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RESPONSE CHARACTERIZATION OF A NEW RADIOCHROMIC FILM TO ULTRA-HIGH DOSE RATES FOR LIGHT IONS BEAMS

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Objectives

The ARRONAX facility can deliver proton and alpha beams (68MeV) at ultra-high dose rates (UHDR). Our preclinical beamlines are specifically set up to easily shift between conventional and UHDR irradiation conditions. A major challenge of these irradiations is to control their dosimetry in both modes. In a previous study [1] in proton beams, we showed a significant increase of the net optical density (netOD) for EBT3 and EBT-XD at 7.5kGy/s and above 10Gy compared with conventional dose rate while OC-1 response was not impacted.

In this study, we first evaluate the response of OC-1 in proton beam up to 60kGy/s and in alpha beam up to 20kGy/s. Then, with the objective to use OC-1 films as dosimeter, we characterize its response in terms of fading, particle dependency, orientation and lateral scanner effect.

Material and Methods

Scanner: V700 Epson Perfection flatbed color, RGB 48 bits 72 dpi

Scanning mode: Transmission (EBT3 and EBT-XD), reflection (OC-1).

Batch number: 12131904 (EBT3), 11062002 (EBT-XD), 2-20200131-1 (OC-1).

Online dosimetry: Faraday cup (Proton and alpha), ionization chamber PTW ROOS 34001 (electrons) and ionization chamber PTW 30013 (photons).



Figure 1. Scan of OC-1 film irradiated at 2,5,10,20 and 30Gy, respectively from left to right.

Particle dependency

Calibration curves of OC-1 were acquired for several type of particles, in the dose ranging from 1Gy to 100Gy (Figure 2). No dependency on the particle type was observed for photons (10MV), electrons (18MeV) and protons (68MeV) while for alpha-particles (68MeV), the color induced is less intense for the same dose and thus requires the use of a dedicated calibration curve.

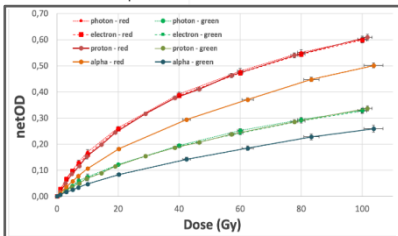


Figure 2. Relation between netOD and dose for photons (10MeV), electrons (18MeV), protons and alpha (68MeV), on both red and green channels. The post-irradiation time is 10 days.

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OC-1 dose rate dependency

The dose rate dependency of OC-1 is confirmed for proton beam up to 60kGy/s and alpha beam up to 20kGy/s in one pulse compared with conventional dose rates of 0.2Gy/s and 20Gy/s respectively (Figure 3). Similar results were obtained for the green channel. Significant impact is observed in netOD for EBT3 and EBT-XD in these conditions.

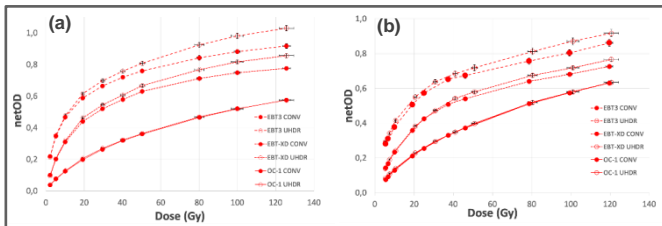


Figure 3. netOD of OC-1, EBT3 and EBT-XD in red channel at conventional dose rate (0.2 and 20Gy/s) and UHDR (60 and 20kGy/s) in (a) proton and (b) alpha beams. The post-irradiation time is 4 days (a) and 2 days (b).

Fading

The staining of OC-1 films continues to intensify several weeks after irradiation. Figure 4a illustrates the OC-1 behavior on the red channel up to 45 days post-irradiation for 20Gy. The scanner response was corrected with a test pattern. Similar result was obtained with the green channel with $R^2 = 0.9415$. Consequently, the use of different post-irradiation times before scanning, even 10 days after irradiation, can significantly overestimate the dose as shown in figure 4b for red and green channel.

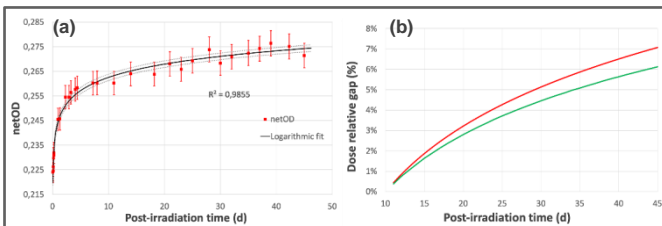


Figure 4. (a) netOD variation with respect to the time between irradiation and digitalization for the red channel and (b) its impact on the calculated dose compared to the one determined 10 days post-irradiation.

Orientation

Contrary to traditional radiochromic films [2], orientation during the digitalization process has no impact on the OC-1 response (Figure 5).

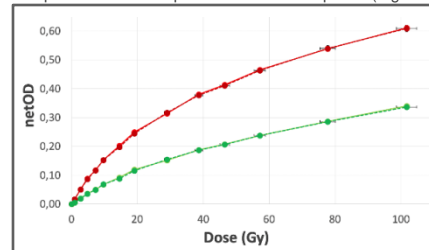


Figure 5. Influence of the film orientation during reading on the measured netOD for red and green channels: portrait (continuous) vs. landscape (dotted). Irradiation was made in proton beam (68MeV) and the post-irradiation time was 10 days.

Lateral scanner effect

The lateral scanner effect was studied over the whole scanner area for dose ranging from 2 to 125Gy. The maximal impact in netOD was 2.6% and 3.1% in red and green channel respectively. These variations are not significant relatively to the netOD uncertainty [1].

Conclusions

The response of OC-1 is independent of

- the particle type for protons, electron and photons,
- the dose rate in proton and alpha beams up to UHDR,
- the lateral scanner effect,
- the orientation during the digitalization process.

The fading of OC-1 that persists for several weeks after irradiation can be very detrimental. Therefore, it should be corrected or a constant delay between irradiation and scanner should be observed.

References

1. Villoing D et al. Proton beam dosimetry at ultra-high dose rates (FLASH): Evaluation of GAFchromic (EBT3, EBT-XD) and OrthoChromic (OC-1) film performances. Med. Phys. 2022.
2. Niroomand-Rad A, Chiu-Tsao ST, Grams MP, et al. Report of AAPM Task Group 235 Radiochromic Film Dosimetry: An Update to TG-55. Med Phys. 2020;47(12):5986-6025.