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Changing the World's Energy Future

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Qualification of Continuous Fiber Reinforced 3D Printed Material for use in Hot Cell Environments

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Background

Additive manufacturing (AM) has rapidly emerged as a cheap and effective means of producing both prototypes and end use parts across industries around the globe. The existing technologies include printing methods deployed recreationally and industrially, printing materials such as low temperature plastics, composite plastics, carbon fiber, stainless steel, and ceramics. The broad development of the AM has facilitated convenient and accessible printing systems that can be rapidly deployed with minimal required space and training. These methods can enable engineers and designers the flexibility to iterate through prototypes quickly and in some cases produce end use parts as shown in Figure 1 without venturing into more costly manufacturing methods.

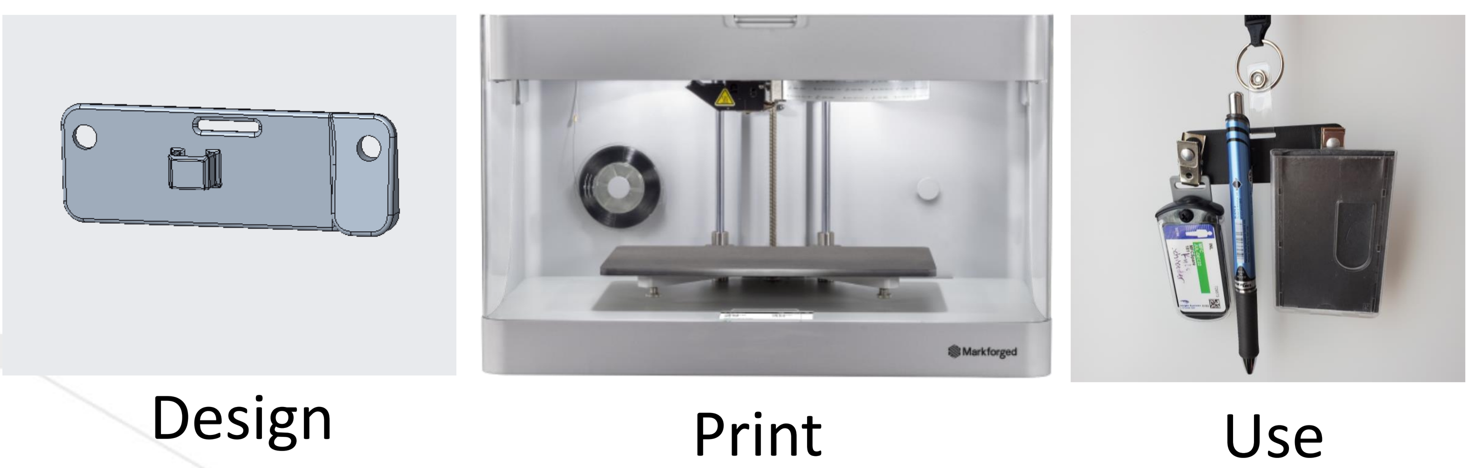

Figure 1: An example of an INL dosimeter, pen, and badge holder created using AM that would normally take thousands of dollars and months to create a molded part.

Objective

The ability to employ additively manufactured polymers in highly radioactive environments facilitates rapid prototyping as well as emergency replacement of various equipment components contained in-cell. A technical evaluation (TEV) exists seeking to qualify 3D printed polymers and carbon reinforcements for use in-cell, the data generated in this project seeks to support the TEV. The goal of the study is to determine if the loss in mechanical properties is low enough to justify semi-permanent use in-cell.

