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INTRODUCTION

The United States Department of Energy (DOE) Global Nuclear Energy Partnership (GNEP) is developing metallic actinide-zirconium alloy fuels for the transmutation of minor actinides as part of a closed fuel cycle. The molten salt electrochemical process to be used for fuel recycle has the potential to carry over up to 2% fission product lanthanide content into the fuel fabrication process. Within the scope of the fuel irradiation testing program at Idaho National Laboratory (INL), candidate metal alloy transmutation fuels containing quantities of lanthanide elements have been fabricated, characterized, and delivered to the Advanced Test Reactor for irradiation testing.

The research presented here describes the microstructural characterization of two samples of 58.5U-20Pu-3Am-2Np-1.5RE-15Zr (wt.%), where RE refers to a rare-earth (lanthanide) alloy whose nominal composition is 6La-16Pr-25Ce-53Nd. One sample represents the as-cast microstructure; the other was repeatedly thermally cycled to 1100°C during differential scanning calorimetry (DSC) measurements.

SAMPLES AND METHODS

Transverse sections of fuel slugs were cut for as-cast microstructure determination by scanning electron microscopy (SEM) and for DSC studies. During DSC analysis, the sample was thermally cycled from room temperature to 1100°C three times at a rate of 10°C/min.

Three SEM samples and one DSC sample were embedded in epoxy, ground to a 1200-grit finish in air, and coated with a thin layer of sputtered Pd. Because two of the SEM samples had large central holes, and were therefore not considered to represent typical as-cast microstructures, all of the as-cast data presented here is from the remaining SEM sample. Secondary-electron (SE) images were collected from the DSC sample and SEM sample. X-ray maps for individual elements were collected using a wavelength-dispersive X-ray spectrometer to map each element in succession. Contrast and brightness were adjusted individually for each X-ray map.

RESULTS

With the exception of thin, discontinuous rims around the edges of the samples, microstructures in each sample were homogeneous on a scale of a few tens of micrometers. To a first approximation, each sample consisted of inclusions that appeared dark in SE images, surrounded by a light-colored matrix. X-ray maps indicate that actinides are predominantly or entirely in the matrix, and that the inclusions can be further divided into two groups: one high in Zr and one high in rare-earth elements.

SE images of the DSC sample show thin, light-colored features forming boundaries of polygonal areas, and numerous light-colored areas within many of the polygons (Fig. 1). Light-colored areas within each polygon are approximately parallel; however,

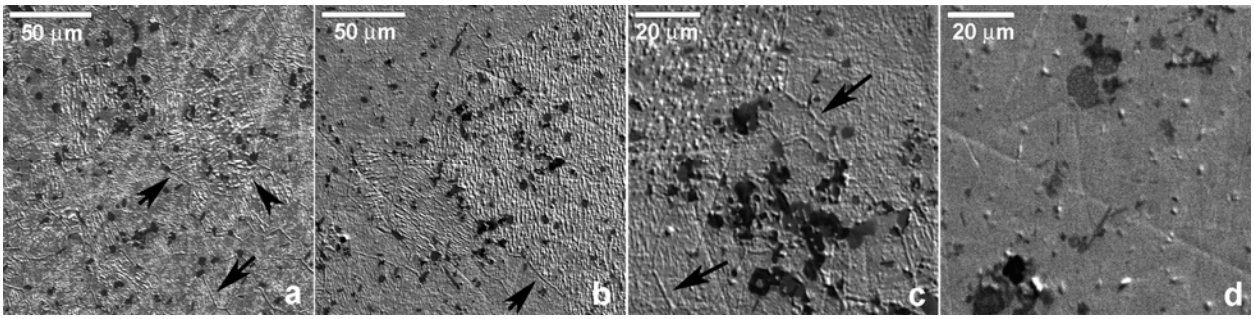

Figure 1: SEM images. Parts a, b, c: DSC sample; arrows indicate polygonal boundaries. Part d: As-cast sample.

orientations commonly differ markedly between adjacent polygons. Comparable light-colored features were not observed in the as-cast sample.

X-ray maps (Fig. 2) suggest that the polygonal boundaries in the DSC sample are enriched in U and depleted in Zr relative to the adjacent matrix. Areas with light-colored features in the interiors of polygons show variations in concentrations of U and Zr relative to adjacent areas. Actinide concentrations in other areas of the matrix in the DSC sample appear uniform. In contrast, a U X-ray map from the interior of the as-cast sample shows patchy contrast that appears unrelated to microstructures in the corresponding SE image.

These results and their interpretation will be discussed.

ACKNOWLEDGMENTS

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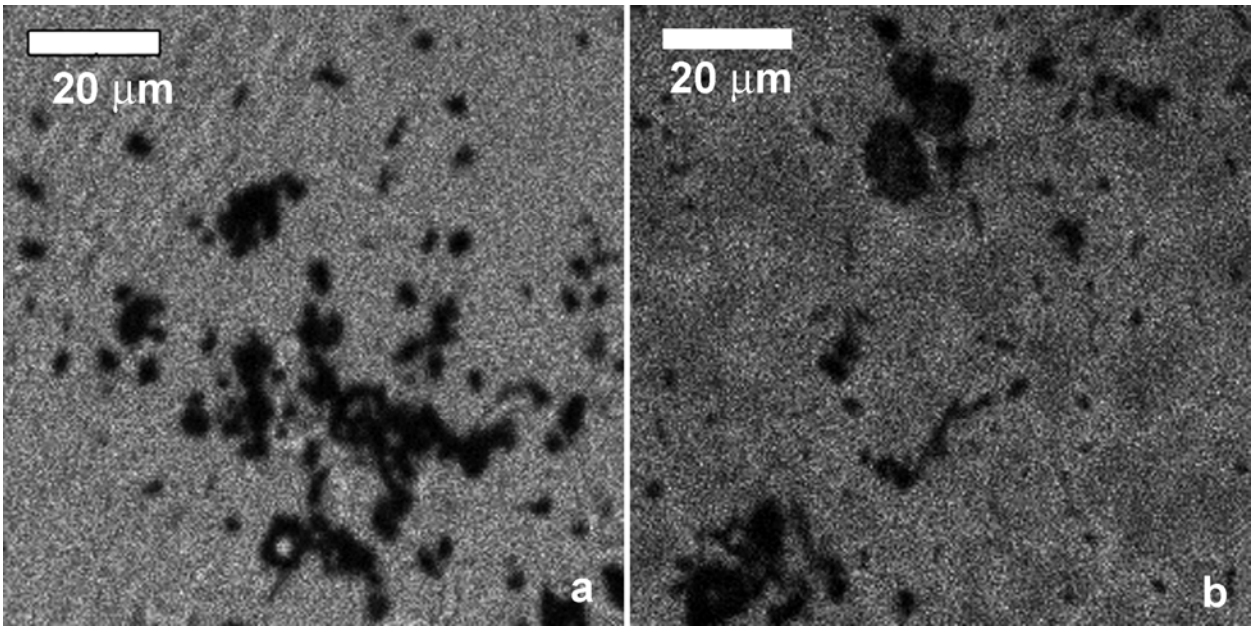

Figure 2: Uranium X-ray maps. Part a: DSC sample, area of Figure 1c. Part b: As-cast sample, area of Figure 1d.