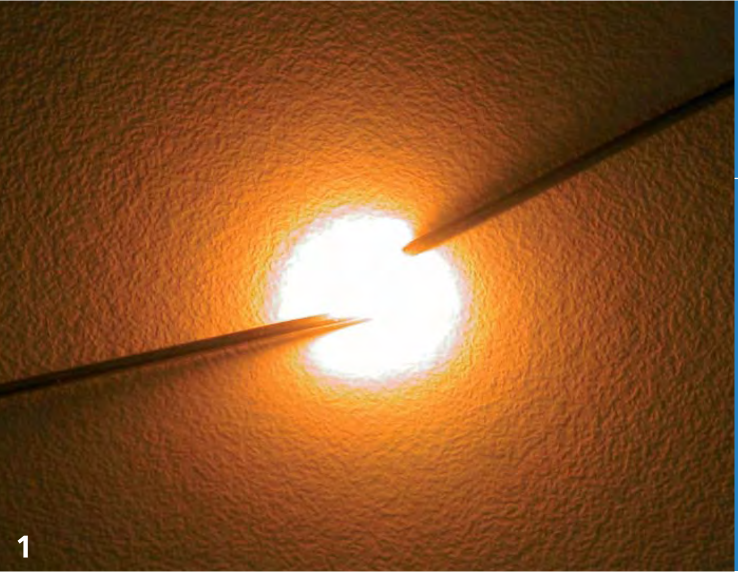

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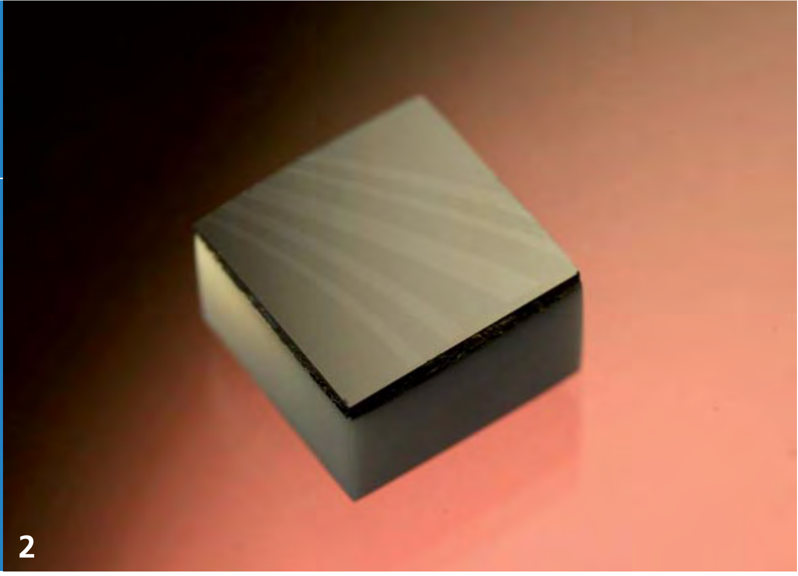

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REACTIVE NANOMETER MULTILAYER SYSTEMS: TAILORED HEAT SOURCES FOR LOW STRAIN JOINING

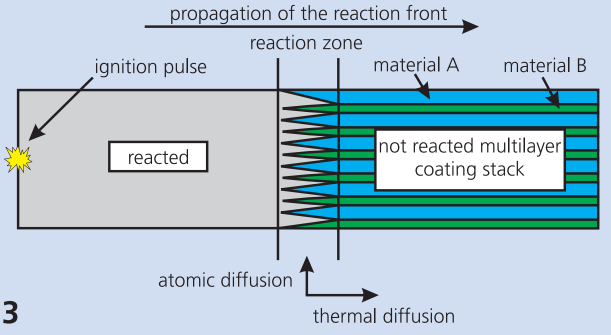
THE TASK

Typical joining processes such as soldering and welding usually require heating of larger regions in the vicinity of the contact zone. This heat input may lead to thermal modification of the material properties or the introduction of stresses in the joint. Such issues could be avoided with a precise heat source that provides heat only to the contact zone of the two material pieces to be joined. If this heat is provided only for a short period of time it could melt the solder without heating the base materials.

OUR SOLUTION

Reactive multilayer systems (RMS) can deliver heat energy precisely and reproducibly to the contact zone. RMSs consist of nanometer multilayers with hundreds or thousands of individual films in their initial state. These films can exothermally react with each other if activation energy is introduced. Then the originally separate films start to atomically diffuse at the interfaces. Given an appropriate material selection, the atomic inter diffusion leads to an exothermal chemical reaction (i.e. 5 Ti + 3 Si → Ti_5Si_3). This reactions progresses along the entire RMS and provides heat energy for melting the solder. By tailoring the coating stack design, it is possible to configure special heat sources, that are adapted to a particular joining task. Reactive multilayer coatings can be produced on parts and also in from of freestanding foils. It is also possible to deposit the solder.

