Nanofoil Bonding of Laser Micromachined Components

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This paper describes a bonding technology using Nanofoils, which enables furnace-free, low-temperature soldering of transparent or non-transparent laser micro-machined components, without reaching the bonding temperatures for solder reflow processes. Nanofoils can be patterned with ps-laser into exact preform shapes. An example is given of a silicon gear mounted onto gold-coated stainless steel with a shear force above 10 MPa.

Manufacturing of small and complex laser micro-machined parts in silicon with high quality is a complex task which is becoming more and more popular due to the availability of laser equipment and corresponding processing software (Figure 1) looking back to at least 10 years developments in the field.

Figure 1: ps-Laser facility in Center Alpnach.

Assembly of a laser-machined MEMS with high precision onto a substrate is a complementary technology to laser manufacturing of micro-machined parts. In this respect both bonding process and pick & place automation strategy play a significant role. The Nanofoil technology enables to be independent of the solder material choice and of its melting temperature, and moreover, is a furnace-free bonding process [1]. It requires for its ignition a very small access point where an electric current or a laser beam can start the fast exothermic reaction. The Nanofoil bonding is much faster than any soldering or adhesive snap-cure process, since no heating ramp is required and it takes only a few milliseconds to perform the assembly.

The advantage of using Nanofoils for bonding are manifold: a significant advantage comes in view of the temperature budget since the Nanofoil reaction is very fast, i.e. below 1 ms for a 1 mm size part. Therefore the parts do not overheat and very little stress is embedded into the solder joint. This enables to provide a bond close to surfaces which are sensitive to temperature and otherwise cannot withstand more than e.g. 150°C. The Nanofoil is also adapted for non-transparent components [2] or substrates if compared to low-temperature laser bonding, providing a significant improvement. The solder schematic including additional preforms and coatings is shown in Figure 2. The pre-forms and are part of the solder joint, being placed both above and below the Nanofoil preform itself to achieve the mechanical interconnection.

An example is hereafter discussed to underline the key aspects of the assembly process, according to the bonding scheme in Figure 2. The demonstrator is made by laser micro-machining of a gold-coated silicon gear and a Nanofoil preform, laser-cut into the exact preform shape (Figure 3).

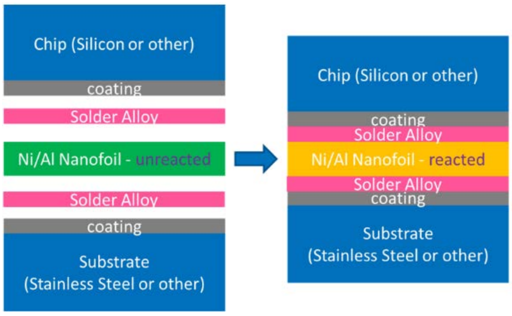

Figure 2: Nanofoil-based solder joint configuration.

Figure 3: Laser micro-machining of coated silicon wafer and of Nanofoil metal sheet into small shape preforms.

The final assembly can be seen in Figure 4a where the small Nanofoil foil is protruding where the exothermic process is triggered. This enables the ignition by electrical contact with a 9V battery electrodes directly shorted onto this foil tip. The laser-milled Nanofoil is shown zoomed in Figure 4b and the small hole for an eventual pin or gear axis insertion can be exactly manufactured without triggering any exothermic reaction. The joint interconnection was tested for shear force and yielded average shear values above 10 MPa [3].

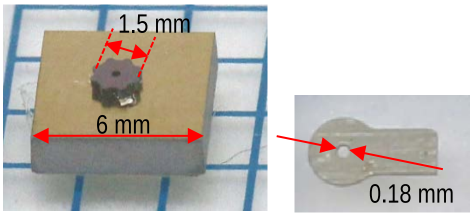

Figure 4: a) Hermetically sealed glass on silicon package; b) Nanofoil laser micro-machined showing a small feature of 180 um diameter.

CSEM is further investigating the Nanofoil technology to achieve cost effective bonding solutions, taking advantage of the flexibility and speed of the bonding process. Process adaptations are required to use the Nanofoil approach to customer specific bonding applications, respectively substrate materials, ensuring optimal coating and assembly strategy with higher shear test values, if compared to standard adhesive solutions.

1 G. Spinola Durante, *et al.*, "Furnace-free micro-joining with reactive Nanofoils", CSEM Scientific and Technical Report (2015), 34.

[2] G. Spinola Durante, *et al.*, "Low-temperature reactive NanoFoil die-attach bonding for MEMS ", in this report, 30.

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