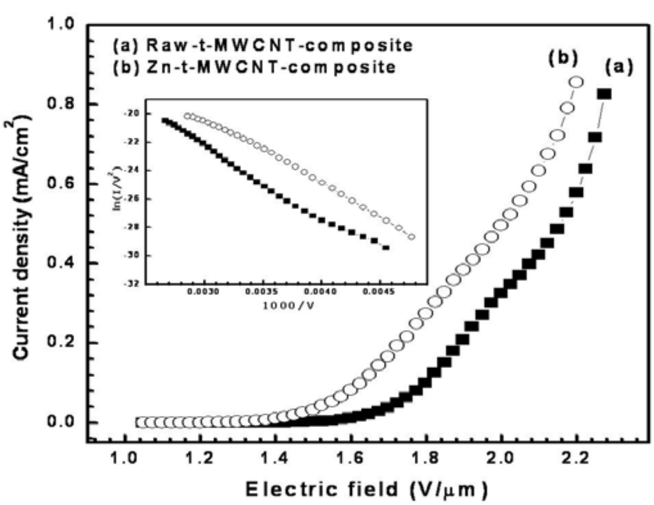

Figure 2: Variation in field emission current density (measured in mA/cm^2) as a function of applied electric field (V/μm) for (a) raw carbon nanotube composite, (b) Zn incorporated carbon nanotube composite. Inset is corresponding Fowler–Nordheim plot.

Moreover, the J–E behavior typically follows the F–N tunneling mechanism at low electric field, from 1–1.4 V/μm, and current densities. With subsequent increase in the field, from 1.4–1.6 V/μm, and increased current density (> 0.1 mA/cm^2), the plot (b) exhibit a marked current density variation that sharply deviates from the plot (a). With further increase in the applied electric field, from 1.6–1.8 V/μm, and current density, the J–E characteristics yield to the electron tunneling behavior governed by the F–N theory. For each plot, the magnitude of the turn–on–electric field (measured in V/μm) has been estimated at a current density ~ 10 μA/cm^2, where as, the magnitude of measured current density, J, is coated at 2.2 V/μm. One can see that, for the raw–composite, the turn–on–field is ~ 1.4235 V/μm and is decreased upto ~ 1.22 V/μm for the Zn–t–MWCNT composite. Thus, significant improvement in the turn–on–field has been achieved for the Zn–t–MWCNT–composite. Furthermore, the magnitude of current density, J, is ~ 577.397 μA/cm^2 for the raw–composite and observed to be increased from ~ 577.397 μA/cm^2 to 856.683 μA/cm^2 for the Zn–t–MWCNT–composites.

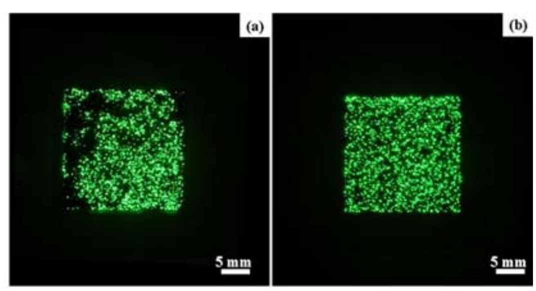

Figure 3: The field emission uniformity has been measured at a magnitude of current density ~ 100 μA/cm^2. Recorded digi–cam photographs for (a) raw-composite, and (b) Zn-t-MWCNT-composite.

The field uniformity has been measured for the composite cathode layers [5]. The data has been recorded at a magnitude of current density ~ 100 μA/cm^2. Figure 3 is the typical digi-cam photographs recorded for the (a) raw composite, (b) Zn–t–MWCNTs composite. The luminescent emission area was kept constant (~ 1 X 1 cm^2). For the raw composite, a large number of dark zones have been observed typically at the left side of the photograph (a).

The dark zone indicates no electron field emission region. In contrast, the absence of dark zones indicates that emission uniformity is improved significantly for the Zn–t–MWCNTs composite. This shows that, the connectivity of the nanotubes, in the Zn–t–MWCNTs composite, with the substrate is improved significantly. As a result, the number of nanotubes participating in the turn–on process is increased, which in turn influences the luminescent uniformity of the samples [5].

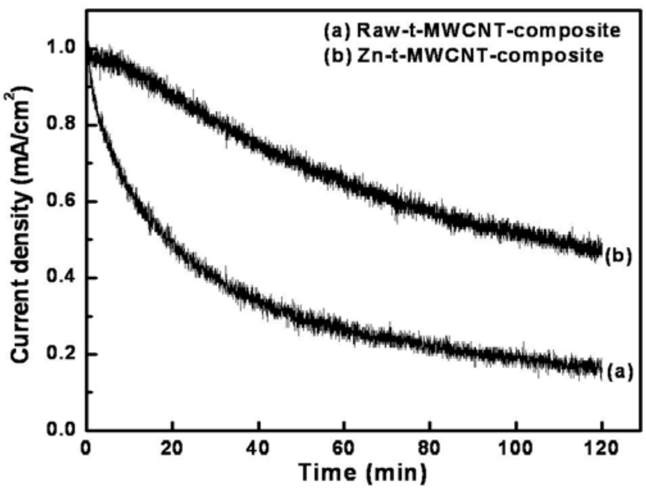

Figure 4: Variations in measured current density as a function of time for the (a) raw–composite and (b) Zn-t-MWCNT-composite.

Figure 4 shows the plot of the lifetime behavior measured for (a) the raw composite and (b) the Zn–t–MWCNTs composite. These measurements have been carried out by setting the magnitude of current density at ~ 1 mA/cm^2. It shows the variations in the field emission current density (μA/cm^2) over the measured time (in min). The lifetime measurements have been carried out for ~ 120 min (2 hrs). Furthermore, Figure 4 shows that, in the first 20 min the measured current density decreased rapidly, however, the degradation behavior is reduced in the next 20 min and continuous to reduce further till the end of the measurements, for the raw composite. In contrast, the overall emission stability and degradation behavior is improved significantly for the Zn–t–MWCNTs composite. For the Zn–t–MWCNTs composite, the variation in the measured current density is negligibly small over the first 60 min and there after almost constant, over the next 60 min i.e. till the end of the measurements (Figure 4(b)). Thus, result shows that, the raw composite degrades rapidly, as shown in Figure 4(a).

4. Summary

The incorporation of Zn nanoparticles could influence the field emission parameters, luminescent uniformity, degradation rate and half life, $t_{1/2}$, of the raw t–MWCNT composite. The Zn nanoparticles get coupled to the nanotubes via the ITO medium and in turn increase the connectivity between the nanotube and substrate. As a result, the probability of nanotubes participating in the turn–on process increases, which in turn influences the turn on field, active geometric field emission area and luminescent uniformity of the Zn–t–MWCNT composite.

5. References

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