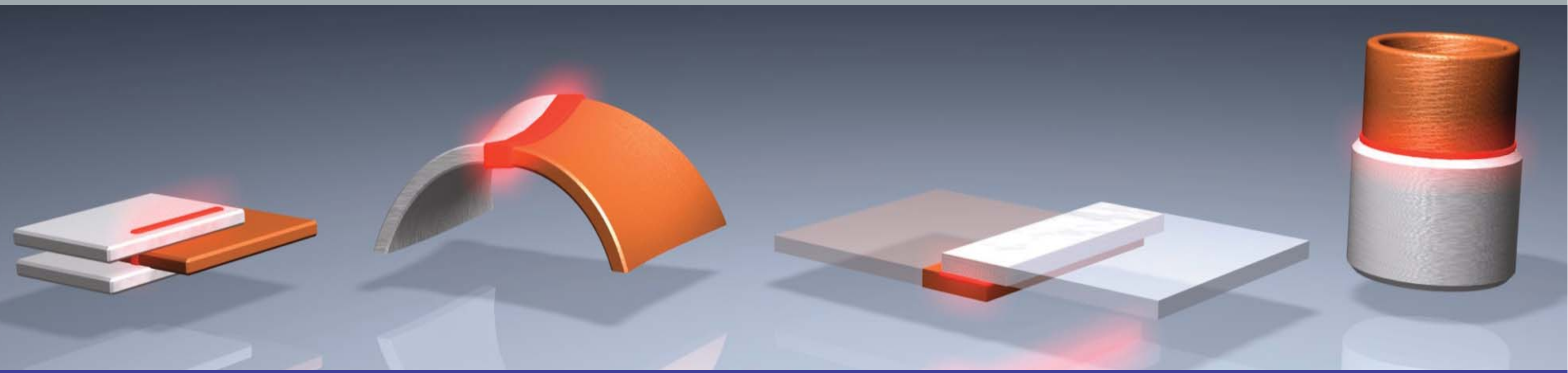
Fraunhofer

IWS Dresden

FRAUNHOFER-INSTITUT FÜR WERKSTOFF- UND STRAHLTECHNIK IWS



JOINING OF AL-CU MIXED COMBINATIONS

Technologies for Electromobility

Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS

Winterbergstraße 28, 01277 Dresden, Germany

Fax +49 351 83391-3210
www.iws.fraunhofer.de

Contact:
Dr. Jens Standfuß
Phone +49 351 83391-3212
jens.standfuss@iws.fraunhofer.de

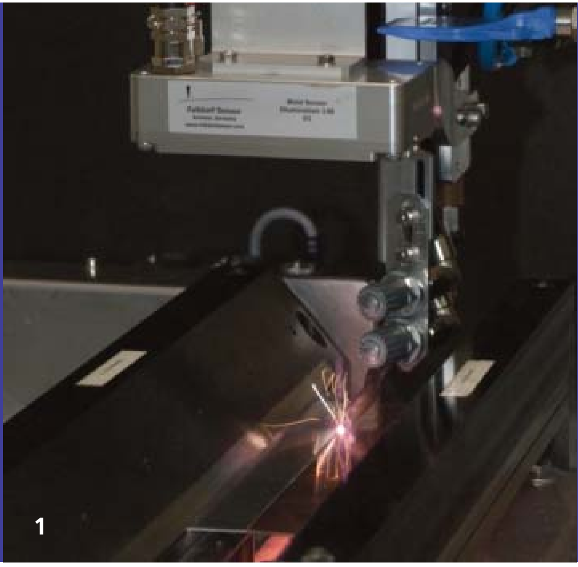
info 300-4a

Motivation

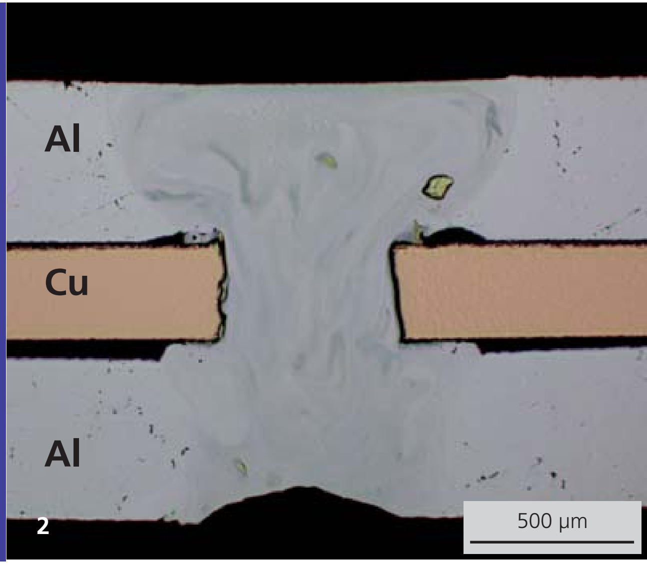
Electromobility is what everyone is talking about nowadays. The German automotive industry and its suppliers are adapting energetically to these novel developments. New companies are being established – in the field of battery manufacture, for example. The effective joining of aluminum with copper is one of the central technical challenges involved in Electromobility. The Fraunhofer IWS Dresden has many years of experience in the joining of difficult-to-weld materials and material combinations which cannot be fusion-welded by conventional means. It is, thus, in a position to be able to offer various new joining technologies to industry, which are able to perform different tasks and applications dealing with the joining of aluminum and copper.

