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JOINING OF METAL FOAMS FOR ENERGY STORAGE DEVICES

THE TASK

The demand for energy storage devices continuously increases due to the rising electrification of private and public transportation and the transition of Germany's energy policy. The performance of electrical energy storage devices needs to be improved for mobile and stationary applications. Fraunhofer IWS engineers in Dresden work on novel electrochemical, material and manufacturing concepts for battery cells.

Using metal foams as electrodes offers a very high specific active surface area with respect to material volume and weight. However, such open and more than 90 % porous cellular materials pose a challenge in terms of connecting them to the battery tabs. In addition to mechanical strength requirements, such connectors need to have low contact resistance and they have to be chemically stable. The foam structures are loaded with active material. Therefore they need to be processed in an inert gas environment.

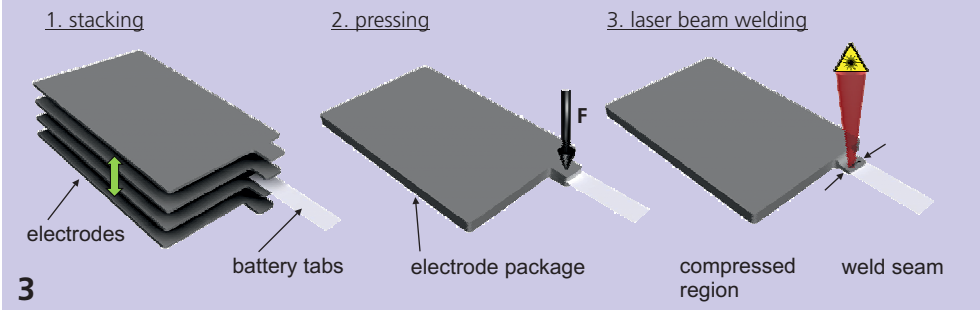
OUR SOLUTION

Chemical, materials science and process technology competences in battery research are bundled and expanded within the federally funded research projects "BamoSa" (BMBF, project number: 0344637A) and "BaSta" (BMWi, project number: 0325563A).

The metal foams were studied for applications in three-dimensional current collectors. To connect the metal foams with the tabs, a joining technology is required which ensures a firm bond and which does not deposit too much heat into the electrodes. The joining process must also be performed in an inert gas environment. Therefore laser beam welding is the technology of choice since it features small spot diameters and low linear energy deposition densities.

The battery tabs are made from nickel, copper or aluminum. The metal foams are nickel, nickel-based alloys, copper or stainless steel. To connect them the first step is compressing the materials to stacks. The applied mechanical force strongly reduces the porosity of the foam material.

Schematics of the joining process combining pressing and laser beam welding



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An additional form-fitting connection is introduced for thicker battery tabs (> 50 µm). These tabs have pre-punched holes to receive the foam when pressed. This technique provides both a form fitting and a frictional connection between metal foam and tab.

A laser beam welding process finally firmly bonds two materials in their compressed state. No filler material is required. The fiber laser beam is coupled via a protective window into the glove box, which holds the electrodes. Highly dynamic scanner technology is used to control the laser beam path to match the desired weld seam shape of the battery electrode (Fig. 2).

RESULTS

Experiments were performed with numerous connections and material combinations. As expected the cellular materials with smaller pore sizes are more stable during the welding process and also have a lower porosity in the resulting weld seam. This is caused by a stronger material accumulation during the compression of materials with smaller pore sizes.

The weldability of different materials depends on the metallurgical behavior of the melts and the coupling conditions of the laser radiation into the cellular material (Fig. 5).

Weldability of different material combinations

foam material	tab material		
	nickel	copper	aluminum
nickel	very good	good	limited
nickel-based	very good	good	limited
copper	limited	limited	very limited
stainless steel	good	medium	medium

5

The connections were mechanically tested and showed excellent tensile strength. Ultimately all samples failed in one or the other base material, not in the joint.

The electric conductivity of the connections was measured with a four-point probe setup. The contact resistance was always lower than the resistance of the metal foams.

By tailoring the battery tabs and combining compression and laser welding it is possible to firmly connect open cellular materials to foils. Typically the mechanical strength and electric conductivity of the joints exceeds those of the basic foam materials.

1 Battery electrodes with welded aluminum tab
2 Different seam geometries
4 Polished cross section of a welded joint with 4 layers of stainless steel (1.4404), metal foam and battery tab

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