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NOVEL LOW-DIFFUSION PVA-GTA FRICKE GEL WITH SILVER NANOPARTICLES

A.V.S. Alves[1], W. de Almeida[2], E.M. Sussuchi[2], S.O. Souza[3], F. d'Errico[1,4], J.J. Rodrigues Jr[3]

[1]School of Medicine, Yale University, New Haven, CT, USA, anderson.kimurasilvaalves@yale.edu
[2]Departamento de Química, Universidade Federal de Sergipe, São Cristóvão, SE, Brazil
[3]Departamento de Física, Universidade Federal de Sergipe, São Cristóvão, SE, Brazil
[4]Università di Pisa, Scuola di Ingegneria, Pisa, Italy

Introduction: Three-dimensional dosimetry allows the evaluation of complex distributions and steep gradients of ionizing radiation doses providing accurate 3D maps. Tissue-equivalent gels infused with ferrous sulfate ("Fricke gels", FG) are widely studied systems as they behave as continuous 3D dosimeters that can be analyzed with optical imaging techniques. Radiation causes the oxidation of Fe^{2+} to Fe^{3+}. Adding a ligand, as xylenol orange (XO), enables the optical readout of the gel by forming a complex that has an absorption band centered at 585 nm, and the intensity of this band in FG-XO increases proportionally to the absorbed dose.

Recent studies focus on the reduction of spontaneous oxidation and diffusion characteristics, which are the main disadvantages of this class of dosimeters [1]. The PVA-GTA matrix developed within our collaboration, with xylenol orange added as metal-organic ligand, offers one of the best overall performances concerning the two main disadvantages. The current work examined the addition of silver nanoparticles to the PVA-GTA matrix.

Nanoparticles (NPs) are widely used for their intense influence on many applications, including radiation dosimetry. Concerning FGs, the addition of silver NPs to their formulation was reported by Vedalego et al. (2018) [2]. However, their work used FG in a gelatin matrix and focused mostly on the enhancement of the dose-response to low energy X-rays due to the K-edge effect of high-Z Ag-NPs.

We hereby present a novel formulation and synthesis of Fricke gels using our original PVA-GTA matrix with the addition of Ag-NPs and comparing it to our gel matrix without NPs. The addition of Ag-NPs allows a stronger complexation between XO and Fe^{3+}, which affects the diffusion properties of the gel. We investigated the influence of two routes of silver colloid synthesis [3] and different final concentrations of colloids.

Material and method: Two methods of wet chemistry silver colloid synthesis were investigated. Both were based on the reduction of $AgNO_3$ using sodium citrate as the principal stabilizer, the first one without PVA on the route (A) and the other with PVA (B). The silver colloids were added to the gels during their synthesis. The sensitivity was optically measured in 10 mm cuvettes after 6 MV X-ray irradiations up to 10 Gy. The diffusion coefficient was obtained with the use of a sample transporter in a spectrophotometer with a readout at 585 nm.

Results: Our Ag-NP-added Fricke gels present similar sensitivities to our original PVA-GTA gels without NPs (0.080 ± 0.003 $Gy^{-1}.cm^{-1}$) and lower increase of absorbance during storage (0.0037 ± 0.0002 day^{-1}). Moreover, the Ag-NP-added Fricke gels showed a significantly lower diffusion coefficient (0.129 ± 0.004). Table 1 summarizes the obtained results in comparison.

Conclusions: To our knowledge, the properties obtained for the silver nanoparticles are the best reported overall characteristics for PVA-GTA Fricke gels. The use of the NPs provides an additional mechanism of interaction between the ferric ions and the XO molecules, resulting in a more stable matrix.

Table 1. Obtained gel properties with and without silver nanoparticles.

Gel Type	**Diff. Coef. (mm^2/h)**	**Sensitivity ($Gy^{-1}.cm^{-1}$)**	**Stability (day^{-1})**
FG-XO	0.184 ± 0.022	0.077 ± 0.001	0.0113 ± 0.0003
FG-XO-Ag-A	0.155 ± 0.009	0.084 ± 0.003	0.0075 ± 0.0003
FG-XO-Ag-B	0.129 ± 0.004	0.080 ± 0.003	0.0037 ± 0.0002

References:

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