Developing High Entropy Alloys for Nuclear Applications

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I. Background

- Nuclear reactors are an evolving technology in the path to improve nuclear energy in the United States.
- Advanced test reactors need materials that can withstand demanding and extreme environments.
- The development of these materials requires extensive qualification and testing.

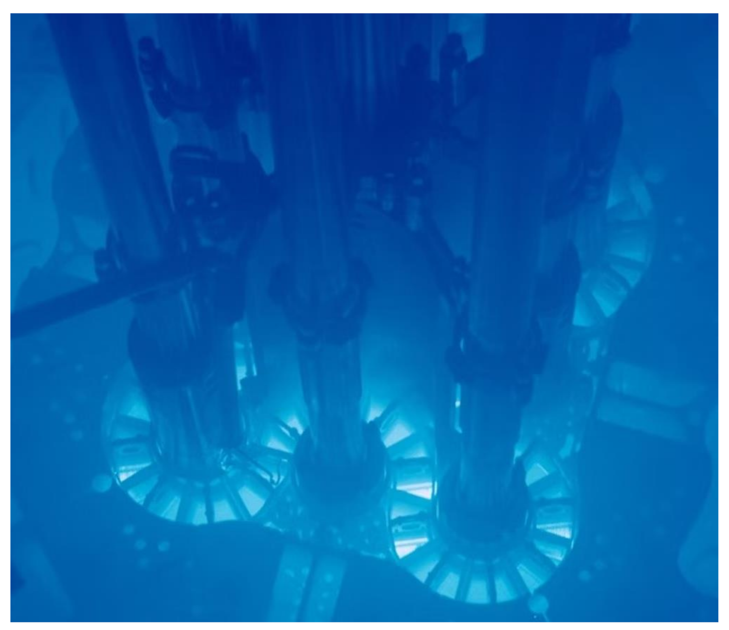

Figure 1 *Inside of Idaho National Lab's advanced test reactor [1]*

II. Introduction

- High entropy alloys (HEAs) were developed for their desirability of strength, hardness, and corrosion, wear, and radiation resistance.
- This makes them ideal for nuclear applications in advanced reactors.
- High entropy alloys are characterized as alloys containing at least 5 principal elements, each with an atomic percentage between 5 and 35% [2].
- A process for fabrication and characterization of these alloys entails ball milling and spark plasma sintering (SPS), then characterization tools such as x-ray diffraction (XRD) and scanning electron microscopy (SEM).

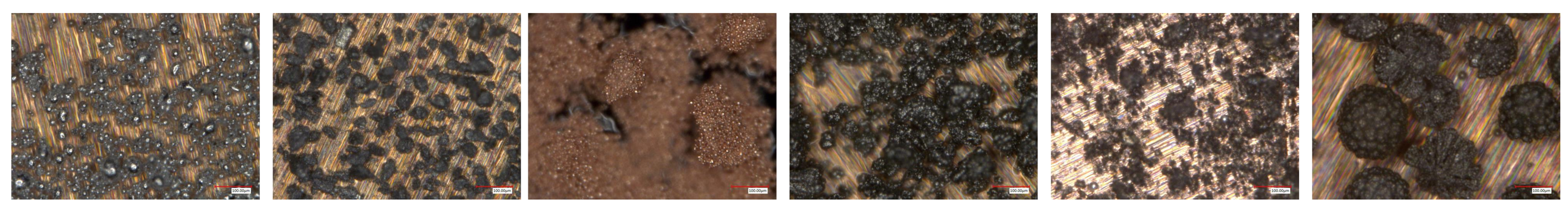

Figure 2 *Optical imaging of Aluminum, Chromium, Copper, Iron, Manganese, and Nickel powder*

III. Materials and Methods

- Equiatomic amounts of Aluminum, Chromium, Copper, Iron, Manganese, and Nickel were ball milled in the high energy ball mill Emax for 30 minutes at 500 rpm, with a 1 minute stop every 10 minutes to alloy the metals together.
- The powder alloy was pressed into a 16 mm diameter graphite die to put into the Spark Plasma Sintering System to form a pellet.
- The die was heated to 650, 750, 850, and 950 ˚C and held at each temperature for 8 minutes under a uniaxial pressure of 50 MPa.
- With the pellet from SPS, XRD and SEM were performed to observe structure and to determine if the compound had alloyed properly.

