HERMETIC JOINING BY MEANS OF REACTIVE SYSTEMS

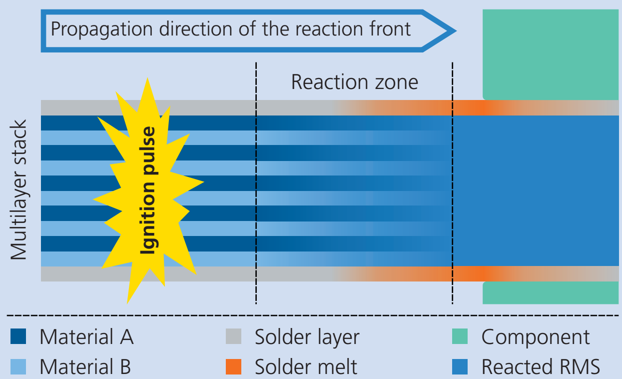
Fraunhofer IWS scientists have successfully engineered reactive multilayer systems (RMS) that are not only used as an innovative joining technology in mechanical engineering, but also for microsystems engineering. These RMS systems generate a heat source inside the joining zone and provide ultra-short process times, which enables to solder even difficult-to-join materials very quickly, without heating the surrounding area. Hermetic joining is a real challenge.

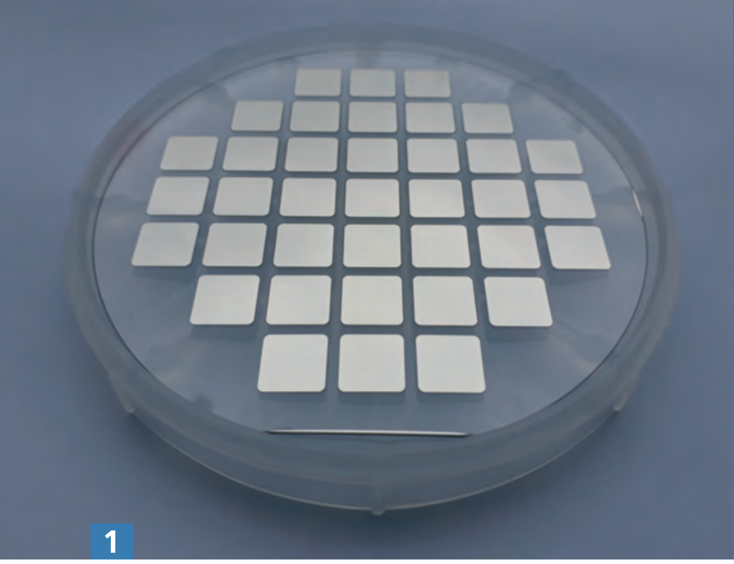
In microsystems engineering, joining processes not only have to build up a permanent bond between the components of an assembly, but also generally perform additional functions. In particular, they provide electric contacts, thermal bridges, and hermetically sealed cavities. Wafer bonding techniques, such as anodic fusion, glass frit, eutectic, or thermocompression bonding, demand high process temperatures. Using different materials with varying thermal expansion coefficients result in stress in the joining zone and high thermal load on the parts being joined. We can avoid the abovementioned disadvantages at increased process temperatures if the required temperatures are limited just to the joining position, while the parts themselves are protected. This is possible thanks to the short process times using reactive multilayer systems.

Joining strength values of maximal 30 Megapascal feasible

RMS consist of hundreds of periodically structured individual layers of two materials that can react to one another. Single layer thickness amounts to only a few nanometers. The RMS thickness ranges from 5 to 120 micrometers and can be brought into the joining zone – in the form of a freestanding film or as an integrated direct coating of the joining partners. The subsequent introduction of activation energy into the RMS results in a chemical reaction: In this process, thermal energy is set free, which can melt the parent materials or solders and thus create a joint in just fractions of seconds. The reactive joining technique makes it possible to fabricate soldered and thermoplastic joints – not only at the part, but also at the chip and wafer levels. In these joints, the researchers can achieve 30 Megapascal strength values. The joints are not only characterized by minimal stress in the joining zone, but are also highly thermally and electrically conductive, as well as extraordinarily resistant to warm, damp environments. The business unit team at Fraunhofer IWS Dresden has succeeded in demonstrating the potential of the reactive joining technology. Continuous refinement of the technology is currently opening up additional fields of application. Both projects on brazing and hermetic joining using RMS are being focussed.

