THE RESEARCH ON THE CARBON NANO TUBE CATHODE

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Abstract

Joint experiment, the research of new carbon material, started in collaboration of KEK (High Energy Accelerator Research Organization) and IHI (Ishikawajima-Harima Heavy Industries Co.,Ltd.). Main target is new carbon material, CNT (Carbon Nano Tube) and related materials like GNF (Graphite Nano Tube). The purpose is developing high-current, high-duty electron gun with cold cathode for injectors of accelerators. From the beginning, relatively high current was observed. It seems to have a high potential.

INTRODUCTION

It is well known that field emission from a CNT makes quite high current density (around 10^6A/cm^2 was reported [1]). But many of those measurements were performed as a development of FPDs, total current was not enough to use for an accelerator. Electron current of 1-100A/1cm^2 is needed. One difficulty of cathode is less field enhancement with a flat surface. So, the first step of this research was to find a suitable material.

In this paper, main results of the first experiments were reported.

CATHODE MATERIALS

Samples of CNT and GNF (Graphite Nano Fiber) were employed. Typical microscopic image of the CNT is shown in fig. 1.

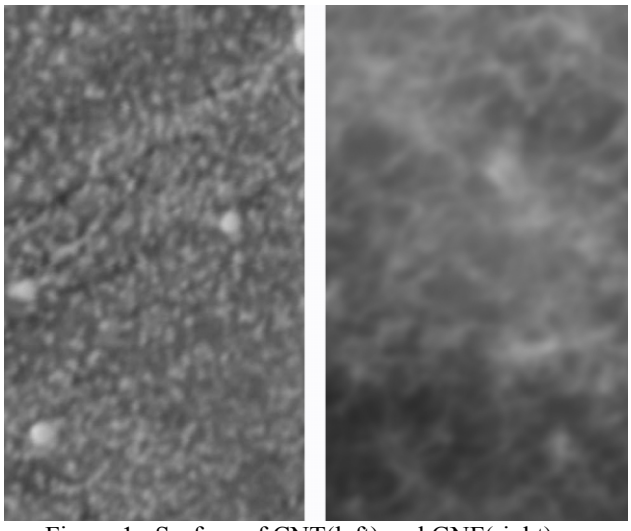

Figure 1: Surface of CNT(left) and GNF(right)

Table 1 shows tested materials. CNTs were employed form three different manufactures. CNT#3 and GNF were the same manufacture. Therefore measurement condition was almost the same, results were much different. Following results were focused on two remarkable material, CNT#3 and GNF.

Table 1: tested cathodes

No	Emission Area	Substrate	Emission	Remark
CNT#1	i)10mm square ii) ϕ6mm circle	Inver i) 10mm square ii) ϕ25mm circle	10mA /cm^2	tube / vertical to substrate
CNT#2	10x20mm	Inconel	few μA /cm2	tube / random
CNT#3	ϕ6mm	Stainless	150mA /cm^2	tube / random
GNF	i) ϕ20 mm ii) ϕ6mm	Inver i) ϕ20mm ii) ϕ25mm	40 mA /cm^2	fiber / random

EQUIPMENTS

Triode electron gun with few kV voltage was employed. Electrodes were adjustable to use various cathodes. Conductive and luminous glass was placed in the anode. Cathode was bound by insulators. Some cathode, which had large emission are, was covered by film with ϕ6-8 mm hole, to adjust emission area.

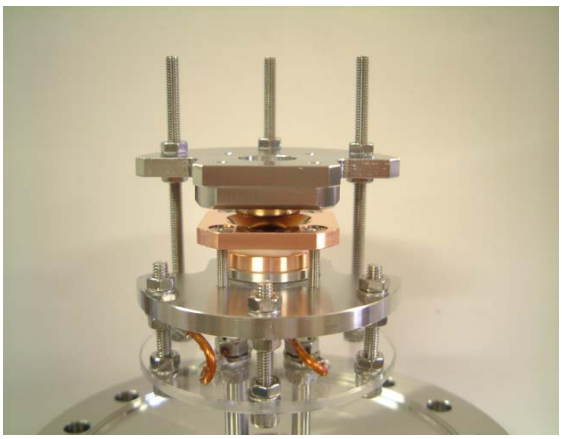

Figure 2: Triode gun with adjustable electrodes

- Grid-Cathode voltage: 0-3.5kV pulse or dc.

- Grid-Cathode gap: around 0.2mm
- Cathode-Anode voltage: 8kV dc fix.
- Cathode-Anode gap: 8mm

RESULTS

Measurements had been performed during a few days - weeks for every sample. Peak currents and long time stabilities were recorded. Summaries are as follows. These characteristics are common for all material.

1) Higher current could be obtained by increasing grid voltage. But it is limited by break downs. Frequent discharge made damages on a cathode surface (see fig. 3). That damage led decrease of a current.

Figure 3: Damage of the cathode surface
CNT was processed in the center.
Left: new cathode (black circle)
Right damaged by discharge

2) Decay of a current was observed at the starting of every measurement. But then it became stable and the current was constant, while all conditions were kept.

3) Currents were stable, while no discharge took place.

4) By those measurements, maximum currents were far to saturation with grid voltage. So, it is possible to obtain higher current, with preventing discharges. Following improvements seems to be effective.

- Pulse width : shorter
- Grid mesh : smoother
- Cathode surface : smoother
- Electrodes : optimisation of materials

Following descriptions were results of two materials. Those cathodes marked relative high current and long time stability.

CNT#3

For this cathode, two samples were tested by improvement of equipments.

