Miniature X-ray Tube for Electric Brachytherapy using Carbon Nanotube Field Emitter

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1. Introduction

An electric brachytherapy using a miniature x-ray tube has a major advantage to reduce the x-ray exposure of human body during the cancer radiation therapy by optimal positioning of x-ray radiation source and treatment objectives.[1-5] In the view of a smaller electronic x-ray source, the CNT field emitter based x-ray tube can be more minimized than thermionic filament emitter based one because of a simple power supplier connection of cold field emission in diode type as well as a higher electron emission brightness of CNT. This abstract is for introducing the design of a proto-type CNT field emitter based miniature x-ray tube. We have vacuum sealed CNT miniature x-ray tube with 7~10 mm diameter, and characteristics of electron emission and x-ray transportation using MCNP5 code are surveyed.

2. Methods and Results

The CNT field emitter based miniature x-ray tube (Fig. 1) consisted with the CNT cathode on the diameter of 0.25~0.8 mm flat W tip, a focusing electrode, a transmission-type x-ray target, and HV isolation ceramic. The CNT tip has been fabricated by coating 2~6 μL CNT mixture of 4.2 weight% (w%) of a purified CNT and 4.2 w% of ~60 nm Silver (Ag) nano particle in isopropyl alcohol on the flat W tip and by heating at 500℃ for 2hours in 10^{-1} Pa vacuum ambient. All electrodes and metalized high voltage (HV) isolation ceramic are the brazed in a 10^{-6} torr of vacuum furnace. The electron and x-ray characteristics are simulated by EGN2 and MCNP5 program, and measure using a precision current meter (Fluke multimeter 189)

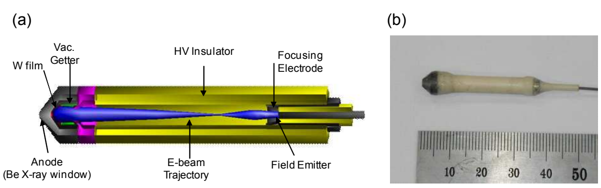

Fig. 1. (a) Schematic layout of the CNT miniature x-ray tube. (b) The fabricated CNT miniature x-ray tube.

Figure 2(a) shows that the CNT cathode tip emitted electron current over 100 μA at 2.32 kV/mm for over 60 hours with decrease ratio of -0.01 μA/min. The diode-type of CNT miniature x-ray tube emitted 4 mm diameter and 80 μA of electron beam at 45 kV with the 0.5 mm and 10 mm of cathode-focusing electrode-anode gap.

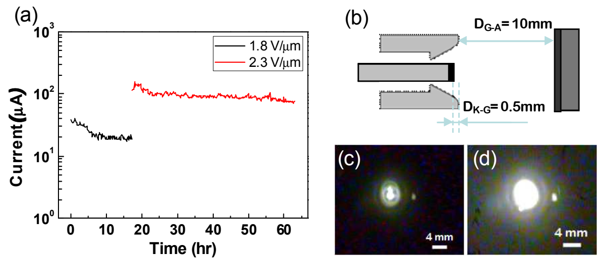

Fig. 2. (a) Field emission plot of the CNT cathode tip. (b) Scheme of diode-type CNT miniature x-ray tube. (c) and (d) Phosphorus screen image of emitted electron beam in diode (80 μA at 45 kV)

The x-ray transportation of three shapes of the transmission x-ray target, a truncated conical, a hemispherical, and a cylindrical has been calculated using MCNP5 program. For uniform 3-dimensional distribution of x-ray dose rate, the truncated conical shape is proposed and the optimum cone angle of the target has been decided as 90^{o} when 50 keV electros are collided onto W/Be: 1.5 μm/500 μm x-ray target.

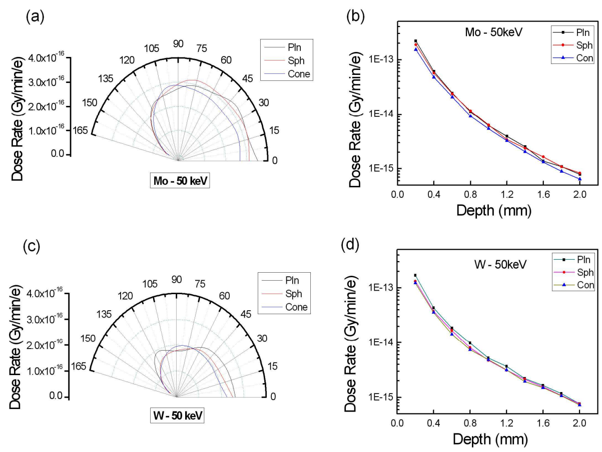

Fig. 4. MCNP5 simulation results of x-ray dose rate distribution of a truncated conical, a hemispherical, a cylindrical Be window at 50 keV electron incidence. (a) and (b) Azimuthal and axial distribution for molybdenum (Mo) target. (c) and (d) Azimuthal and axial distribution for W target.

3. Conclusions

The CNT field emitter based miniature x-ray tube has been designed and demonstrated by characterization of

CNT cathode tip and the diode-type electron generation, the optimized transmission-type x-ray target, electron and x-ray transport simulation. We are looking forward that a CNT field emitter based miniature x-ray tube with less than 5 mm diameter will be fabricated, soon.

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