Development and characterization of radiochromic and radiofluorogenic solid state polymer dosimeter material - DTU Orbit (18/11/2018)

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Due to the complexity of external radiotherapy based on, e.g., LINAC, gamma knife and particle therapy, it is important that the treatment plans and the actual absorbed dose distribution received by the patient is in agreement. Radiochromic films, radiochromic and polymerizing gels, and radiochromic solid state dosimeters have been developed over the years for that purpose. However, 3D dosimetry is still not in use in the clinic. This PhD-project proposes a novel method that potentially could lead to a polymer-based solid-state dosimeter suitable for use as 3D dose verification using optical fluorescence tomography. In this PhD project a radiochromic and radiofluorogenic solid state dosimeter was developed.

The radiation-sensitive component of the dosimeter is pararosaniline leuco dye, originally used for its radiation-induced color change in the Risø B3 radiochromic film. This material is well-known from high-dose (> 1kGy) dosimetry in radiation sterilization of, e.g., disposable medical devices. In this PhD project, a solid-state polymer material doped with this dye has been developed. The material has maintained its radiochromic properties even at thickness 500 times thicker than the conventional film dosimeter. This property has been achieved by the use of two biocompatible monomers. The first one, poly(ethylene glycol) diacrylate (PEGDA), possesses two important properties in this context, namely, tissue equivalence and ion-mobility. Ion-mobility is very important as it facilitates mobility of the free radicals formed during irradiation and their subsequent reaction with the radiochromic dye. The second polymer, 2-hydroxyethyl methacrylate (HEMA), facilitates mechanical stability of the dosimeter after it has been polymerized. The fabrication process of the dosimeter is fast and easy. The radiochromic leuco-dye is dissolved in PEGDA and HEMA together with a photoinitiator. Subsequently, the mixture is photopolymerized using a 385 nm UV LED light source. The use of photopolymerization makes it possible to control the process temporally and spatially. The absorbance and fluorescence responses of this dosimeter were characterized using a Co-60 gamma-source. Within clinical dose range (0-30 Gy) the material had linear response of absorbance and fluorescence. The main contributing factors to the dosimeter response were identified, mainly related to the effect of the photoinitiator, the secondary polymer, and the photocuring process. The contribution from the dye and from the matrix to the radiation response was determined by absorbance, fluorescence, and EPR measurements. This new solid state dosimeter does not need a container, it presents good optical and mechanical properties, it is tissue equivalent, and it can be made in any shape. The studies carried out along this PhD project have shown that this dosimeter is a potential candidate for use in 3D dosimetry, but further investigation is required to increase the fluorescence sensitivity to low doses (< 10 Gy).

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