DISCHARGE CHARACTERIZATION OF CARBON NANOTUBES COATED ELECTRODE USED IN GAS DISCARGE TUBE.

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Introduction

Gas discharge tube(GDT) was used to protect against transient overvoltages in a circuit. GDT was designed to have high resistance to prevent electric currents under normal voltage and current flow, whereas under overvoltage, such as from lightning, a discharge was formed between the metal electrodes, creating electric breakdown of the noble gases inside the tube. During the electric breakdown, the GDT becomes a conductor, creating a new circuit system to protect the other electrical components from overvoltage damage. The good GDT was required to have relatively high electron field emission[1].

Recently, conductive carbon materials have been considered as cathode materials for electron field emission to replace metals. The carbon materials had lower work function than metals. For metals, the electric voltage over 5000MV/m was required for electron field emission, whereas only 3 MV/m was required for electron field emission of carbon materials. Electron field emission of carbon materials was caused by sp^2 and sp^3 carbons. It was reported that with increased sp^2 carbons, the effect of electron field emission of the carbon material was improved [2], showing sp^2 carbons were important in electron field emission of carbon materials.

Of carbon materials, carbon nanotubes were potentially more useful than the others in nanometric scale electronic and mechanical applications, due to their unique electrical properties. One of those applications was a carbon nanotube-coating for electrodes. Carbon nanotube-coated electrodes had two advantages in electron field emission. First, the type of almost all of the carbon atoms inside nanotubes was of sp^2 type which was important in electron field emission. Second, the carbon nanotube-coated electrodes exhibited better electro-activity than any other carbon-based electrodes, due to the large surface area of carbon nanotubes[3].

Therefore, in this paper, the characterization of electron field emission from carbon nanotube-coated electrode was reported. The breakdown voltages of carbon nanotube-coated electrode was measured and compared with non-coated beryllium-copper electrode in GDT.

Experimental

Materials

The constituent of the beryllium-copper electrode used was shown in Table 1. The electrode had diameter of 13mm, height of 3mm, and a hole (diameter = 4mm, height= 0.2mm) for MWCNTs coating. The multi-walled carbon nanotubes (MWCNTs, tube diameter of 110 - 170 nm, length of 5 - 9 micron, 90+%) were provided by ALDRICH. Colloidal graphite (isopropanol base, THD PELLA, INC.) was adopted as a binder.

Table 1. The constituent of electrode

Constituent	Amount (%)	Work function(eV)
Copper	96.5 - 97.1	4.47
Cobalt	2.4 - 2.7	5.00
Beryllium	0.4 - 0.7	4.98
Iron	0.1 max	4.36

MWCNTs-coated electrode

20 mg of Colloidal graphite was coated onto the electrode hole first and then, 40 mg of MWCNTs was coated on it. The coated area was pressed with 10 bar of pressure. The prepared electrode was dried at 50 ℃ for 1 h. The morphology of coated MWCNTs was analyzed using SEM.

Electron field emission test

Impulse voltage was used as applied voltage and its wave was shown in Fig. 1. Surface roughness of the MWCNT-coated electrode was evenly distributed by polishing with abrasive paper(cw1200-2c, DAESUNG, Korea). The polished electrode was kept in dark place to prevent electron field emission induced by light. Electron field emission properties were measured in the parallel plate geometry at 1 bar under N_2 and anode-cathode distance was fixed with 0.5 mm. The MWCNTs-coated electrode or non-coated beryllium-copper electrode was used as cathode. Only beryllium-copper electrode was used as anode.

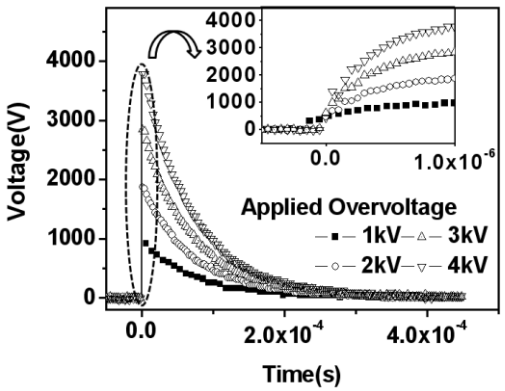

Fig. 1 The wave of impulse voltage in this study.

