Characterization of CNT-ink and fabrication of a cold cathode using jet-printing technique.

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Abstract

Aquesous carbon nanotubes (CNTs) solutions were prepared using SDS (sodium dodecyl sulfonate) and NADDBS (sodium dodecylbenzene sulfonate). Our inks are found to have the viscosity of 1-2 cps. In addition, the surface tension of inkș inversely decreased with increasing surfactant concentration and then saturated at critical micelle concentration (CMC). The low surface tension at CMC gave rise to lower contact angles on Indium layers, resulting in larger printable feature sizes. In the fabrication of cold cathode, jet-printing is feasible to modify and scale up the cathode structures. These feasibilities could contribute jet-printing method to be more adaptable for making large-area cold cathodes.

1. Objectives and Background

Ink-jet printing is capable of dispensing drops where they are needed and furthermore defining features less than a micrometer.[1,2] In addition, a higher flexibility and scalability of jet-printing method in structure designs are strong advantage in fabricating large area flat panel displays (FPD). For jet-printing applications, CNTs should be dispersed in water using surfactants. However, the successful application of CNT solution can be achieved on characterization of fluidic properties including surface tension, viscosity, and proper contact angle. Unfortunately, however, these important issues in CNT inks remain unexplored.[3,4]

2. Results

In order to make an ink using NaDDBS and SDS, we increased the amount of CNTs from 3 mg to 15 mg in 30 g of dionized water. To maintain the same dispersability, 5 times amount of surfactant was added in CNT/water. The SWCNTs were purchased from Carbolex Inc. After an intense sonication of the aqueous solution, a centrifugation at 10,000 RPM for 10 minutes was followed to exclude CNT bundles and catalytic particles. The viscosity of resultant inks was measured using a temperature-controlled digital viscometer (DV-II Pro, Brookfield). The surface tension of inks was measured by a pendant drop analysis (PAT 2P-USB, Sinterface Technologies Co). A sessile drop method with a digital optical contact angle meter (G-10 Kruss) was employed for the contact angle. The contact angle was measured over 30 times and averaged. All the fluidic properties were characterized at about 25 ^{o}C. Both CNT/NaDDBS and CNT/SDS solutions exhibited a low viscosity, 1.1~1.3 cp. Nevertheless, all CNT inks were well printable.

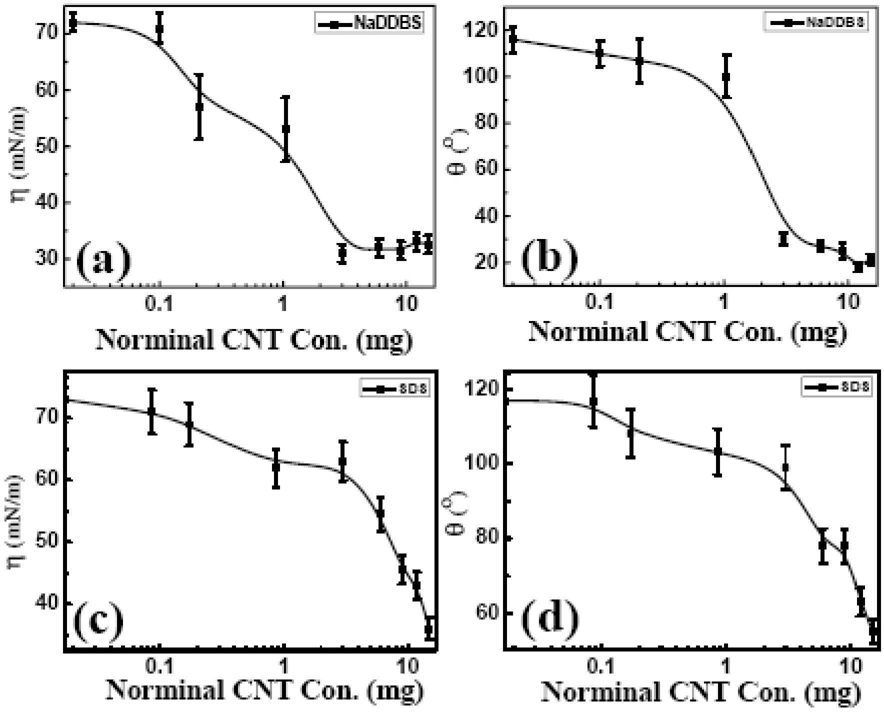

Figure 1. (a) Surface tension and (b) Contact angle of CNT/NaDDBS solution as a function of NCC. (c) Surface tension and (d) Contact angle of CNT/SDS solution as a function of NCC.

