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Advanced Manufactured Sensors: Feedstock Development, Fabrication and Process Control

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Changing the World's Energy Future

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Idaho National Laboratory

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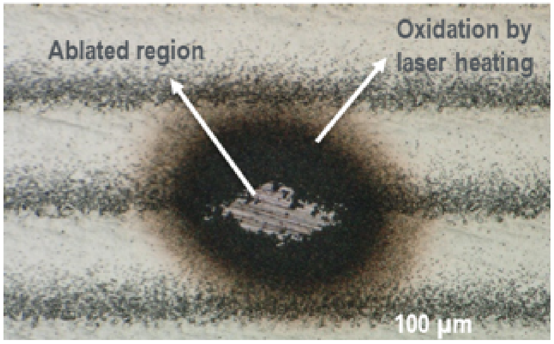
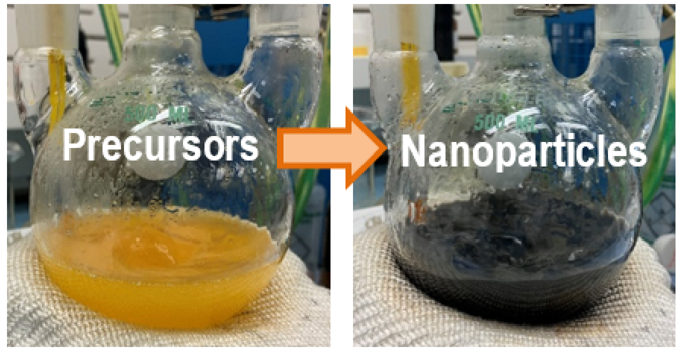
Project Description: Advanced manufacturing (AM) based sensor development using direct-write (DW) technologies such as aerosol jet printing (AJP), plasma jet printing (PJP), and micro-dispense printing (MDP) has emerged as the predominant enabler for the fabrication of active and passive sensors deployable in the types of harsh operating environments seen in a nuclear reactor. This activity aims to expand the current library of commercially available feedstock materials so as to encompass nuclear-relevant materials utilizable for manufacturing in-pile sensors and advanced nuclear instrumentation. Such sensors must withstand degradation against the coupled extremes of high-temperature and high-radiation fields. To this end, a post-fabrication process control protocol using laser-based techniques is being developed to evaluate the influence of substrate surface conditions—as well as that of deviations from ideal printing parameters—on the quality, robustness, and integrity of the printed sensor. Print parameters that affect the performance of active sensors will also be assessed via electrical resistivity measurements.

Impact and Value to Nuclear Applications: The limiting factor in implementing AM for novel sensor design is the current selection of commercially available feedstock materials that are compatible with these technologies. Significantly expanding this library of materials will enable the necessary pathway for incorporating these novel methods into nuclear energy applications, potentially revolutionizing the development of in-pile nuclear sensors. The laser-based techniques developed in this project for sensor-substrate adhesion measurement are expected to aid in determining the dominant combination of factors that significantly alter sensor durability, thus providing vital process control for printing novel nuclear-relevant materials via DW technologies.

Recent Results and Highlights: Feedstock development efforts elucidated a synthesis pathway for bismuth and bismuth-platinum (BiPt) bi-metallic nanoparticles – a pathway aimed at enhancing the temperature resolution of printed melt wires. While slight deviations from the theoretical melting point values occurred, the varying melting point of each different BiPt composition showed that the melting point can be altered by varying the composition of the BiPt nanoparticles. Additionally, a laser ablation technique was used to systematically study the influence of substrate roughness, substrate surface energy, and post-printing ink sintering conditions on the sensor-substrate adhesion strength of AJP-printed sensors. The ink sintering duration and temperature were found to be the dominant factors affecting adhesion, while substrate surface roughness was a secondary factor



Optical micrograph showing the region of the sensor ablated by a pulsed laser beam.



Reduction of bismuth and platinum ions to form BiPt nanoparticles, with nanoparticle formation being indicated by color change.