Results and Discussion

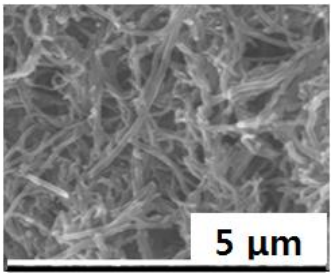

Fig. 2 The SEM image of coated MWCNTs.

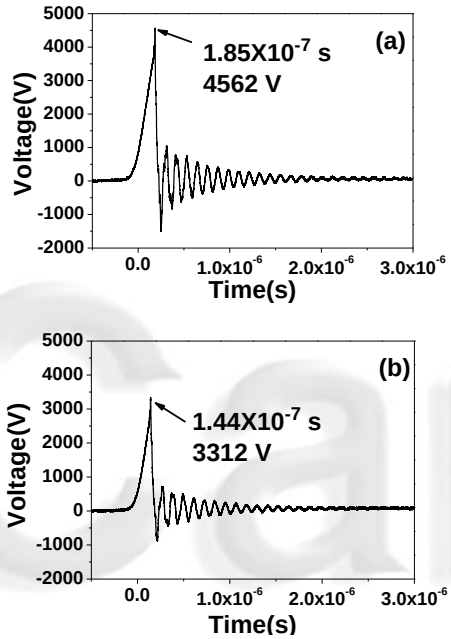

Fig. 3 The results of breakdown voltage measurements in 4kV applied overvoltage; (a): non-coated electrode, (b): MWCNTs-coated electrode

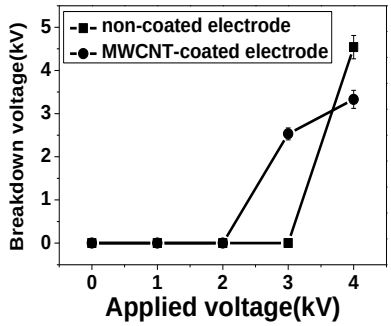

Fig. 4 Breakdown voltage vs applied voltage measured for non-coated electrode and MWCNTs-coated electrode.

Fig. 2 showed SEM image of coated MWCNTs. In Fig. 2, the MWCNTs had many voids. Because MWCNTs had a high aspect ratio, it was deposited irregularly, resulting in many voids. Those voids increased surface irregularity[4]. Fig. 3 showed the breakdown voltages of the MWCNTs-coated and uncoated electrode when 4kV was applied. The breakdown voltage of MWCNT-coated electrode decreased around 27% comparing with that of non-coated electrode. And it appeared faster than non-coated electrode with 22% decrease in breakdown time. This phenomenon was also observed in the other experiments with various applied voltage, as shown in Fig. 4. In Fig. 4, when 3kV was applied, the MWCNTs-coated electrode broke down, whereas the uncoated electrode did not. When electric voltage was applied less than 2 kV, there was no breakdown. In this case, even though the electron was emitted from the surface of electrode, emitted electron was absorbed into the inert gas, which can result the no breakdown. These results might be attributed to the excellent electron field emission caused by lower work function MWCNTs on electrode [5]. The excellent electron field emission lowered break-down voltage. The lower breakdown voltage made carbon nanotube based GDT more attractive for overvoltage protection units.

Conclusions

The breakdown voltage of MWCNTs-coated electrode decreased around 27% comparing with that of non-coated electrode. This phenomenon was also observed on different applied voltage. Therefore, it could be suggested that electron field emission of MWCNT-coated electrode was better than that of uncoated electrode, so it could be used for GDT protector.

References

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