Process 1: Laser welding using highly dynamic beam deflection

The welding of combinations of various materials enables optimum use of the specific properties of those materials. In particular, laser beam welding is quite well suited to the economic production of mixed combinations. Nevertheless, the different thermophysical and material properties of the joining parts often lead to loss of quality, since any intermetallic phases which are generated can greatly restrict the attainable strength of the joint. The use of a highly dynamic beam deflection at the Fraunhofer IWS has shown that improvements in quality can be attained with laser welding of the mixed combinations Al-Cu.



1



2

With this technology, a brilliant laser beam is deflected over quickly tiltable mirrors and projected on to the joining impact. The good focusability of high-brilliance laser beams makes it possible to obtain extremely narrow welding joints with high aspect ratios and extremely short melt pool operating cycles. The energy input into the work-piece is thereby considerably reduced and the formation of the brittle inter-metallic phases significantly decreased.

The results shown have been obtained within the framework of the BMBF-sponsored project »WELDIMA – Verfahrens- und systemtechnische Entwicklungen zum Schweißen von Mischverbindungen mit brillanten Laserstrahlquellen«.

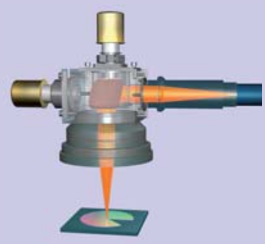
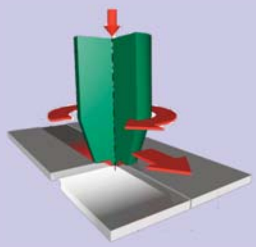
Process 2: FSW - Friction Stir Welding

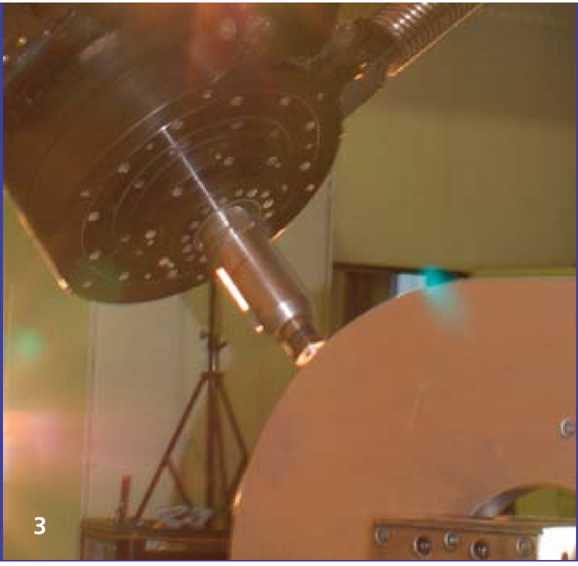
FSW is a mechanical joining method, which combines the joining parts in the solid phase. This makes it possible to largely avoid undesirable metallurgical fusion effects such as intermetallic phases from the very beginning. The rotating FSW tool exerts pressure on the material surface at the joint via a so-called "shoulder" and plasticizes the material by means of frictional heat. A pin immersed into the material regulates the material flow. This makes it possible to obtain a fine-grain, thermo-mechanically treated joint seam with high strength values.

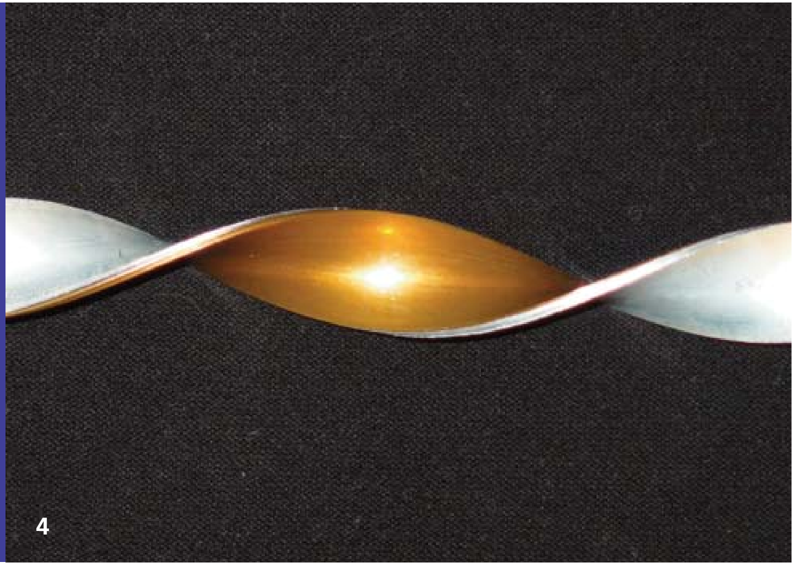
The process was realized at the IWS on a 3D milling processing center, which is based on the concept of Parallel Kinematics – a so-called Pentapod. The necessary closed loop control strategies were implemented in cooperation with the manufacturer Metrom GmbH. This machine concept permits both the three-dimensional friction stir welding of complex components and upstream mechanical processing of the joint edges in a clamp.

