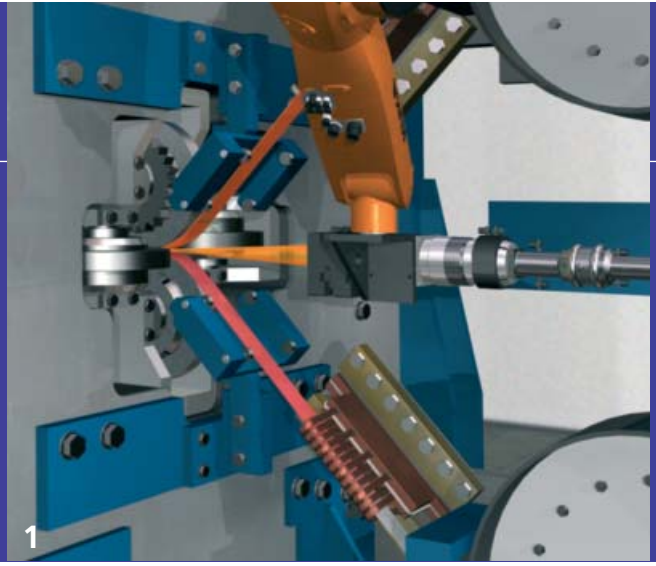


MATERIALS ENGINEERING STUDIES FOR THE FABRICATION OF AL/CU CONNECTIONS

THE TASK

Energy storage devices that can be produced in large quantities and put on the market at reasonable prices are an essential precondition for electric mobility. The interconnection of cells by means of so-called high-current cell connectors is a key process in the configuration of battery modules from individual battery cells. This process has been hitherto implemented mechanically by screwing with all of its disadvantages in terms of costs and reliability over the duration of the battery life. The joint project "BatCon" was aimed at replacing the screwing solution. Function-integrated high-current connectors for battery modules had to be developed by means of cost-optimized manufacturing technologies in a holistic approach.

The most difficult challenge in the use of thermal joining techniques is the limited solubility of the associated metals with one another (Al, Cu) in the solid state, tending to form brittle, intermetallic phases. At the beginning of the project, the fabrication of fusion-welded joints of aluminum and copper was not state-of-the-art because brittle intermetallic phases emerged. Consequently, the aim of the project was to develop process technologies and a fundamental understanding of the material behavior related to the joining of aluminum with copper, and to engineer new joining technologies for the manufacturing of semi-finished products for cell connectors optimized in terms of function and costs.

OUR SOLUTION

Making use of the IWS' expertise in joining materials or material composites for which fusion-welding either requires special conditions or cannot be done at all, the innovative special joining techniques of laser induction roll plating (see also ps. 64/65) and friction stir welding were refined to make them applicable in the production of Al/Cu cell connectors as semi-finished products. During this process the required reproducibility, efficiency and functionality was also taken into account.

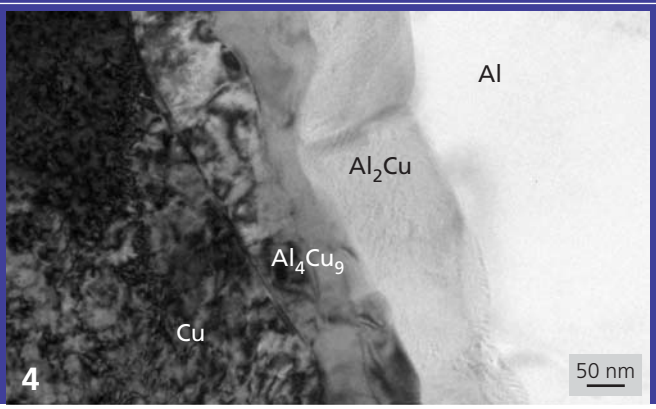
Other core competencies used within the project are material development strategies accompanying the process development, materials characterization and materials testing. They are used in the project, for example, to understand the predominant joining mechanisms and to test the joint connections reliability.

RESULTS

The first project stage was focused on the comparison of different joining approaches for bi-metallic Al/Cu composite fabrication of semi-finished products. Laser beam welding, friction stir welding and laser induction roll plating were examined in this technological assessment.

In terms of materials engineering, friction stir welding and laser induction roll plating can be considered most suitable for joining Al and Cu sheets because they guarantee a thin and continuous phase seam, sound adhesion and low contact resistance values. As a result of the technology itself the joint areas (intermetallic phase seam) through friction stir welding are clearly smaller than in laser induction roll plating. However, this phenomenon can result in low strength, especially under cyclic load.

Due to its high productivity laser induction roll plating is the most economical technology by far for the production of large quantities, despite the high investment costs. Since laser induction roll plating has hitherto been performed only to join completely overlapping strips, a hardware concept intended for



partial overlapping strips was developed (Figures 1, 2). The goal was to fabricate the Al/Cu cell connector whose bonding zone is located not symmetrical as shown in Figure 3.

The implementation of this complex and novel solution for laser induction roll plating included design, fabrication and use of special calibrating rolls, as well as the integration of a diode laser with specific line optics. It also demanded comprehensive process development to achieve the necessary speed, quality and reliability of the joining process. The feasibility of the fabrication of the semi-finished products of bimetallic Al/Cu cell connectors could be demonstrated in the project.

In comparison with the state-of-the-art, represented by screwing of the cell connectors, welding of the cell connectors fabricated by laser induction roll plating offers the following advantages:

- higher level of automation with clearly reduced production costs,
- significantly reduced contact resistances and thus lower electrical losses,
- enhanced long-term reliability and mechanical stability as well as
- less weight and more freedom of design to reduce the installation space.

The Al/Cu connections produced by means of various joining techniques were subject to comprehensive comparative structural analyses. Apart from friction stir welding and laser induction roll plating, the examinations also involved the techniques developed by the project partners: laser beam welding, ultrasonic welding and electromagnetic pulse welding. The formation of the intermetallic phases Al_4Cu_9 and Al_2Cu in the joint zone is characteristic for all of the joining techniques (Fig. 4). During laser beam welding, the thickness of the intermetallic intermixture zone cannot be reduced below 10 µm, which results in relatively high embrittlement and thus risk of cracking and breakage. In general, for this material combination, laser beam welding shows better suitability for thin films (thickness < 1 mm) than for sheets of higher thickness and thus stiffness.

However, with the other techniques investigated, it is possible to limit phase seam thickness to approximately 1 µm, which is not critical for the electrical properties and mechanical stability. The phase seam necessary for the actual joining do not show any ageing characteristics even at maximal temperatures of 100 °C relevant for use over more than 500 h.

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1 Process principle – laser induction roll plating (with laser beam (middle) and the Al and Cu strips fed into the rolls)
2 Detail of the roll stand
3 Al/Cu cell connector welded by laser beam
4 TEM image: intermetallic phase seam

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