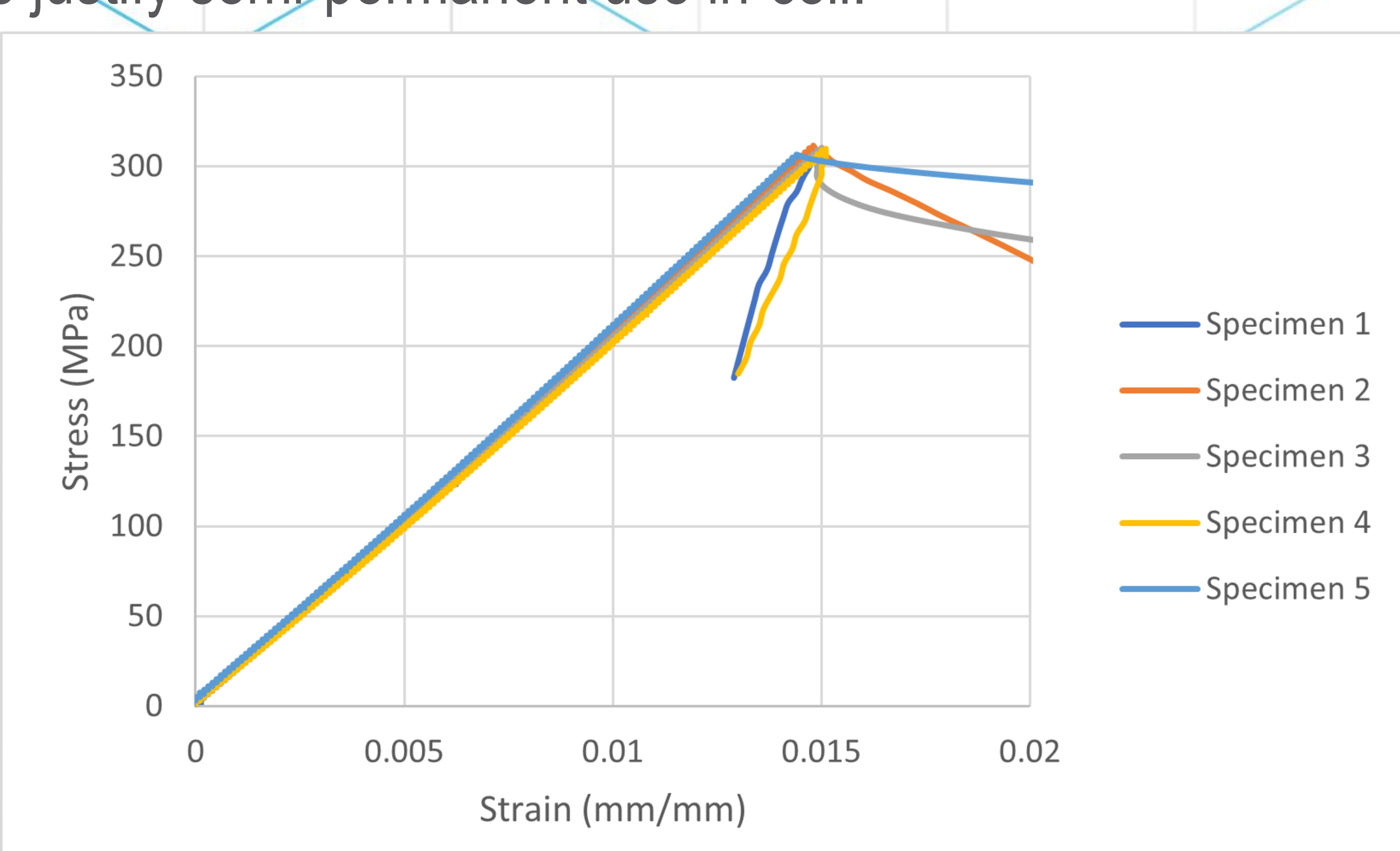

Figure 3: Stress Strain diagram for unirradiated tensile samples tested using ASTM D3039.

Methods

Samples are printed with a Markforged Mark 2 printer using the continuous fiber reinforced (CFR) AM technique. ASTM testing standards are used to measure tensile and flexural properties of sample specimens and compared to relevant published data. Identical samples are irradiated and tested according to the same standards. Two batches of samples totaling 24 samples are irradiated, half of which are irradiated using a cobalt 60 source and half are placed in the Hot Fuel Examination Facility (HFEF) main cell where an estimated radiation rate is known, images of these are shown in Figure 2.

Figure 2: Left to right: CFR printed Tensile and Flexural samples, Cobalt 60 source irradiator, samples placed in the HFEF main cell (circled).

Results

The results for tensile and flexural testing of unirradiated samples are shown in Figures 3 and 4. Completion of the project is conditional upon mechanical testing after irradiation at various levels so a trend in material property degradation vs exposure may be quantified. Twelve samples have been placed in the HFEF main cell and 12 more are scheduled for irradiation in August 2022. It is anticipated that embrittlement of the plastic matrix component of the composite will decrease overall composite material properties with increases in radiation dose.