Figure 3 *Retsch Emax*

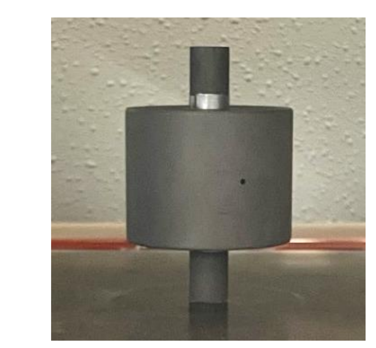

Figure 4 *SPS die configuration*

IV. Results

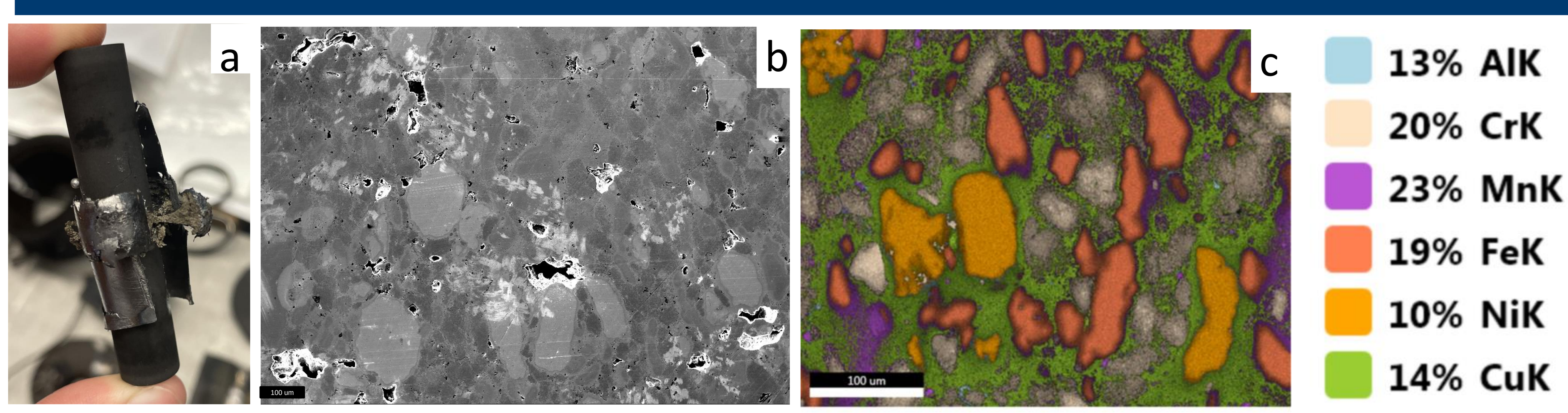

Figure 5 *a) Initial SPS experiment b) SEM of SPS experiment c) EDS of SPS experiment*

