Electrodeposition of nanocrystalline metals on open cell metal foams: improved mechanical properties

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Open cell metal foams are a relatively new class of materials. They are metal cellular structures which consist of a three dimensional network of pores. Due to their high stiffness to weight ratio, they are used in lightweight constructions and show potential as energy absorber and for mechanical damping. Due to their high surface area, they are used as filters, heat exchanger and sound absorber.

Fig. 1: 3D network structure of an open cell metal foam.

As a result of the open structure of the metal struts, open cell metal foams could be used as substrate for coating by electrodeposition. The coating could enhance the mechanical properties of the foams or provide additional functional features like corrosion protection or catalytic activity.

The deposition process and thus the coating thickness and the metal distribution on the metal foam cathode strongly depend on mass transport limitation effects. At nickel coated foam. the metal distribution of the foam have been visualized by measuring the magnetic flux density distribution by scanning the surface of cuts of coated foams with a commercial Hall probe. By measuring the magnetic flux density distribution, deposition parameters such as the current density and flow conditions could be optimized with regard to a more homogeneous metal distribution on the foams.

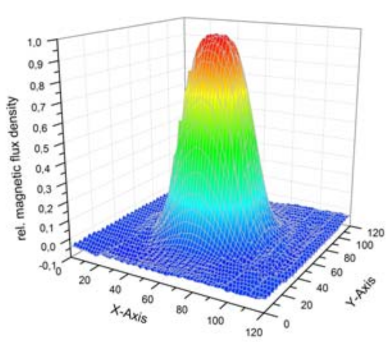

Fig. 2: Magnetic flux density distribution of a nickel coated metal foam.

From the magnetic flux density distribution of cuts of nickel coated foams a model of the mass transport limitation at a complex three dimensional foam electrode could be evaluated.

X-ray computed tomography shows hydrogen evolution as a further problem of the coating of metal foams via electrodeposition.

The stiffness and strength of aluminium foams have been increased by a nanocrystalline nickel coating via an electrodeposition process. If the coating is thick enough, the properties of the foam-composite structures are dominated by the properties of the coating. Coating of the metal foams should enhance the stiffness and compression strength of the foams and also the energy absorption capability.

The mechanical behaviour of open cell aluminium foams with coatings of different metals (Ni, Cu, Fe) have been investigated under quasistatic and dynamic compression loading in order to enhance the energy absorption capability of the foams. The best performance in reference to enhanced energy dissipation during compressive loading has been provided by a coating of nanocrystalline nickel. In a second step the effect of coating thickness and pore size was studied by slow and fast quasistatic compression tests and additionally dynamic compression tests with a Split-Hopkinson-Pressure-Bar (SHPB). There was a linear increase in energy absorption capability with coating thickness for the absolute values and per foam thickness but per density or mass the energy absorption capability reached a saturation level. So there is an optimum in coating thickness.

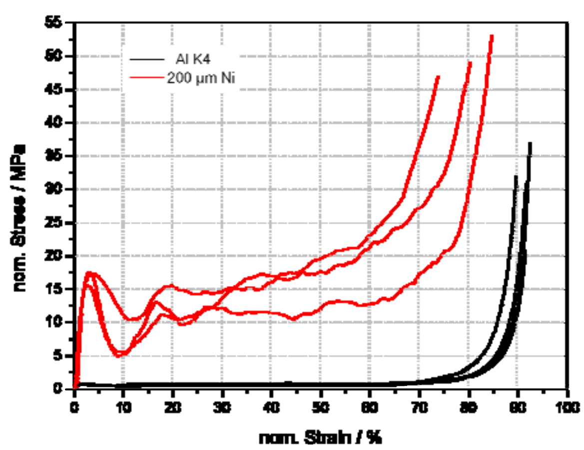

Fig. 3: Stress-strain-curves of open cell metal foams with a coating thicknesses of 200 µm nickel.

Compared to uncoated aluminium foams there was an increase in plateau stress by decreasing pore size. A decrease in pore size from 10 to 30 ppi more than doubled the energy absorption capability per foam thickness of coated foams.

Under dynamic loading there was also an increase in energy absorption capability by a factor of 10 for a coating thickness of 50 µm in comparison to uncoated foams even at a very small foam thickness of 4 mm.