A Novel Dispersing Agent for Carbon Nanotubes

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Introduction

Since the discovery of carbon nanotubes (CNTs), researches of field emission display (FED) have been mainly focused on it, because of their high-aspect configuration, low work function, high mechanical stability and high conductivity. For CNTs to become a viable engineering material for FED applications, efficient assembly and integration processes for large size are required that are currently lacking.

Several techniques have been developed to assemble/integrate preformed nanostructures into functional hierarchical structures. Screen-printing is currently used to fabricate CNT cathodes for FED with large screen size [1-3]. The primary advantage of the process is that the cathode can, in principle, be manufactured with a price that can be afforded.

For the fabrication of cathode by the printing method, the CNT paste critically determines the cathode characteristics and hence the quality of the FED. Since the CNT has a cohesive characteristic in its nature, the CNT is not dispersed uniformly in the paste. Therefore the CNT is not equally distributed in the cathode layer which is fabricated by printing the paste. Moreover the printed layer becomes a rugged surface by the aggregation of the CNT. The rugged surface leads to the local field strengthening even when the uniform external electric field is applied on the cathode surface. By the non uniformity of the electric field and the CNT distribution on the cathode surface, the emission uniformity from the cathode is severely degraded and the picture quality of FED with the cathode is deteriorated.

To overcome the difficulties, we developed a new dispersing agent and a process for preparing finely dispersed CNT paste. By using this paste, we obtained the flat CNT with the surface roughness (Ra) of less than 0.20um and the excellent emission property was obtained. The details of the results will be described in the followings.

Experimental

In this section, the process for the finely dispersed paste is described. In this experiment, CNT synthesized by CVD was prepared. The purity of the multi-wall CNT was over 95% and the diameter of the CNT was less than of 10nm. Due to this small diameter, a large field enhancement factor is expected which is beneficial for the field emission application. Figure 1 shows the fabrication flow for the finely dispersed CNT paste. First the raw powder of the CNT is treated by an ultrasonic wave in order to rend the CNT and is dispersed in terpene alcohol with the newly developed dispersing agent.

After the dispersion, most portion of the terpene alcohol is removed by centrifugal force to concentrate the CNT and then the dispersed CNTs are obtained.

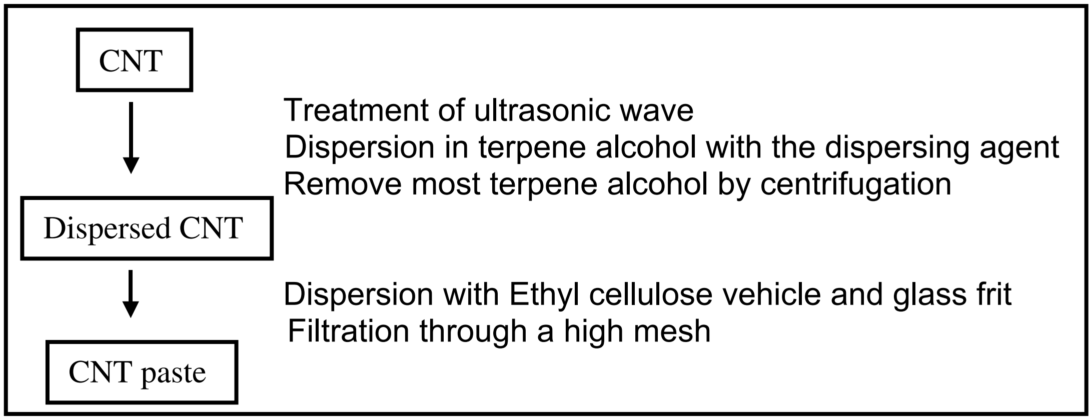


Fig.1 Flow of the new CNT paste

Next, the CNTs are mixed with ethyl cellulose vehicle and glass frit to adjust the viscosity. The glass frit is to improve the adhesion to the cathode electrode.

Finally the CNTs are filtered through a high mesh to remove the coarse particles. In order to fabricate the CNT cathode, the CNT paste is printed on a cathode electrode and fired at 400 degrees for 2 hours to remove the organic binder.