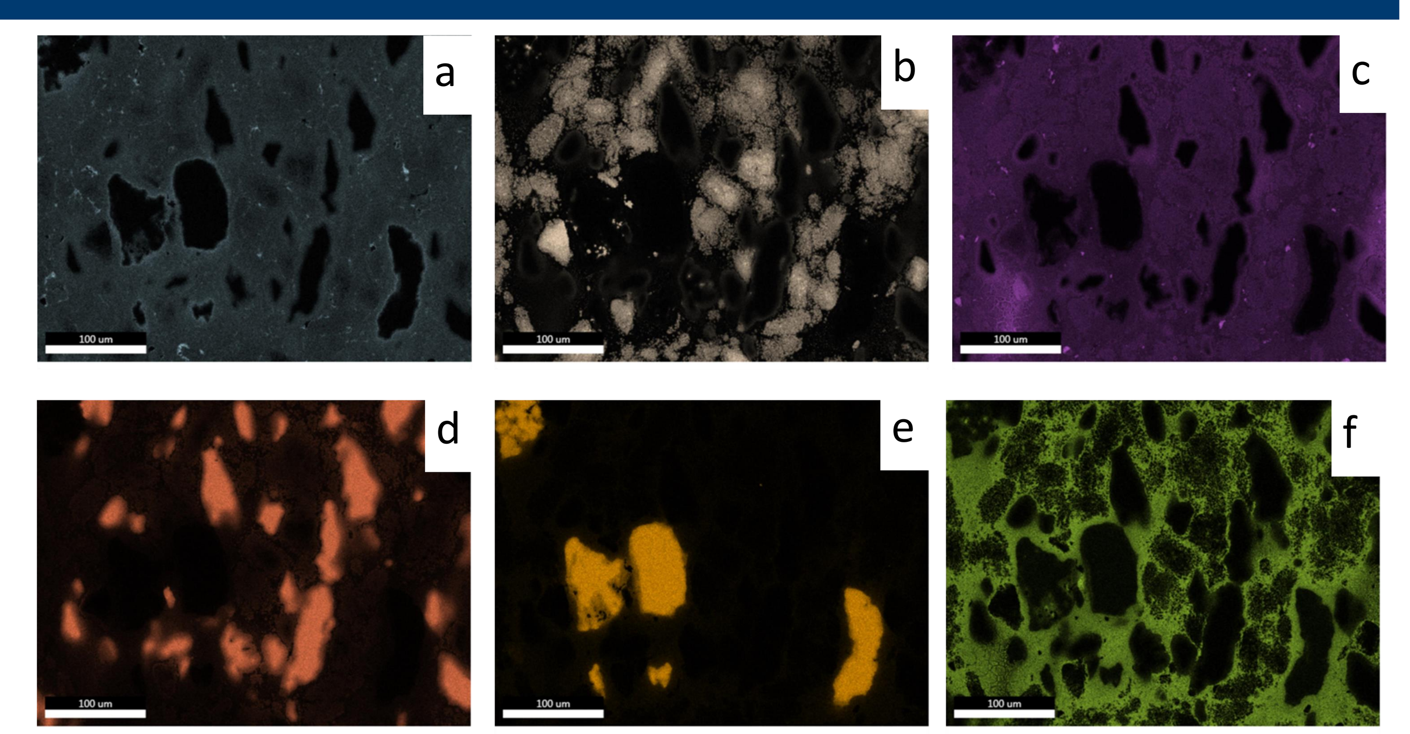

Figure 6 *EDS of individual elements in SPS experiment a) Aluminum b) Chromium c) Manganese d) Iron e) Nickel f) Copper*

