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Radiation-Induced Effects on Commercial 3D Printing Materials Exposed to High X-Ray Doses

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Non-metallic materials for 3D printing are of increasing interest for the realization of components operating in extreme radiation conditions, such as particle accelerators, nuclear facilities, medical field, space missions, and repositories for radioactive waste. For this reason, radiation effects on several categories of commercial printing materials must be evaluated.
Considering the incomplete and limited existing data on this topic, a new research activity is being developed to broaden the available knowledge about radiation effects on 3D printed parts, using a multi-scale approach. Four non-metallic materials commonly used for 3D printing have been selected for investigation: Poly(Lactic Acid) (PLA), Acrylonitrile Butadiene Styrene (ABS), Thermoplastic Elastomer (TPE), and High Temperature Polyamide reinforced with Carbon Fibres (PAHT CF). The materials have been irradiated at the Hubert Curien Laboratory (LabHC), using X-ray tubes operating at a voltage of 160 kV. Monte Carlo simulations realized with PHITS and GEANT4 have been implemented to guide the optimization of the experimental setup and estimate the dose in the material.
Both raw filaments for 3D printing and samples printed in selected geometries have been irradiated and tested to assess the dependence of radiation effects on the printing process and on the sample geometry. Samples were irradiated at doses ranging from about 100 kGy[H_2O] to 1 MGy[H_2O] at a dose rate of 0.6 Gy[H_2O]/s, at room temperature and in air atmosphere. An additional set of samples has been irradiated at 0.2 Gy[H_2O]/s, to investigate the dose rate and the oxygen effect. The total absorbed dose has been measured during the irradiation duration with a set of FD-7 radiophotoluminescent glass dosimeters, whose readout, specifically adapted to high doses, is performed in collaboration with CERN.
Sample characterizations are jointly performed at LabHC and at the Materials Science and Technology Laboratory of the University of Brescia. The performed multi-scale investigations include thermal, mechanical and spectroscopical analyses, such as Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), tensile test, Dynamic Mechanical Analysis (DMA), Fourier-Transform Infrared spectroscopy (FTIR), and Raman spectroscopy, aiming at finding correlations between structural and macroscopic radiation effects.
Results of the irradiation campaign evidence a progressive evolution of the properties of the materials with dose. In addition, the collected data allow the different materials to be systematically compared, providing useful information for the selection of the most radiation tolerant ones. More details on the performed characterizations will be presented.
Future experimental campaigns will target the dependence of radiation effects on other parameters, such as temperature, environmental atmosphere, and dose rate in view of specific applications.

Scientific Topic 1

Scientific Topic 2

Scientific Topic 3

Scientific Topic 4

Scientific Topic 5

Scientific Topic 6

Radiation damage to materials

Scientific Topic 7

Scientific Topic 8

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