Morphological and Chemical Evolution of Nanoporous Metal using X-ray Nano-tomography and Hard X-ray Spectroscopic Imaging

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Advancing technologies in energy storage and conversion devices such as batteries and fuel cells depends on developing novel materials. In particular, nanoporous materials—also known as nanofoams—exhibit unique properties such as high surface-to-volume ratio and a continuous network, which enables transport of fuels or electrolyte. A new dealloying method based on utilizing metallic melt as the dealloying agent instead of an aqueous solution has led to the successful fabrication nanoporous metal from less-noble metals, for example, stainless steels. This greatly reduces the cost of the material, while preserving the unique morphological factors that are desirable for energy applications. It is, however, critical to establish the correlation between the processes, morphology (2D & 3D) and chemical heterogeneity of these novel nanoporous metallic materials for suitable applications.

We utilized full-field nano-tomography via transmission x-ray microscopy to study the evolution of the morphology as a function of processing conditions, including precursor compositions, dealloying temperature and time. A systematic trend of spontaneous coarsening as a result of prolonged dealloying time and increased temperature was observed: the precursor compositions significantly impact not just the porosity of the nanoporous materials, but also the surface shape of the nanofoams. A gradient of the ligament size and compositional change along the dealloying direction were also observed. In addition, spectroscopic imaging at synchrotron sources is a powerful technique for spatially resolving chemical and elemental distributions in these materials. Utilizing the Sub-micron Resolution X-ray Spectroscopy (SRX) beamline at NSLS-II provides additional elemental and chemical information of the nano-porous materials.

References

[1] http://www.bnl.gov/ps/nsls2/beamlines/SRX.php

[2] T. Wada, H. Kato, “Three-dimensional open-cell macroporous iron, chromium and ferritic stainless steel”, Scripta Mater. 2013, 68, 723