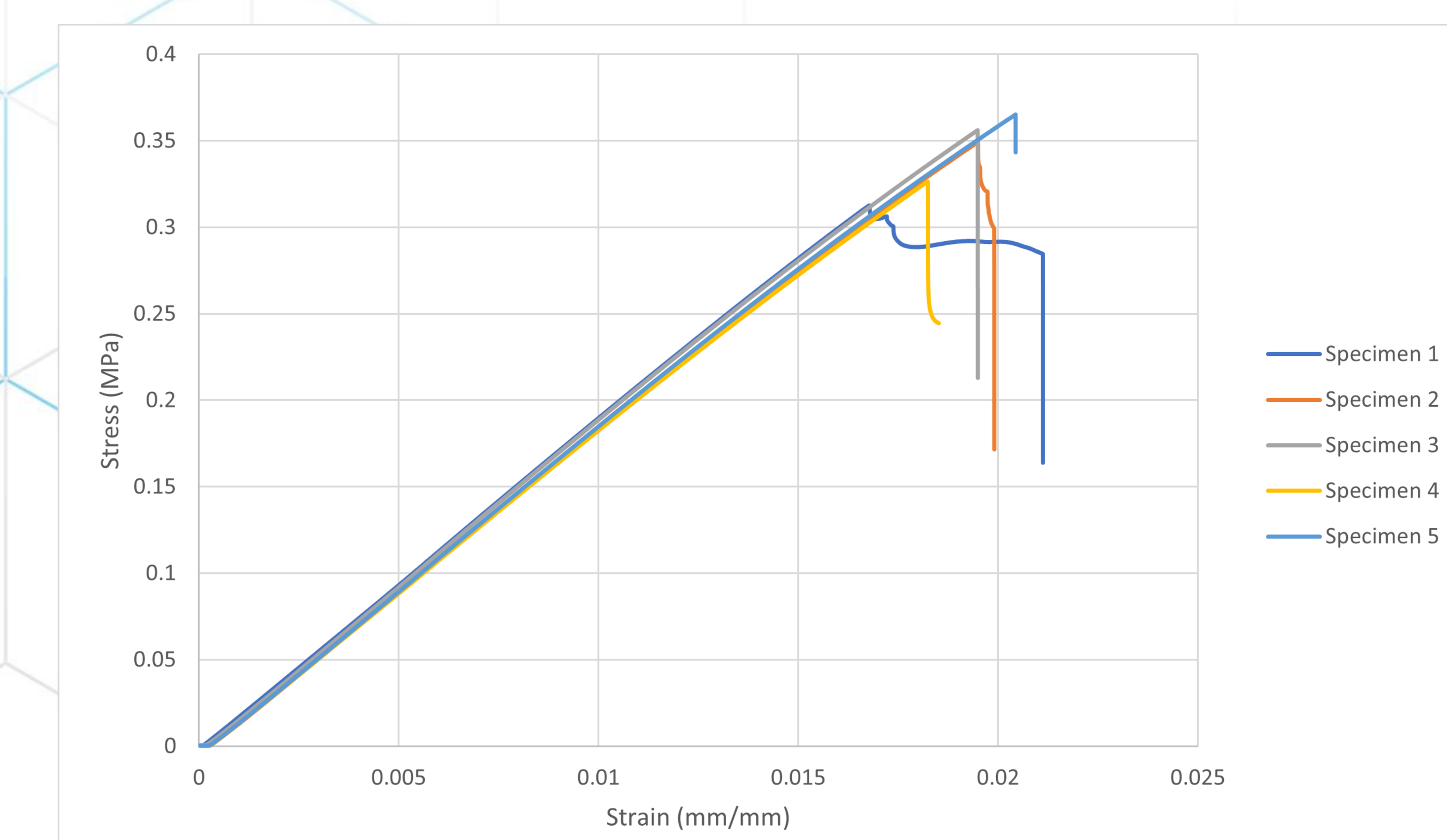

Figure 4: Stress Strain diagram for unirradiated flexural samples tested using ASTM D7264.

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