

Fabrication of Lightweight Radiation Shielding Composite Materials by Field Assisted Sintering Technique (FAST)

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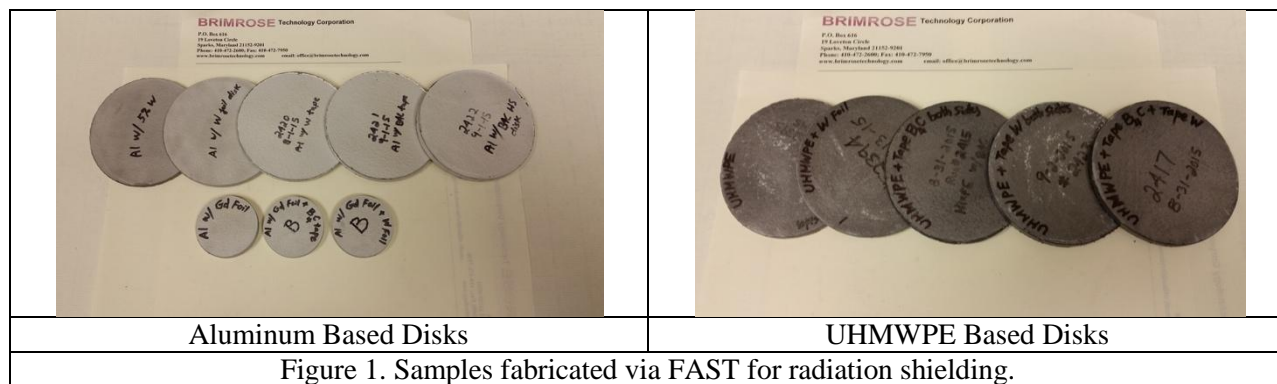
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Advances in radiation shielding technologies are needed to protect humans and electronic components from all threats of space radiation over long durations. In this paper, we report on the use of the innovative and novel fabrication technology known as Field Assisted Sintering Technology (FAST) to fabricate lightweight material with enhanced radiation shielding strength to safeguard humans and electronics suitable for next generation space exploration missions. The base materials we investigated were aluminum (Al), the current standard material for space hardware, and Ultra-High Molecular Weight Polyethylene (UHMWPE), which has high hydrogen content and resistance to nuclear reaction from neutrons, making it a good shielding material for both gamma radiation and particles. UHMWPE also has high resistance to corrosive chemicals, extremely low moisture sensitivity, very low coefficient of friction, and high resistance to abrasion. We reinforced the base materials by adding high density (ie, high atomic weight) metallic material into the composite. These filler materials included: boron carbide (B₄C), tungsten (W), tungsten carbide (WC) and gadolinium (Gd).

UHMWPE has an extremely high viscosity and cannot be processed via conventional methods. Special fabrication techniques are extremely costly and have also been found to lead to the incorporation of fusion defects such as grain boundaries or voids, which are widely believed to be the limiting factor of the wear resistance of UHMWPE. Moreover, conventional techniques to press the powders lead to inhomogeneity and cannot be used to easily produce shaped components. Therefore, an alternative new manufacturing technology that is flexible, robust and capable of fabricating components of desired recipe and architecture for radiation shielding is needed. FAST has been identified as an emerging process for such applications. FAST, also referred to as spark plasma sintering (SPS) or pulsed electric current sintering (PECS), is an innovative one-step process that simultaneously compacts and sinters powder with close to 100% theoretical density and is capable of producing scalable components in a short time (15-20 minutes). This method is much more cost effective in comparison to conventional compaction and sintering methods, and it is also amenable to large scale production. The innovative FAST process provides critical advantages to this initiative.

Using FAST, we produced several samples of UHMWPE and Al composite materials, some with the incorporation of metal or metal carbide powders. All of the samples worked well in shielding high and low energy gamma radiation; however, the inhomogeneous distribution of the powders could possibly lead to secondary radiation generation from multiple points in the matrix, which would be very difficult to mitigate effectively. We then used a new technique where the metal and metal carbides were incorporated as foils or disks. This technique worked well with the Al material. However, UHMWPE is very difficult to bond with resulting in delamination at the polymer/metal-metal carbide interface. We ultimately solved this bonding issue by using a new processing technique where we prepared flexible inserts by using stick

polymer tape impregnated with the metal/metal carbide materials and then encapsulated these flexible structures in UHMWPE powders. Sintering of these structures was successful with samples showing no signs of cracking. The samples were mechanically robust with respect to normal handling conditions. Figure 1 shows a photo of all of the Al-based and UHMWPE-based disks.



The shielding impact of all of the materials was characterized experimentally via gamma spectroscopy measurements using both low energy (Am-241 60keV) and high energy (Cs-137 662 keV) gamma point sources. An example of the shielding capability of UHMWPE is shown in Figure 2. All of the materials produced worked well in shielding both high and low energy gamma radiation. We will also discuss further improvements to the mechanical strength of UHMWPE composites suitable for radiation shielding applications.

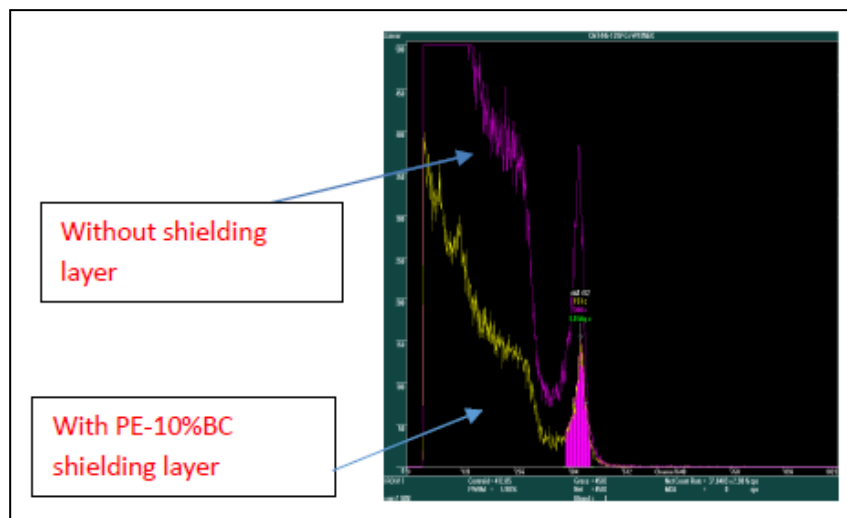


Figure 2. Comparison of Cs-137 662keV gamma response of CMT446 w/o (Pink curve) and with one layer of UHMWPE material (Yellow curve).

Acknowledgement: This work was partially supported by the NASA SBIR Phase I Contract # NX15CL50.