Although the CNT is strongly cohesive materials in its nature, the cohesion of CNT was effectively suppressed by applying the newly developed dispersion agent and process.

The newly developed dispersing agent contains more amino groups in the molecule than the conventional agent. It is well known that the amino group is able to adhere to CNT effectively. As the developed agent has many amino groups, the amino groups adhere to CNT at many points on the CNT surface. And as the result, the CNT is surrounded by the dispersing agent as shown in Fig.2. The surrounding agent prevents CNT from cohering to each other and therefore the CNT are well dispersed even after the pasting.

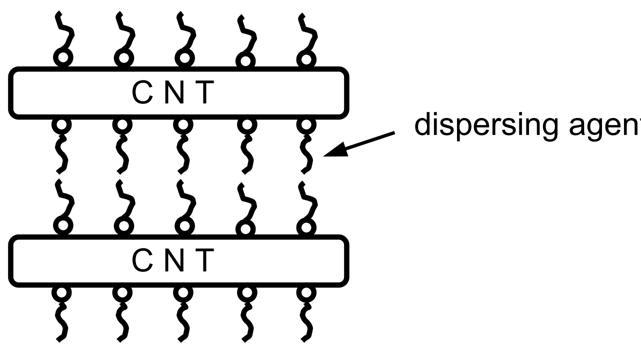


Fig.2 The mode of action of the dispersing agent

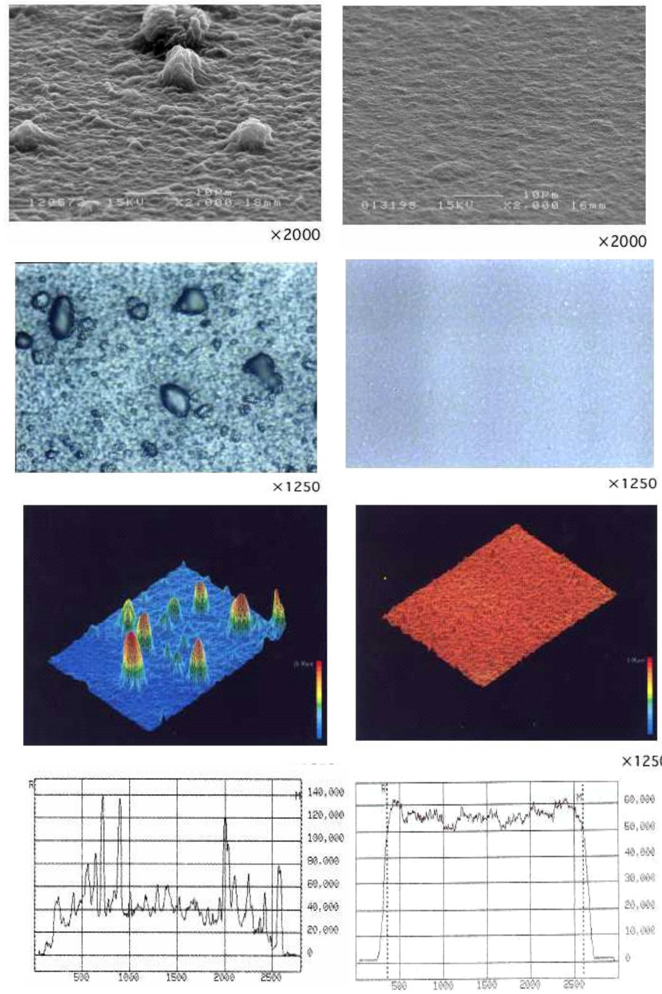
Results and Discussion

After the dispersion treatment, the median particle diameter of the CNT was less than 0.4 μm, which was measured by the laser Grain size classification distribution measuring device of the light scattering diffraction type. This result indicates that the interaction of the newly developed dispersing agent is effectively carried out to CNT as shown in Fig.2.

The surface of the printed CNT layer using the paste was measured by a microscope and a laser profile monitor. The results are shown in Fig.3. In the figure, left side (a) is the CNT layer using a conventional dispersing agent and right side (b) is the layer using a newly developed dispersing agent.

