Low-temperature Reactive Nanofoil Die-attach Bonding for MEMS

G. Spinola Durante, R. Jose James, K. Krasnopolski, S. Mohrdiek, U. Lang •

This new furnace-free [1] sealing technology enables a MEMS die-attach solder process onto a generic substrate material. As opposed to laser bonding, this additional low-temperature approach is viable also for non-transparent MEMS components and substrates. In this paper a technology demonstrator is shown with silicon chips mounted on coated stainless steel, achieving shear strength values above 10 MPa. Direct bonding on stainless steel and on other hard-to-bond materials is also evaluated.

MEMS components have reached a very high penetration in the consumer market, largely covered by bulky sensor solutions. Miniaturized and robust solutions for MEMS-based sensors is in growing demand to address higher performance requirements specifically for use in harsh environments. These sensors have usually critical parts and the housing is made of stainless-steel, since this material has proven to survive many chemically aggressive environments. "Packaging for harsh environments" is considered an enabling technology being part of the global "Internet of Things" (IoT) trend.

The Nanofoil technology fits quite well to this requirement of industrial sensors to keep stainless steel as a base manufacturing material. The Nanofoil is a commercially available metal based on reactive foils that enables the die-attach soldering of a silicon chip onto a small or even bulky stainless steel part. The assembly of a MEMS chip cannot be done directly onto stainless steel substrates due to its surface inertness, but requires a solderable coating on both sides of the solder joint. In Figure 1 are shown the assembled chip on coated stainless steel and the different solder & Nanofoil preforms. The stainless substrate and the silicon chip are also shown.

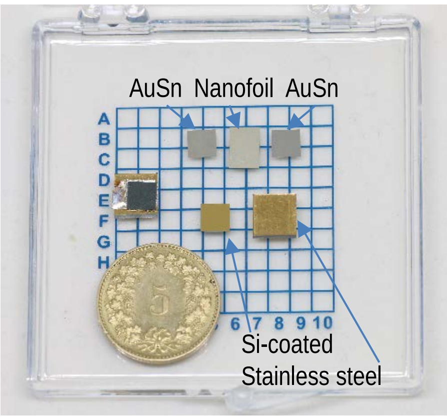

Figure 1: Solder and Nanofoil preforms are shown on the top. The gold-coated chip and stainless steel are also shown below. The mounted chip is shown on the left side above the coin.

The main advantage of the Nanofoil-based reflow process is the inherently low temperature and therefore low stress at the bulk level of components. The heat generated by the triggered exothermic process with the Nanofoil will only melt the thin solder preforms layers. Moreover, the process does not need a dedicated reflow oven like in the case for soldering and is therefore furnace-free.

This coating strategy can also be implemented with different silicon to generic substrate combinations and with any solder having melting point <300°C. The solder will melt when the Nanofoil is ignited. This bonding configuration can be used with non-transparent substrates, as opposed to low-temperature laser bonding, provided there is access to ignite the Nanofoil.

A key to the success of this technology is the customization towards different solder melting points, different chip dimensions, and substrate sizes and materials. CSEM has developed a solderable coating strategy consistent with the AuSn solder choice, exploiting results from previous projects. Both solder and Nanofoil are cut into preform shape to ease the assembly procedure, providing the exact match to the solderable metallization layout (Figure 2). A cutting process has been developed which does not trigger the exothermic reaction using picosecond laser micromachining done in-house at CSEM.

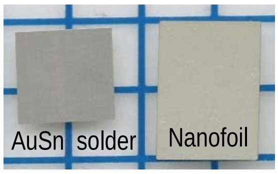

Figure 2: AuSn solder preform 4×4 mm², Nanofoil preform 4×6 mm².

The Nanofoil preform (Figure 2 on the right side) is larger than the solder preform size to enable the ignition. This protrusion could be made much smaller or even laser-cut to ensure a proper clean bonding edge. Laser cutting after ignition is also an option.

The Nanofoil-based solder joints have been tested for shearforce, according to tests performed at the HSLU* Laboratories[1]. The resulting shear stress according to standardized measurements [2] are in the order of 10-15 MPa for silicon chips in the range of 4-16 mm² of bonded surface. While these values are lower compared to typical solder values of 30-50 MPa and more similar to adhesive bonding shear values, the throughput of the Nanofoil bonding is quite high. Reflow process usually take between 10-30 minutes depending on solder melting point and component size. Nanofoil bonding in comparison takes around 1 ms for 1 mm-scale parts.

There is a push for technology enabling direct integration of sensors into high-end sensing systems. Implementation of Nanofoil technology to a production environment requires activation of hard-to-bond substrates in a viable and cost-effective manner. This strategic research is ongoing at CSEM with the collaboration of HSLU, to enable direct soldering on stainless steel and highly corrosion resistant alloys, targeting highly demanding industrial MEMS-based applications.

• Hochschule Luzern Technik & Architektur (HSLU)

[1] G. Spinola Durante, R. Jose James, K. Krasnopolski, "Furnace-free micro-joining with reactive Nanofoils", CSEM Scientific and Technical Report (2015), 34.

[2] MIL-STD-883 method 2019.9 Die shear strength.