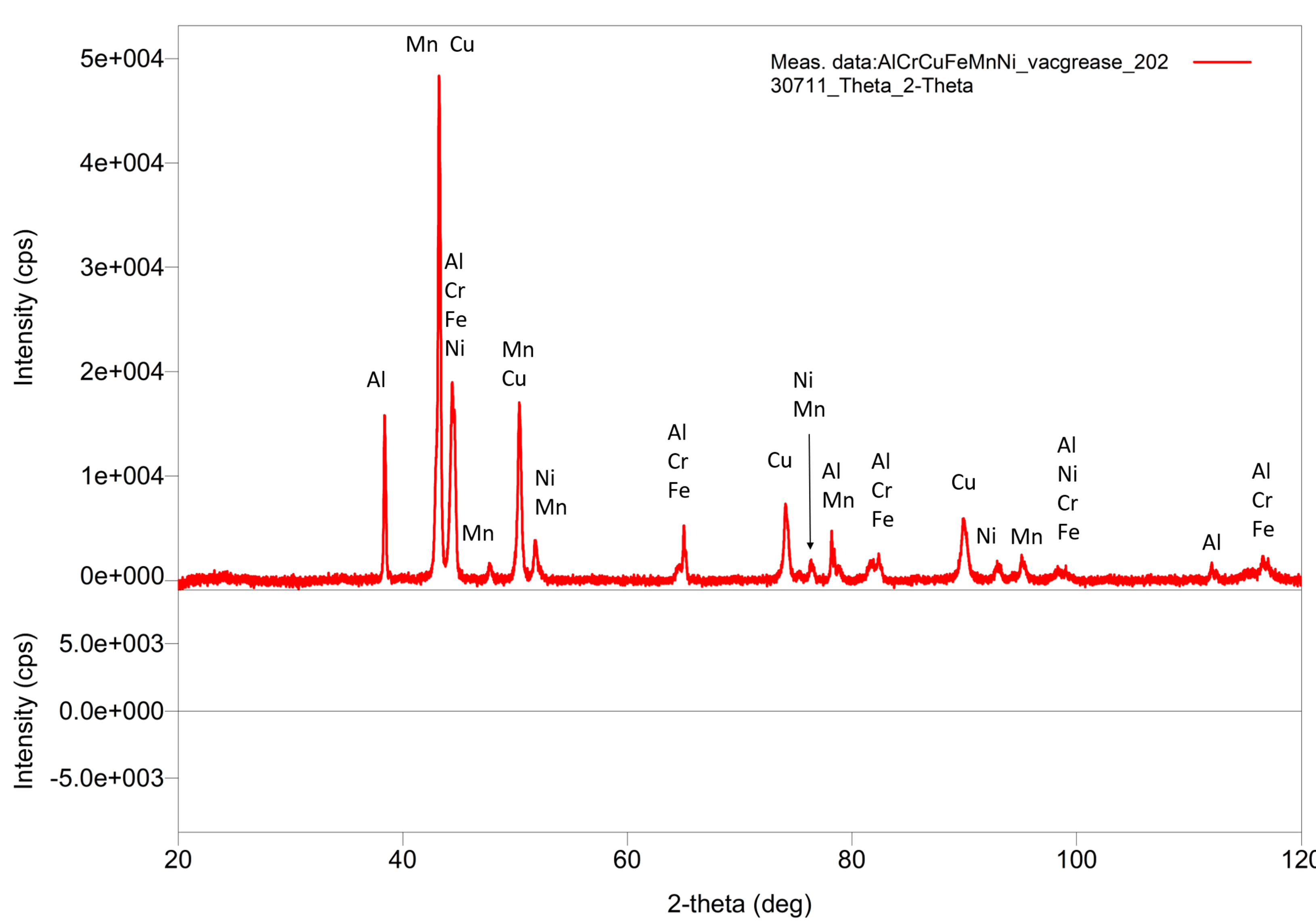

Figure 7 *XRD of milled powder*

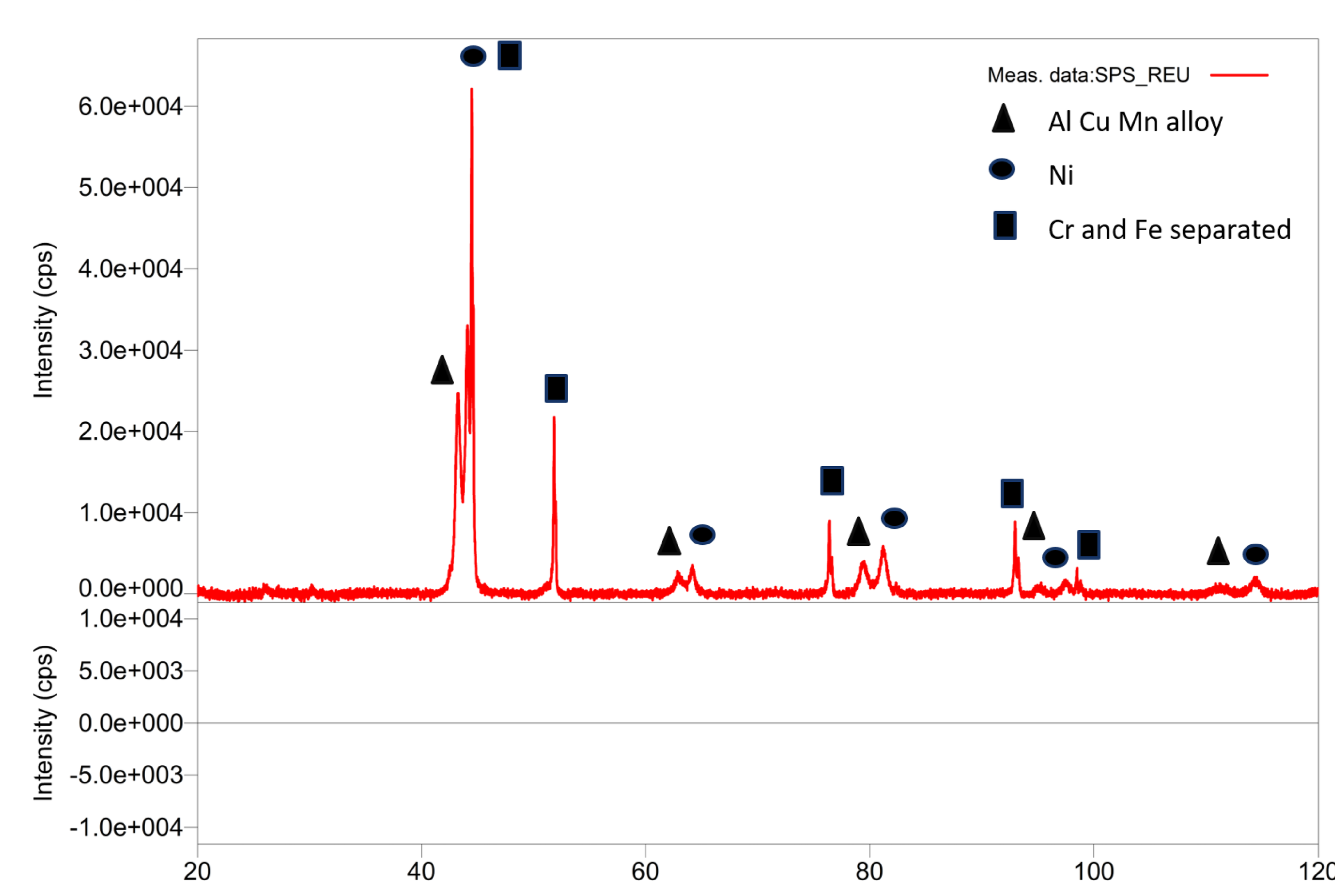

Figure 8 *XRD of SPS pellet*

V. Conclusion/ Future Work

- The EDS of the SPS experiment shows that Aluminum, Copper, and Manganese alloyed together which is also shown by XRD.
- Prior to SPS, the milled powder shows individual phases of the elemental powders rather than peaks of an alloy.
- Based on the results found from this experiment, this process for developing HEAs is plausible.
- The ball milling conditions of the Emax were not ideal to create a proper alloy, but it worked as a pivot when there were technological issues with the desired planetary ball mill.
- By following the preferred specifications for this ball mill and a proper SPS trial, future HEA sample pellets show promise.
- A successful fabrication method will allow for the further study of developing HEAs and fabrication possibilities.

VI. Acknowledgements and References

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