Hybrid pyroelectric/nanotube LiTaO$_3$/TiO$_2$ X-ray source

**Innovation/Impact:** Demand for effective cancer radiotherapy requires development of new type X-ray sources most adapted to such disease treatment. Currently there are several radiation sources for such applications as isotopes and conventional X-ray tubes. Pyroelectric X-ray source is another promising type of X-ray source due to a number of advantages. Compared to other radiation sources it consumes less power (operates with 12V battery), does not require high voltage power supply, can be portable, and uses no radioactive sources. Recently pyroelectric crystals covered with tungsten (W) nanotubes were reported to significantly increase X-ray photon emission flux due to electric field amplification on the tips of the nanotubes [1]. The density of the W nanotubes in this work, however, was extremely high producing large electric field screening. Titanium dioxide (TiO$_2$) nanotubes grown by electrochemical oxidation are much more suitable for such purpose as the density of nanotubes can be easily controlled and the growth techniques is very simple ensuring cost effectiveness [2]. In this study, we have fabricated hybrid LiTaO$_3$/TiO$_2$ pyroelectric/nanotube X-ray source and studied its performance.

**Method:** TiO$_2$ nanotubes were grown via electrochemical oxidation of Ti sheets using ethylene glycol + NH$_4$F electrolyte. An anodization potential ranging from 30 to 60 V was used to grow samples. TiO$_2$ nanotube arrays were attached on top of LiTaO$_3$ with conductive carbon paste to form LiTaO$_3$/TiO$_2$ hybrid system. The schematic of the experimental setup is shown in Figure 1. The Z-polarized face was epoxy-bonded to a grounded 2 ohm 20 W resistor such that a negative polarity with respect to the electron target is achieved during heating. Generated x-rays from directional anode geometry passed through a 2.0 mm thick borosilicate window mounted on a stainless steel vacuum chamber and were detected by an Ortec NaI (TI) detector. Working vacuum level was in the range of 0.03-3 mTorr. Thermal cycling to a difference of 140 °C was provided by use of a battery-based thermostatic controller which raised the temperature at 1.2 C°/s rate until the desired temperature difference was achieved.

**Results:** Figure 2 shows representative scanning electron microscope image of TiO$_2$ nanotubes grown by electrochemical oxidation. Figure 3 presents X-ray spectra measured from hybrid LiTaO$_3$/TiO$_2$ structure at two different nominal pressures of 0.03 and 3 mTorr. It was found that the spectrum at 0.03 mTorr spanned in 10-50 keV range and peaked at 23.5 keV. After increasing the pressure to 3 mTorr the peak position shifted to 18.5 keV, and photon flux dropped by about 50% (Figure 3) due to reduced electron mean free path. The results show potential of LiTaO$_3$/TiO$_2$ system as a portable X-ray source for imaging and radiotherapy applications. Low energy X-ray emission in the range 10-50 keV is known to be more efficient in destroying tumor cells [4].

**Conclusion:** The performance of pyroelectric X-ray source based on hybrid LiTaO$_3$/TiO$_2$ system was studied. It was found that this type of X-ray source had higher X-ray output compared to LiTaO$_3$ based one. This is explained as a result of electric field amplification on nanotube tips.

**References:**