With two conventional surfactants, SDS and NaDDBS, the surface tension exhibited similar tendencies at a moderate NCC but behaved differently at higher NCC, as shown in Fig. 1(a) and (c). At low NCC like 0.003 mg/ml, the surface tension of both solutions was measured to be about 72 mN/m, similar to water. At moderate NCCs, the surface tension of CNT/NaDDBS decreased considerably from 71 mN/m at 0.03 mg/ml to 32 mN/m at 0.1 mg/ml. Further decreases did not occur at higher NCC. For CNT dispersion, the mole fraction of surfactant to water is a parameter of significance and a good dispersion is observed at the critical micelle concentration (CMC). NCC of 0.1 mg/ml of NaDDBS is corresponding to 1.43 mM. Therefore, above 0.1 mg/ml, the concentration of surfactant is high enough to achieve a good dispersion of CNTs. Once CNT/NaDDBS reached CMC, the surface tension, however, did not change to additional surfactant and CNT. In case of SDS, CMC is reportedly to occur at 10 mM, slightly higher than the highest NCC, 8.7 mN.

The contact angle of CNT solution has been studied only on Indium layer. In both CNT/NaDDBS and CNT/SDS, the change of θ vs. NCC followed that of surface tension, as shown in Figs. 1 (b) and (d). θ of CNT/NaDDBS leveled off at 0.1 mg/ml, indicating the saturation of surface tension. Above this NCC, θ did not change with further addition of the surfactant as the surface tension did. This is a typical behavior of type-I wetting that can be observed from ionic surfactants.[5]

After characterizing the properties of CNT solutions, field emission array has been fabricated using jet-printing method. To see how the ink cooperates with microstructures, an array of dots, 20 μm diameter and 400 μm dot-dot distance, was pre-patterned over 2 x 2 cm^2 on an ITO glass using photo-lithography, which can be seen in the inset of Fig. 2(a). For the adhesion of CNTs on the substrate, thin Indium layer was deposited on ITO glass using e-beam evaporator prior to jet-printing. The substrate was printed at 1800 DPI, followed by PR removal and thermal treatment for adhesion. Figure 2(a) is an image zoomed in on one of the dots from FEAs in the inset. The emission properties of FEAs printed at 1800 DPI were studied in Fig. 1(b). We observed that the portion of working dots in each FEA was 85 % for 1800 DPI. In addition, the FEAs emitted 335 μA at 80 kV/cm (Fig. 2b).

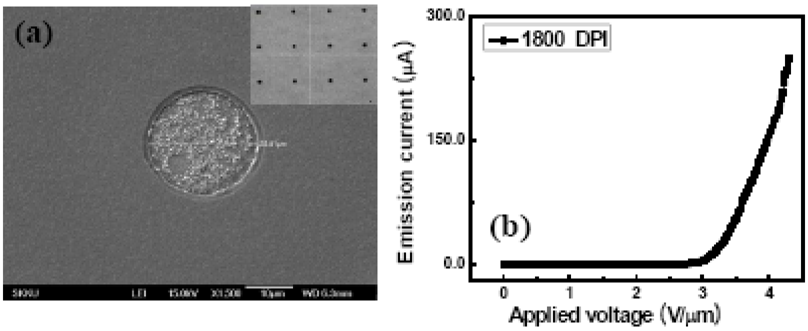

Figure 2. (a) A single dot emitter printed at 1800 DPI with CNT/NaDDBS at 0.3 mg/ml. (b) I-V curves from dot arrays. The inset shows a FEAs.

3. Impact

1) In aqueous CNT/NaDDBS and CNT/SDS, CMC is necessary to achieve a good CNT dispersion. However, at CMC, the surface tension of inks dropped to 20-30 mN/m and patterning line width increased because of spreading.
2) Ink jet-printing provided better controllability on key parameters such as emitter density and emitter positions without loosing scalability and patterning resolution.

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5. References

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