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COMPOSITE METALLIC NANOFOAM STRUCTURES

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Metallic nanofoams made of metals such as nickel (Ni) or gold (Au) with ligament sizes on the order of 10's to 100's of nm's exhibit several remarkable properties as a consequence of their low relative density and high specific surface area, such as outstanding strength to weight ratios, enhanced plasmonic behavior and size-effect-enhanced catalytic behavior. However, these metallic nanofoams suffer from macroscopically brittle behavior due to plastic deformation in individual ligaments. With little or no barriers for slip, work-hardening is not possible within ligaments and extremely localized plasticity, once initiated, leads to a few ligaments necking and what appears to be macroscopically brittle failure of the structure under load. Many of the nanofoams produced from metals were originally formed via dealloying.

Recently both simulations and experiments have identified that layered ligaments of metallic foams can exhibit significantly improved strength and hardening in Ni-Au core-shell foams[1]. Simulations of Cu-Ni predict that this material combination will exhibit pseudo-elastic behavior and eliminate the macroscopic brittle failure [2]. However, using a metallic foam as a substrate for subsequent layered metallic films limits the amount of metallic layers that can be deposited because the initial foam must have a minimum amount of material (often a solid fraction of approximately 25%). Using a significantly less dense foam as a template should allow for subsequent multilayer growth that would enable larger numbers of layers, and therefore a possible increase in overall strength to total ligament diameter. Single layers have been demonstrated in a prior study [3].

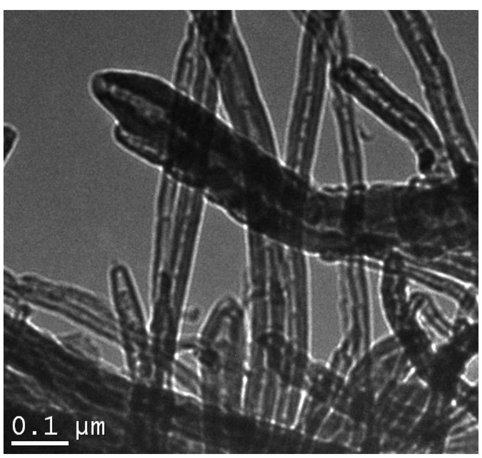

Figure 1 – Cu-Ni layers on CNT foam

Pulse electroplating from a nickel sulfamate electrolyte bath was used to deposit alternating layers of Ni and Cu. The bath consisted of 90 g l^{-1} Ni, 0.9 g l^{-1} Cu and 30 g l^{-1} boric acid (pH 3-3.5). This solution allows for alternating Ni and Cu layers to be alternately plated by varying the applied voltage, the end layer is actually an alloy of mostly Cu with Ni, and then mostly Ni. Low density foams were selected as a template for subsequent deposition. These included 2% volume carbon nanotubes as well as electrospun carbon fibers. Typical structures are shown in Figure 1. The resulting foams were then indented using flat punch nanoindentation and the effective modulus increased by a factor of three and the elastic recovery after indentation increased substantially (to about one half the original impression depth).

The presentation will describe the processing method, the structural changes that occur when the films transition from layer by layer to island growth, and the resulting properties of the foams.

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