Metallurgical Design of New Nanoporous Structures

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Abstract: New nanoporous metallic materials based on non-Pt group metals have been synthesized via dealloying of rapidly solidified alloys and aimed to demonstrate competitive catalytic performance in the field of direct alkaline fuel cells and SERS-active substrates. Nanostructured copper surface and nanoporous copper matrix with very fine morphology and specific surface area were obtained by chemical dealloying of bulk Cu90(HfZr)10 and melt-spun amorphous CuxCa100-x (x ranging from 35 to 80 at.%) family of alloys accordingly. Nanoporous silver and cobalt substrates were produced by dealloying of M38,75Cu38,75Si22,5 crystalline ribbons (M = Co and Ag) as a result of the removal of Cu and Si-rich phases. In addition to conventional characterization methods, all nanoporous structures have been reconstructed by FIB-nanotomography, clearly exposing the morphological diversity of the three systems with transversal porosity when visualized and color-mapped in 3D by a special numerical tomography tool. It is for the first time that a practical significance of these materials has been explored in the scope of self-supported anodic catalysts, suggested throughout this study as an alternative to the unstable Pt-based carbon-supported commercial composites. Half-cell electrochemical tests demonstrated an excellent catalytic activity towards the oxidation of a borane fuel and superior stability of functioning in the alkaline environment compared to Pt/C catalyst. In similar conditions, nanoporous Co showed higher efficiency but lower stability, attributed to the complex chemical composition of its porous scaffold. Nanoporous Cu has not been exploited for the mentioned applications due to its high brittleness and is suggested to go through improvements on the step of precursor synthesis. Lastly, while exploring the mechanical behavior of the NPMs by instrumented nanoindentation of different nanoporous Ag substrates, a load-displacement dependence phenomenological model has been suggested for this class of metallic materials.

Keywords: Nanostructures, nanoporous, microstructures, microporosity, dealloying