Benefits typical of FSW:

- joining of materials which are difficult to weld using fusion welding techniques
- low component deformation

Comparison of the joining processes	**Laser Welding using Beam Deflection**	**Friction Stir Welding (FSW)**
Process principle (schematic)		
Characteristics	- Defined degree of dilution	- Solid-phase joining procedures
Applications	- Thin-walled components - Example: contacting of Al-Cu diverters for Li ion cells - Other materials: e. g. Al + Mg, stainless steel + copper	- For (three-dimensionally curved) linear joints, also with Al die casting, for example on casings - Other materials: Al + Mg





- no additional welding material necessary
- manufacture of mixed combinations possible
- high strength

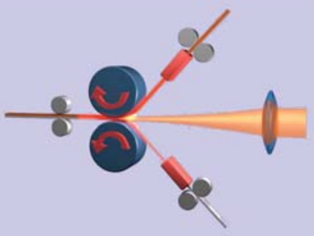
Advantages arising from the new equipment concept:
- equipment set-up which is much simpler and far more cost-effective
- large working area
- high rigidity and position accuracy
- quick and flexible process control

Process 3: Laser Induction Roll Plating

Suitable composite semi-finished products of aluminum and copper, adapted to the concrete component requirements, could open up new constructive possibilities in the design of electrical drive components which are as compact and as light as possible and nevertheless capable of bearing high mechanical loads. The Laser Induction Roll Plating procedure developed at the Fraunhofer IWS is suitable for the realization of such composite semi-finished products. In this case, an aluminum band and a copper band are combined with each other in a single rolling process and with low overall deformation (< 11 %). The uniqueness of this procedure lies in the combination of a conventional pre-thermal treatment of both the bands to be joined and of a laser beam tapered to a line. This then heats the inner sides of both bands to the temperatures necessary for the cladding process immediately in front of the roll gap. This procedure is very suitable for the manufacture of e.g. bimetallic connectors (transition joints). The local influence of deformation results in a comparatively large degree of freedom in the combination of the semi-finished products to be joined. These do not have to be geometrically congruent with each other.

The results shown have been obtained within the framework of the BMBF-sponsored project »DeLIZ - Produktionstechnisches Demonstrationszentrum für Lithium-Ionen-Zellen«.

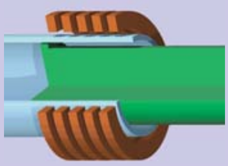
Laser Induction Roll Plating



- Joining by means of deformation and locally increased temperature

- Ribbon-shaped semi-finished products, in planning: band on profile
- Example: joining of Al-Cu connectors for Li ion cells
- Other materials: steel + steel, Al + steel, Cu + steel