Setup and principle of reactive multilayer systems (RMS)



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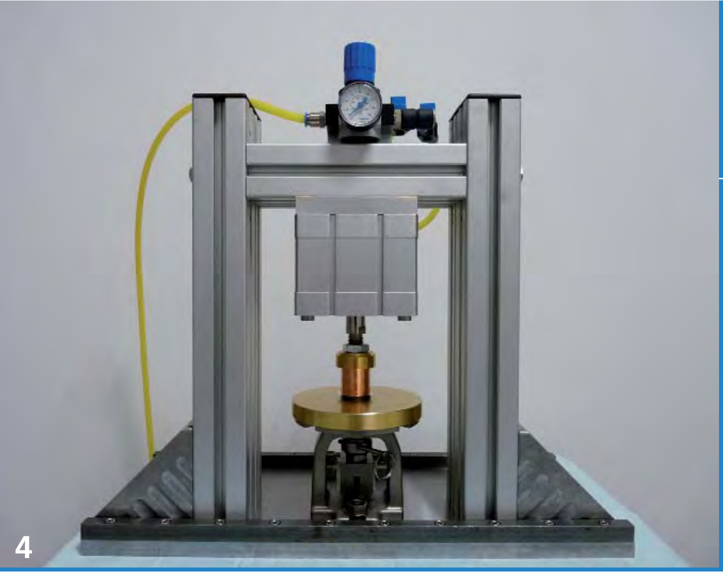
RESULTS

Fraunhofer IWS engineers develop reactive multilayer coatings of various material combinations. Experiments determined the temperature maxima after igniting the RMSs. They ranged from 900 °C to 1400 °C. The released energy was measured using differential thermo analysis (DTA). Typical values are 1.4 to 1.6 kJ g^{-1}. The total released heat directly correlates with the total RMS thickness, which can be between 10 µm and currently 60 µm.

Another important parameter is the velocity of the reaction front, which can also be influence by the detailed design of the RMS. The period thickness of the RMS determines the diffusion length. A smaller period thickness leads to shorter diffusion lengths and faster propagation velocities of the thermal wave and thus to higher reaction velocities.



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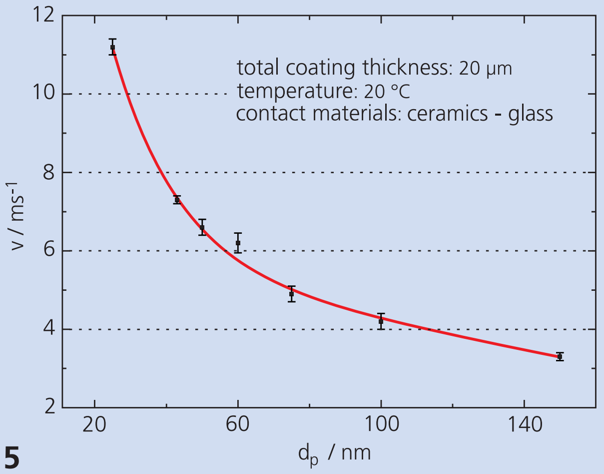
From differential thermal analysis (DTA) it is known that changing the period thickness does not change the energy content of the reactive multilayer coatings. Thus RMS can be exactly tailored to a joining problem.

Reaction front propagation velocity versus reactive multilayer period thickness



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There are numerous advantages when using reactive multilayer coatings. The released heat energy can be precisely portioned because it is possible to calculate the chemical reaction of the RMS due to its well-defined structure. The process times are very short, typically less than a second. There is no significant heating of the components that are being soldered together. The heat is deployed directly in the soldering zone where it briefly acts on the solder. Thus it is possible to join thermodynamically very different materials such as metals and ceramics. Based on the well-defined RMS design the joining process is very reproducible. Compared to adhesive bonding, the joining with reactive multilayer coatings provides the advantage of fabricating electrically and thermally well conductive metallic joints. No outgassing and aging is expected from the joint. The exothermal reaction of the reactive multilayer coating does not require oxygen. This enables special applications such as joining under vacuum conditions, in protective gas or immersed in water.

1 *Electrical ignition of a reactive multilayer system (RMS)*

2 *Joining of a Si wafer with Marcor glass ceramics using reactive multilayer systems*

4 *Setup for pressure ignited joining with reactive multilayer systems*

The following material combinations were successfully tested at IWS: brass - brass, ceramics - silicon, invar - silicon, silicon - silicon and ceramics - stainless steel. In principle it can be assumed that RMS joining works with any material combination.

RMS joining should be considered when conventional joining techniques fail. The special advantages of RMS joining processes benefit the precision joining of microsystems technology, optics and precision mechanics, mechanical and plant engineering and automotive and aircraft technology.

CONTACT

Dipl.-Ing. Georg Dietrich
phone +49 351 83391-3287
georg.dietrich@iws.fraunhofer.de