35929 – Additive Manufacturing of Corrosion Resistant UHTC Materials

Advanced Design, Materials, and Manufacturing Can Enable Compact Heat Exchangers with Higher Efficiency.

1. Impact

A triply periodic minimal surface (TPMS) can provide up to 10-100x higher heat transfer coefficient per heat exchanger volume. Ultra-high-temperature ceramic (UHTC) materials can retain high strength at CSP operating temperatures and can have excellent stability in molten chlorides.

2. Project Goal

Identify UHTC materials with excellent chloride salt corrosion resistance and demonstrate additive manufacturing for this class of materials and for the heat exchanger designs.

3. Method(s)

Analytical screening of UHTCs accounting for various performance and cost factors, develop additive manufacturing and sintering of a null candidate material and for a TPMS lattice, and corrosion testing of select materials in molten chloride salts at 800°C.

4. Outcome(s)

A figure of merit was developed to rank and down select from 36 materials. Results from corrosion testing of 8 materials were in good agreement with the figure of merit ranking for this class of materials. WC and Mo_2C were found to have excellent molten chloride corrosion resistance, even with water impurity present. Additive manufacturing of UHTC-TPMS cells demonstrate general feasibility of a manufacturing approach.

5. Conclusion/Risks

Two key risks for UHTC-TPMS heat exchangers – molten chloride corrosion resistance and the ability to manufacture the materials/designs – have been addressed. Developing a CO_2 corrosion resistant material with corrosion inhibitors and balancing with the impact on molten chloride corrosion resistance, scaling manufacturing, and joining/system integration development are required to manufacture and test a prototype.

6. Team

Lawrence Livermore National Laboratory

Oak Ridge National Laboratory

Texas A&M University

ExOne

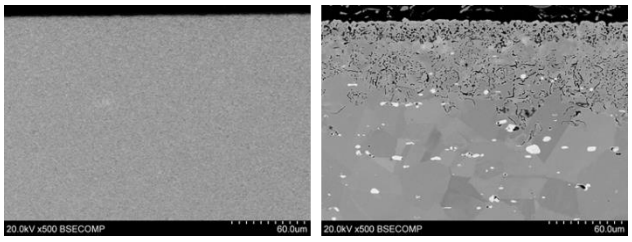

Figure 1. Back-scattered electron micrographs of WC (left) and Haynes 230 alloy (right) after corrosion testing in molten KCl-$MgCl_2$ salt at 800°C for 100 hours. The salt was intentionally spiked with 0.1 mole percent of water impurity.

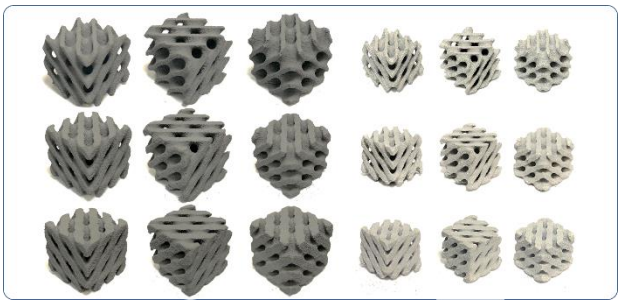

Figure 2. Examples of various printed (left) and sintered (right) UHTC-TPMS lattices having two independent volumetric domains.