RMS set-up and principle





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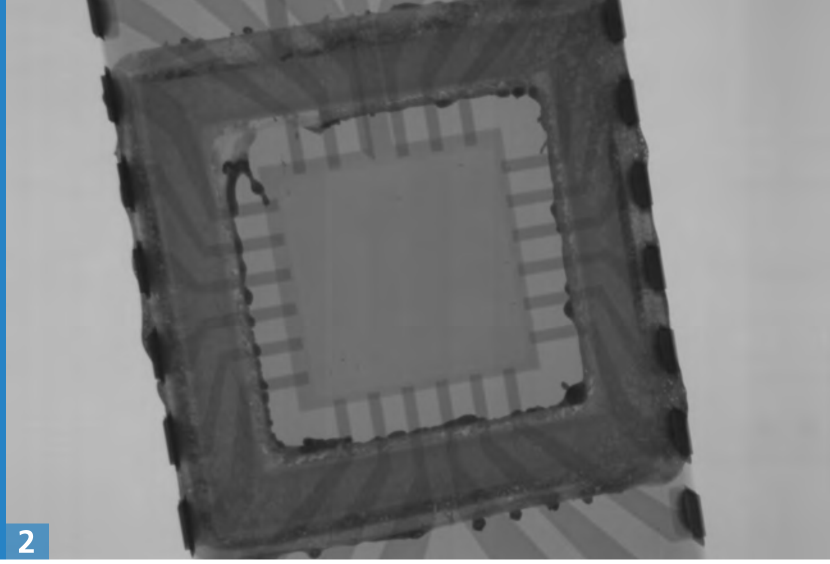

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Thermal energy storage releases energy in joining zones with time delay

During the reaction of nickel-aluminum RMS, which is most often used and is available at low cost, volume is reduced by 12.4 percent by a shrinking process. Cracks, which are a great challenge for hermetic joining, are formed subsequently in the joining zone. In conventional RMS, these cracks are not filled with solder or parent material and thus act as channels between the cavity and the environment. Current approaches to solve this problem seek to adapt the joining process technology and the RMS design in order to guarantee that the cracks are filled during the reaction. To do this, the engineers first have to bring more solder material and keep it in fusion in the joining zone as long as possible to support the flow processes. The IWS scientists achieved this by installing thermal energy storage deposits in the RMS. These deposits intermediately store the energy that is set free suddenly by the RMS reaction and release it into the joining zone more slowly. It is appropriate to use tin for thermal energy storage, because it is not part of the reaction process and functions as additional solder supplier directly in the joining zone. It has proved particularly successful to bring in 10 micrometer-thick tin deposits in a 40 micrometer-thick nickel-aluminum RMS: in this way, the maximal temperature in the joining zone is reliably reduced by up to 400 Kelvin, and the solder remains molten four times longer.

Fewer cracks and reliable filling by solder

As shown by joining tests, the tin deposits within the nickel-aluminum RMS assure hermetic joining by using tin-based solders. It is possible to reduce the number of cracks in the joining zone, on the one hand. On the other hand, we can reliably fill the cracks occurring with the solder material. Due to the energy stored, nickel-aluminum RMS with tin deposits can only use tin-based solders. Consequently, current projects deal with using high-energy zirconium-silicon RMS for hermetic joining in microsystems engineering. These systems provide several advantages; they can set free 100 percent more energy than nickel-aluminum systems and shrink substantially less than the latter. Furthermore, they can be applied for soldering and brazing. Thanks to the higher energy release, layers just a few micrometers thick are sufficient for joining to prevent crack formation and guarantee a transfer to the wafer level. Initial investigations of the use of 25 micrometer thick, freestanding zirconium-silicon RMS show good crack filling and hermetic dense joining with tin-based solders. The team achieved strength values of more than 100 Megapascal in experiments with silver-based brazings.

1 *Current projects at the Fraunhofer IWS focus on transferring the reactive joining technology into microsystems engineering. The researchers demonstrated the structured deposition of zirconium-silicon RMS on wafer level.*

2 *Hermetic joining of sensor housings applying RMS was verified at Fraunhofer IWS. The joining zones of the hermetically sealed encapsulation of the sensor housing do not show any cracks in the X-ray.*

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