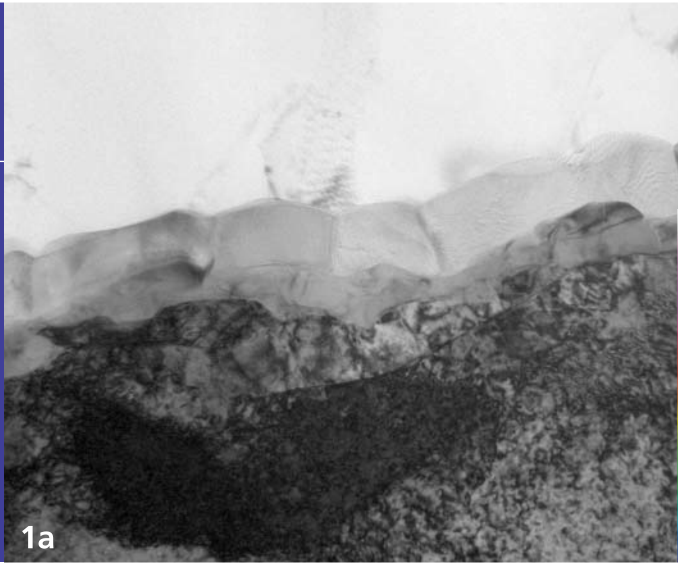

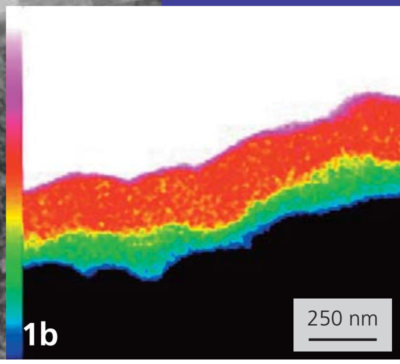

HIGH RESOLUTION CHARACTERIZATION OF THE INTERFACE BOUNDARY SURFACES OF MIXED METALLIC JOINTS

THE TASK

The term "multi materials design" implies that such parts are constructed from mixed materials to provide properties exactly where they are required. The consequent use of mixed materials construction offers new material and processing challenges for joining technologies. One of the most critical issues related to using mixed materials is the formation of brittle intermetallic phases in the welding zone. Such brittle phases lead to significant performance degradation of the welded component. This is the reason why Fraunhofer IWS engineers develop processes such as laser induction assisted roll plating, electromagnetic pulse joining and friction stir welding in parallel to laser beam welding solutions.

A substantial limitation for the development of these new joining technologies is the insufficient knowledge about the joining mechanisms. Conventional metallographic preparation techniques and characterization methods are only suitable to a limited degree, which complicates the research. The goal is therefore to develop and apply appropriate preparation techniques and high resolution characterization methods to fully understand the processes in the boundary region of the joining interface.

OUR SOLUTION

Typical Fraunhofer IWS characterization methods for mixed metallic joints include metallography, scanning and transmission electron microscopy (SEM, TEM) and energy dispersive X-ray microanalysis (EDX). The methods are complementary to each other. All electron microscopy imaging techniques are used. Ion beam based preparation techniques are applied to prepare sharp edges for analysis with minimal artifacts. Procedures are available to prepare samples of various material combinations.

RESULTS

Fraunhofer IWS engineers successfully produce mixed metallic joints of different material combinations (Al-Cu, Al-steel, Steel-Cu) using laser induction roll plating, electromagnetic pulse joining and friction stir welding. The various joining technologies generate very different process conditions (e.g. pressure, temperature, interaction times, degree of deformation). However, there are many and sometimes even surprising analogies between the processes with respect to the actual material joining mechanism. Here we describe the results obtained from a mixed metal Al-Cu joint.

Even with brilliant lasers in the kW power range used at high welding speeds it is not possible to reduce the thickness of the intermetallic interface layer to much less than 10 µm. Subsequently the strength of the mixed joint is always lower than that of the original Al material.

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On the other hand, laser induction roll plating and electromagnetic pulse joining lead to seam thicknesses of less than 1 µm (Fig. 1a and 1b). Consequently, mechanical tests show that the component will fail in the aluminum material rather than in the seam. Thus the joining zone has at least the strength of the weaker partner.

In comparison to the other joining processes, friction stir welding causes significantly higher mixing of copper and aluminum (Fig. 2). The interaction time is relatively long and therefore the formation of intermetallic phases cannot be as effectively suppressed as during laser induction roll plating or electromagnetic pulse welding.

So far the research led to the hypothesis that a very thin but continuous phase-seam benefits the fabrication of Al-Cu mixed material joints. Mechanical clamping only, i.e. no mixed material boundary region is formed, is insufficient to provide adhesion between aluminum and copper.

The detailed structural and analytical investigations showed that the properties of mixed material joints are also significantly influenced by thermally and mechanically induced structural changes in the boundary regions. Typical induced changes can be recrystallizations, phase changes, deformation hardening as well as the dissolution or reformation of segregations.

Current research aims at identifying the correlations between structure and properties for the various mixed metal multi material systems. The results provide the basics for process optimization and for the design of multi material systems in automotive, railway and aerospace industries.

1 TEM image of an interface of an Al-Cu mixed joint, which was produced by laser induction roll plating (LIWP). The image is used to identify the submicroscopic phase seam

a) TEM bright field image

b) Al element distribution (EDX mapping)

2 Cross section through a friction stir welded Al-Cu butt weld (light microscopy overview)

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