Figure 4 shows the record of CNT#3 at 1st time measurement. Current change vs. grid voltage and time were plotted. The stable current value was around 140mA/cm^2. This value was observed after several discharges with higher gird voltage. After 1st measurement, cathode damaged like fig.3. For the 2nd sample of this cathode, measurement was performed carefully not to lead discharge. Figure 5 shows the latest result. The highest current density was recorded as 2.5A/cm^2 at 3.27kV. Few discharges took place, no appearant reduction of current was observed. It seemed to be possible to exceed few 10A/cm2 with development of this cathode.

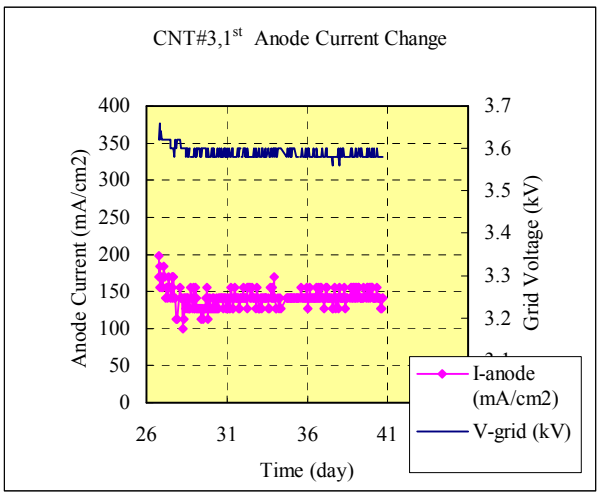

Figure 4: Characteristics of CNT#3, 1st sample.
Long time current change.

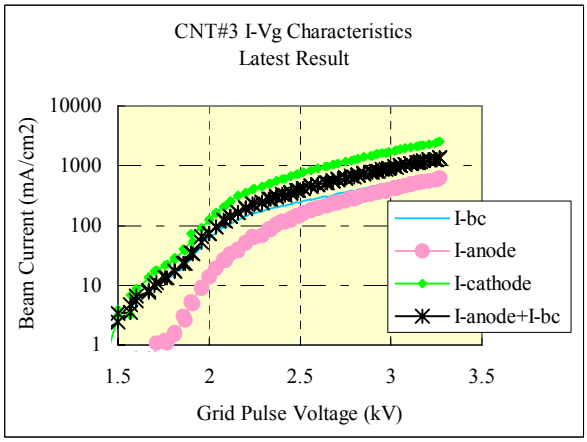

Figure 5: CNT#3, 2nd Grid voltage vs. Emission current.
With improved measurement.

GNF

Figure 5 shows current change of GNF. Peak current was around 150mA/cm^2, and stable current was around 50mA/cm^2. This cathode was very stable and it could be used for middle current application. Higher current also seemed to be possible with higher grid voltage.

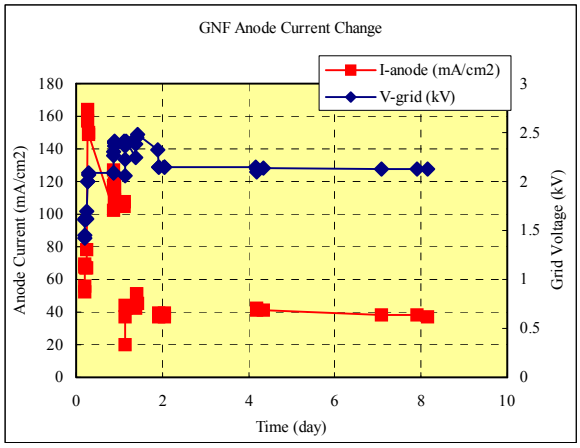

Figure 5: Characteristics of GNF

DISCUSSION

Discharge caused a reduction of emission area. One reason was decrease of emission area. The discussion of the other effects have been started. Molecular structures have analysed by raman shift. From the analysis of the first sample (CNT#1), some interesting data was observed. In figure 6, it is brand-new CNT#1, the spectrum shows two clear peaks. And figure 7 shows the used CNT, it was damaged by discharges. The spectrum shows much different structure. Those change might effect emission characteristics.

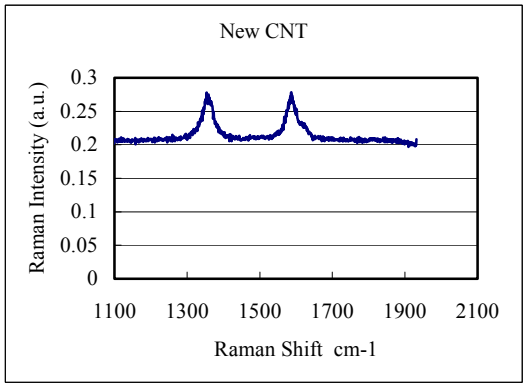

Figure 6: Analyze of CNT#1 Brand-New

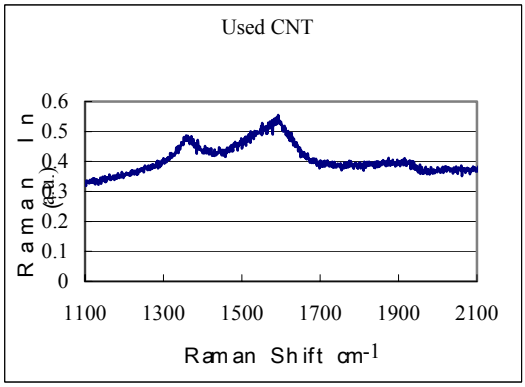

Figure 7: Used cathode damaged by discharge.

ACKNOWLEDGEMENT

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REFERENCES

[1] Y.Saitoh, et al. “Synthesis, Structure and Field Emission of Carbon Nanotubes,” Fullerene Science and Technology, 7(4), 635-664(1999)