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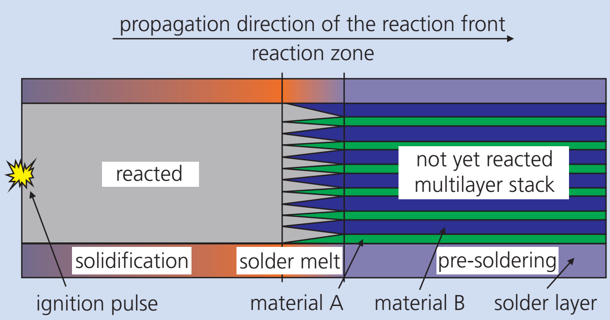
REACTIVE MULTILAYER SYSTEMS FOR JOINING APPLICATIONS

THE TASK

In recent years Fraunhofer IWS engineers have developed so-called reactive multilayer systems (RMS) based on Ni/Al. These coating systems serve as in-situ heat sources for joining processes in temperature ranges compatible with thermoplastics as well as tin-based soft solder joints. RMS find applications in micro systems technology for joining materials with extremely different coefficients of thermal expansion and for joining thermoplastics.

RMS need to be further developed to make this joining technology accessible to other applications. Current research focuses on the use of higher melting point solders and on joining thermoplastic composite materials.

Schematic showing the propagation of the heat wave in a RMS



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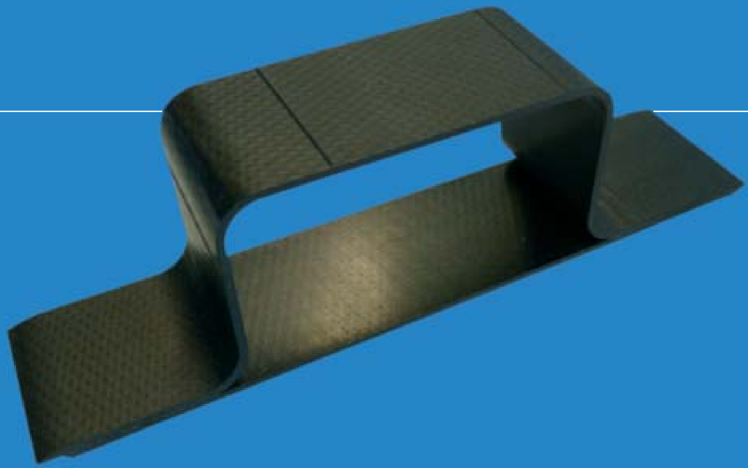
OUR SOLUTION

A multilayer RMS is placed right at the joining zone to serve as an internal heat source for melting the materials or solders. This approach has many advantages. The heat delivery is much localized and occurs over a short period of time. The bonding parts remain at room temperature and only the immediate joining zone heats sufficiently to enable the process. The RMS can be designed for the specific joining task. The multilayer design can be adjusted, which controls the amount of heat that will be released during the reaction (Fig. 2). To achieve higher reaction temperatures, as they are required for hard solders, the amount of heat released during the RMS reaction has to be increased. This is possible by using an RMS stack with a greater overall thickness. If it is impossible to increase the thickness due to design or technical constraints material systems with higher energy densities such as Zr/Si can be used.

Thermoplastics and thermoplastic composite materials can be firmly bonded using the RMS technology. Material systems with lower energy densities such as Ni/Al are used to avoid damage to the thermoplastic matrix.



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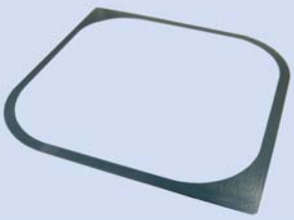
RESULTS

So far this reactive technology has primarily been used for joining applications based on soft solders. Melting hard solders requires temperatures of up to 720 °C, which requires more heat to be released from the RMS. Fraunhofer IWS engineers are using Ni/Al RMS with thicknesses of up to 120 µm. Another approach to increase the released amount of heat is to use novel and highly energetic RMS based on Zr/Si. These deliver up to twice the heat compared to Ni/Al RMS and are especially suitable for hard solder joining applications.

Silver-based hard solders and/or solders based on the eutectic aluminum alloy $AlSi_{10}$ were pre-soldered onto the RMS to join copper, aluminum and steel materials (Fig. 1). Already the first experiments were very successful. The joint strengths ranged from 20 - 40 MPa. An important point is that RMS joining can be done with $AlSi_{10}$ solder without the need for soldering flux, vacuum or inert gas conditions. After the solder is pre-soldered onto the RMS these can be laser cut to specific shapes tailored to the joining application (Fig. 4). The cut shapes solder exactly at the desired location since they provide both the solder and the heat for the soldering process.

Laser structured RMS preform frame for casing construction



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The RMS technology was also further developed for applications with fiber reinforced thermoplastic composite materials. Usually these materials are adhesively bonded, which requires pretreatment and long curing times. Adhesives also suffer from aging. The IWS developed reactive joining technology offers a clear alternative. Almost no pretreatment is required. The joining process is completed in a very short time and ensures a long-term stable bond.

Shear tension tests were performed with RMS bonded sections of non-reinforced polyamide. Once the critical loads passed the material's strength, the polyamide failed in the base material and not in the region where the sections were bonded. It was also demonstrated that the thermoplastic matrix of CFC and GFC materials could be used to firmly bond material sections among themselves and with thermoplastics using RMS technology (Fig. 3). Furthermore, first experiments proved the feasibility of joining thermoplastics with aluminum and steel materials.

Some of the results were developed in a collaborative project "Reactive joining in micro systems technology" (REMTEC, IGF: 17.370 B).

1 *Reactively joined material combinations*

3 *Reactively joined hat profile made of carbon fiber reinforced polyetherimide*

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