The SEM and microscope images show that there exist many projections on the CNT surface with the conventional agent and the size is over 10μm. On the other hand, there is no such projections on the surface with the newly developed agent and extremely smooth surface is formed. The surface roughness was measured by laser profile monitor and DEKTAK(ULVAC DEKTAK3030). The surface roughness (Ra) was less than 0.2μm, which was about 1/8 of the surface with the conventional agent.

Figure 4 shows the TGA curves of the raw CNT, the dispersed CNT and the pasted CNT in air. The TGA curve of the dispersed CNT (2) was nearly identical to the curve of the raw CNT (1) especially at the start of the weight reduction by the burning (at near 550 degrees). The identity of the curve indicates that the heat-resistant of CNT does not change. Because the heat-resistance depends mainly on the defects of the CNT, the TGA results show that there are few structural damages of the CNT in the dispersion process. From the similarity of the curve (2) and (3), it is also concluded that the mixing process of the CNT with glass frit to increase the adhesion on the electrode dose not damage the CNT. Therefore, it has become feasible to fire the CNT paste in air at a high temperature, which is required to burn out the organic binders. The TGA results show that the rigidity and



(a) (b)

Fig.3. The surface of the CNT layer with (a) the conventional dispersing agent and (b) the newly developed agent.

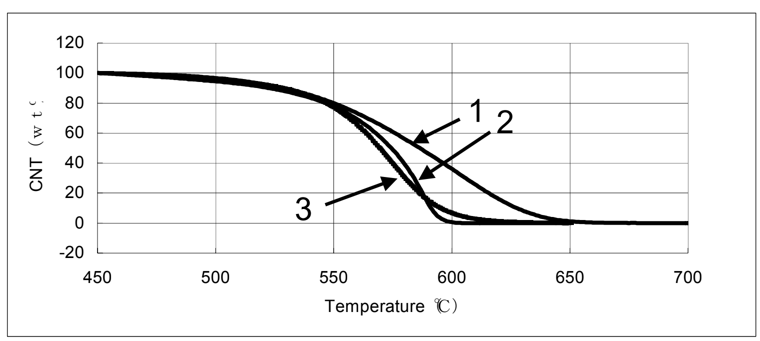
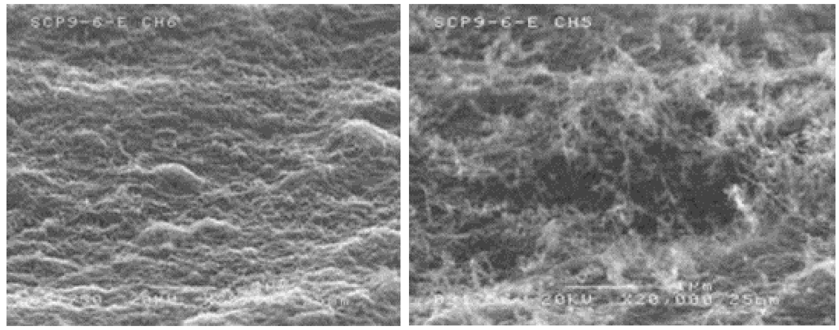


Fig.4 Thermogravimetric analysis of CNT in air (1) raw CNT, (2) dispersed CNT, (3) CNT paste

the chemical stability of the CNT are not damaged in the process.

By using the developed CNT paste, CNT-FED was fabricated. Figure 5 shows SEM photographs of the CNT layer (a) before and (b) after the laser irradiation [4]. The figure shows many tips are formed on the CNT surface by the laser irradiation. From the morphology of the surface, the excellent emission property was expected and the experimental results of the field emission showed the outstanding emission characteristics [1].



(a) (b)

Fig.5 SEM photographs the CNT layer (a) before and (b) the laser irradiation

Conclusions

We developed the dispersing agent and the process for the finely dispersed CNT paste. The cohesion of CNT was effectively suppressed. The surface roughness (Ra) measurement of the printed CNT layer showed that the roughness of less than 0.2 μm was achieved.

From the TGA measurement, it is also concluded that the CNT was not damaged by the pasting process.

It was also concluded that the morphology of the printed surface was effectively deformed and many tips of the CNT were formed by the laser irradiation.

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