

Supporting document for:

NEW GENERATION PORTAL SENSOR BASED ON THIN-FILM CADMIUM TELLURIDE FOR CLINICAL HIGH ENERGY X-RAY IMAGING

Introduction: In radiation therapy the size of a portal sensor is dictated by the largest available treatment field size, typically $40 \times 40 \text{ cm}^2$, not easily implemental with crystalline semiconductors. Currently most popular EPIDs are manufactured from hydrogenated amorphous silicon (a-Si:H). As a material with low atomic number and electron density, it is not the best choice for detection of high energy x-rays and charged particles, generally exhibits low quality images, and exhibits poor radiation hardness. Only in the recent years semiconductor deposition techniques has been developed to a stage where materials other than silicon can be manufactured with quality adequate for use in large-area devices such as in solar cells. We propose new design for a portal imager based on thin-film Cadmium Telluride (CdTe), which is expected to improve the device in both imaging and dosimetric applications in radiation therapy. While crystalline CdTe material is widely used in small-scale radiation detectors and has superior radiation hardness, thin film devices have not been considered from this prospective. We present the result of our investigation of thin film CdTe as a possible large area detector in comparison with a-Si system of the same design.

Method and Materials: The first step in our feasibility study was assessment of radiation hardness of CdTe compare to a-Si. It was accomplished by evaluating performance of thin-film CdTe and a-Si:H solar cells after 6 MV photon beam irradiation. The dose delivered to the devices was 10 times larger than typical EPID lifetime dose.

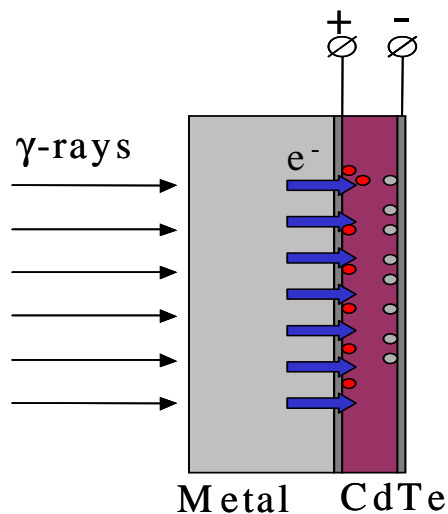


Fig. 1 Sketch of the proposed detector system, with metal plate as a conversion layer, enhancing the dose deposited to CdTe.

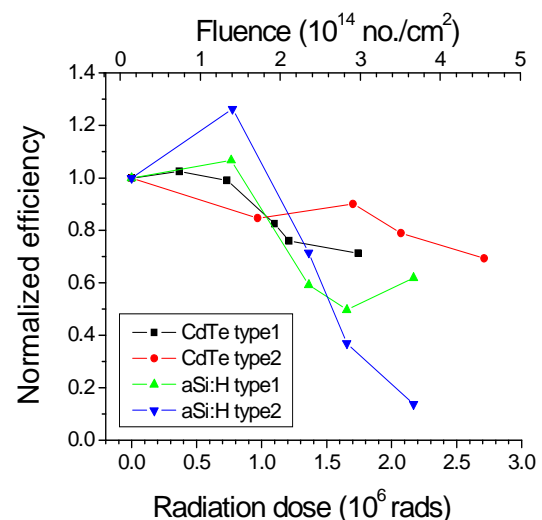


Fig. 2 Radiation hardness comparison between CdTe and a-Si solar cells of two types, irradiated under 6MV photon beam of Elekta SL15 linac.

After material evaluation we considered several possible configurations for the thin-film CdTe detector. Due to very small thickness (in a range of 30-100 microns) the sensor has to be combined with a metal plate facilitating conversion of high-energy photons to

charge carriers directly, maximizing the dose deposited in the sensor layer (Fig.1). The optimum thickness of metal plate for different converter materials was simulated with MCNP5 package. We modeled an image detection procedure under 6MV photon beam of the linear accelerator Elekta-SL25 currently commissioned in our laboratory. We compared performance of a-Si and CdTe detector systems in combination with Cu plate commonly used in current EPID. To predict the imaging performance, we referred to the parameter DQE (Detective quantum efficiency), which shows how efficiently an imaging system transfers the information content of a radiation beam from the input to the output of the system. It was calculated as

$$DQE(0) = \frac{m_1^2}{m_2} , m_j = \int_0^\infty AED_s(E)E^j dE ,$$

where AEDs(E) is the absorbed energy distribution, obtained from MCNP5 simulations using energy distribution of the pulse height tally.

Results: Fig.2 shows efficiency values normalized to the initial efficiencies for CdTe and a-Si thin film devices, corrected for the radiation-induced transmission loss in glass substrate. We found CdTe cells to have superior radiation stability, much better than that of a-Si devices under the same experimental conditions. This finding justified our next step of detector design modeling.

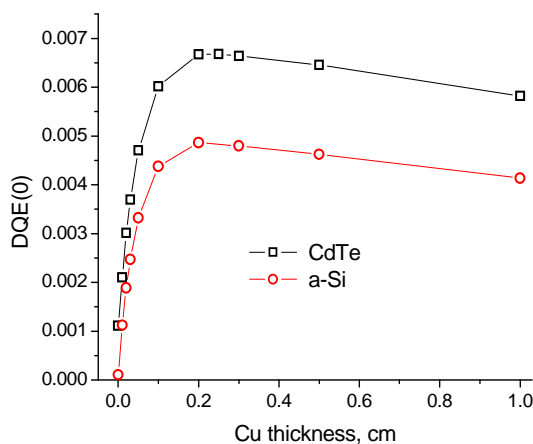


Fig.3 30 μm thick sensor with Cu plate, primary 6MV spectrum input.

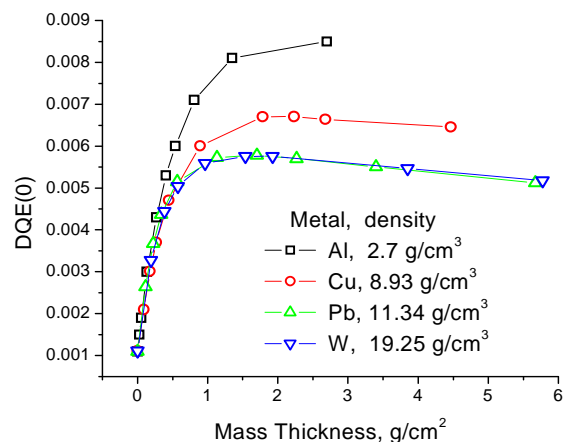


Fig.4 DQE(0) vs. metal plate mass thickness for Al, Cu, Pb and W .

As expected, the higher absorption of CdTe resulted in a higher DQE(0) values as shown in Fig. 3. We also simulated DQE(0) for 30 μm thick CdTe in combination with different metals of varying thickness (Fig. 4) to find detector design with the highest DQE. Even though Al shows the highest DQE(0) values, its corresponding large physical thickness leads to excessive signal spreading, therefore denser metal would be preferable for the converter layer. In the future, we plan to extend our study to DQE(f) to further optimize material type and its thickness.

Conclusion: We found the thin film CdTe is better suited for electronic portal imaging device than a-Si in terms of radiation hardness and x-ray absorption at energies applicable in clinical radiation therapy.