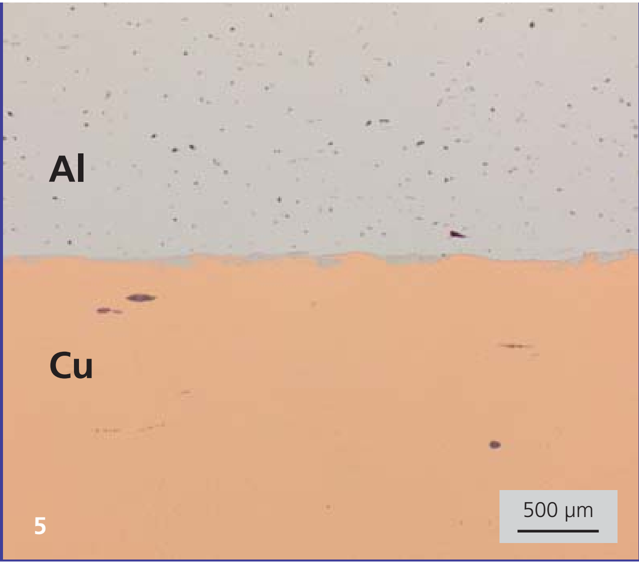
Electromagnetic Pulse Joining

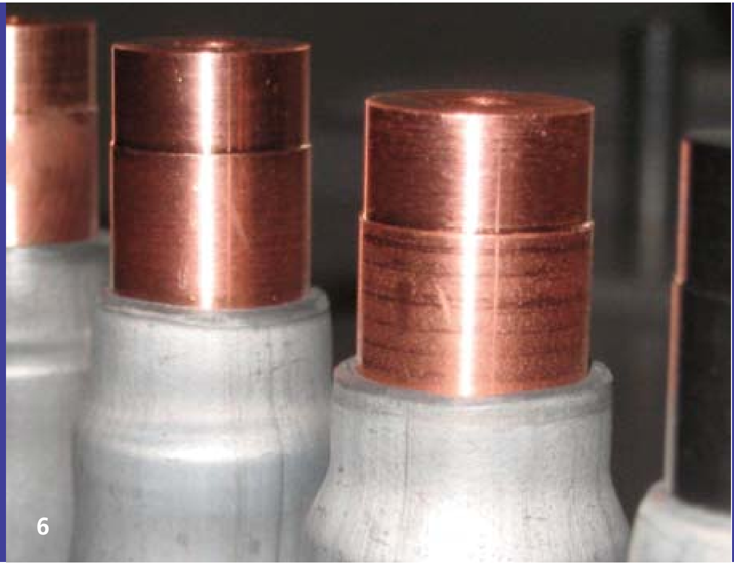


- Atomic bonding, no thermal influence zone

- Particularly suitable for components almost symmetrical in rotation
- Examples: piping, shafts, smaller pressure containers
- Other materials: z. B. Al + steel, Cu + steel, Al + Ti

1 Process of laser beam welding of Al-Cu mixed combinations
2 Microsection of a laser-beam welded Al-Cu combination
3 Pentapod equipment for friction stir welding of Al-Cu
4 Laser induction roll plated and twisted band of Al and Cu





Process 4: Electromagnetic Pulse Joining

By generating extreme local pressures, electromagnetic pulse joining permits almost fusion-free welding of practically any metallic joining parts. Intermetallic phases at the joint are thereby generally avoided due to its inherent working principle. Similarly, in the case of mixed combinations, it is not critical if the joining parts have greatly differing melting points, thicknesses or thermo-conductive properties. The local pressure impulse is generated by means of the contact-free influence of a magnetic field pulse in the component itself. Above all, this technology offers the possibility of a contact-free forming of metals and of manufacturing positive-locking combinations in a highly energy-efficient manner.

Atomic welding is also possible with a corresponding selection of the parameters. This technology is particularly suitable for piping or shaft components. Flat joint designs are however also possible. One of the two joining parts should not exceed a wall thickness of typically 2-4 mm. The welding joints display extremely low thermal input and do not have any thermal influence zone. In addition to research into system technology, the IWS is also studying the optimization of joint quality by means of carefully adapted tool coils and joining geometries.

This research was jointly sponsored by the European Fund for Regional Development and by the State of Saxony.

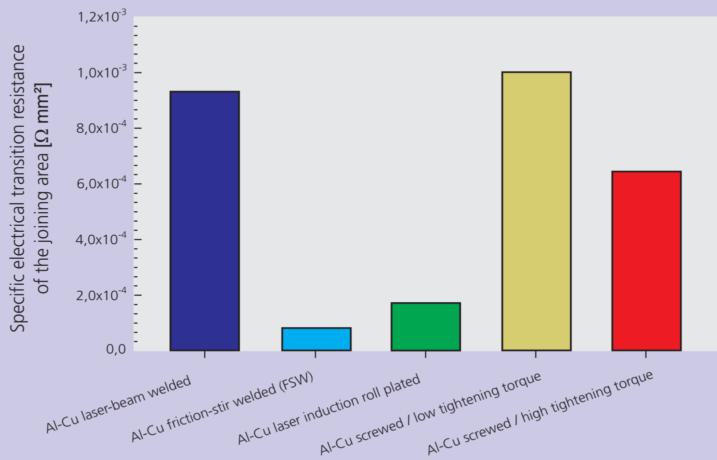
Contacts at the Fraunhofer IWS

Laser Welding
Dr. Jens Standfuß
Phone +49 351 83391-3212
jens.standfuss@iws.fraunhofer.de

Laser Induction Roll Plating
Dipl.-Ing. Volker Fux
Phone +49 351 83391-3243
volker.fux@iws.fraunhofer.de

Friction Stir Welding & Electromagnetic Pulse Joining
Dipl.-Ing. Sebastian Schulze
Phone +49 351 83391-3565
sebastian.schulze@iws.fraunhofer.de

Electrical transition resistance of Al-Cu mixed combinations



5 Microsection of an Al-Cu interface generated using EMP

6 Piping pin mixed combinations of Al-Cu