Correlative Microscopy and Spectroscopy for Characterization of Laser-Based Additive Manufactured Materials

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Laser-based Additive Manufacturing (AM) technology, due to the highly non-equilibrium metallurgical nature of the process, provides a valuable method to develop new materials, complex 3D configurations, and unique microstructures and properties. However, Additively Manufactured materials bear outstandingly different and complex microstructures with a distribution of inhomogeneities, which makes it challenging to obtain fundamental knowledge on how microstructure dictates functional properties of materials. As a result, the properties of metallic materials manufactured by AM involves a chain of mechanisms that spans from atomic to continuum length scales. Accurate understanding of functionality (mechanical, electrical, optical, etc.) of additively manufactured materials requires maximizing the information gain and optimizing efficiency by combining low- and high-resolution data and integrating data from different sources with a multimodality approach [1,2].

Electron and X-ray based microscopy and spectroscopy techniques are inseparable elements of rapidly growing research and development in a verity of areas such as material science, forensic analysis, failure analysis and hardware security. In the AM applications, different characterization techniques of imaging and spectroscopy provide crucial insights into the structure and composition of samples at different modalities and different resolutions. The collection of complementary data from various microscopy and spectroscopy techniques is key in achieving a comprehensive understanding to establish relationships between microstructure properties (grain orientation, and morphology), porosity distribution (size, shape, and location), and process parameters (laser power, scanning speed, hatch spacing, and layer orientation).

For advanced multimodal characterization of AM microstructures, we use a plethora of materials characterization techniques to assess the microstructure and chemistry of the laser processed materials at various spatial scales (atomic to mesoscale) to rigorously connect processing conditions to observed structure and properties. **Figure 1 summarizes some of the techniques that are utilized, such as scanning electron microscopy (SEM), focused ion beam (FIB), SEM-FIB tomography, 3D electron tomography, Energy dispersive X-ray spectroscopy (EDS) and X-ray micro-CT imaging**
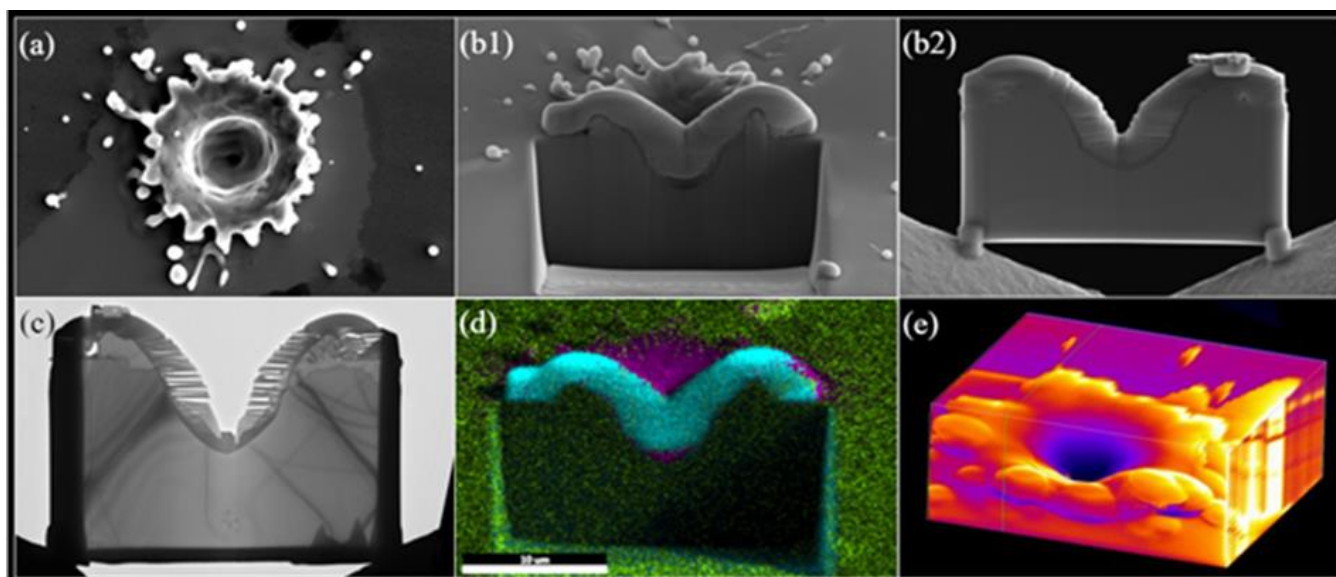
Figure 1. a) SEM images of craters formed with different number of laser pulses. (b1-2) FIB images of a cross-section sample of the crater prepared for TEM analysis and SEM-FIB tomography. (c) TEM image of the cross-sectional prepared by FIB. (d) EDS map of the cross-section sample. (e) 3D-rendering of a crater using SEM-FIB tomography.

References
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