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Prototyping of Hybrid Circuits for the CMS Phase Two Outer Tracker Upgrade at the HL-LHC

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High Density Interconnect hybrids are being developed for the CMS Tracker Phase Two Upgrade for the HL-LHC. These hybrids are flexible circuits with flip-chips, passives and connectors laminated to carbon fibre composite stiffeners. The wirebonding of sensors and the soldering requirements for these components requires an almost perfectly flat surface. A lamination process is proposed, focused on the compatibility with lead-free reflow process. The stack-up of the hybrid was optimized to balance the forces induced by the Coefficient of Thermal Expansion (CTE) differences in the assembly. The proposed lamination process was applied to the 8CBC3 hybrid circuits.

Summary

Components for the Compact Muon Solenoid (CMS) Tracker Phase Two Upgrade for the High Luminosity Large Hadron Collider (HL-LHC) are currently under development. The upgraded Tracker is based on two main types of modules, the strip-strip (2S) and the pixel-strip (PS). The modules contain two parallel sensors and two front-end hybrids interconnected with different service hybrids. These modules require state of the art HDI front-end hybrids hosting the fine pitch flip-chip front-end ASICs and connectors.

The modules will be operated at low temperature: a liquid CO2 cooling circuit, integrated in the supporting structures of the modules, will bring the temperature down to -35 °C. The active components of a 2S front-end hybrid circuit will dissipate up to 1.5 W and an effective cooling path is required. However, this cooling path must contribute as little as possible to the equivalent radiation length of the module. A highly thermally conductive carbon fibre stiffener was selected for this purpose. In addition to its good thermal properties, the carbon fibre material has also a CTE value close to zero. This is desired for a good pitch matching of the hybrid with the silicon sensors at the level of the wirebond interconnecting pads. Moreoverit closely matches the CTE of the module support structure that is made also of a low CTE (4 ppm/°C) aluminium-carbon fibre composite. However, a major thermal mismatch remains with the flexible circuit itself that has a CTE of 16 to 18 ppm/°C.

The hybrid stack-up is also exposed to at least one lead-free reflow soldering cycle for the assembly of dies, passives and connectors. The adhesives used for the gluing of the flexible circuit to the carbon fibre stiffener must remain compatible with this process, up to at least 240 °C, avoiding delamination. Several adhesives were evaluated. The use of rigid adhesives prevents the risk of delamination but results in a bow of the hybrid once it is cooled down. A thermal compensator, added on the other side of the stiffener, with an adequate material and a tuned thickness eliminates the bow for all the temperature range, enabling soldering on a flat hybrid and also minimising the mechanical stress induced by the hybrid once it is glued on its module and cooled down.

Furthermore, the carbon fibre stiffener, which is nearly fully enclosed between the hybrid circuit and its compensator, must be free of any outgassing during the reflow. A post-cure process, combined with sand scrubbing and strict drying just before the gluing provides a suitable lamination process without outgassing.

8CBC3 hybrid circuits were laminated with hard adhesives to post-cured and dried carbon fibre stiffeners and to CTE compensators. The resulting hybrid configuration outperformed all the others in terms of flatness and stability. It remains flat during the reflow process and at low temperatures. However, secondary effects resulting from the compressive stress along the stiffener need to be considered for the soldering process. All the lamination issues and the solution adopted for the CMS hybrids will be presented.

Primary authors: BLANCHOT, Georges (CERN); RASEVIC, Nikola

Co-authors: GADEK, Tomasz (ETH Zurich (CH)); HONMA, Alan (Brown University (US)); KOVACS, Mark Istvan (CERN); LA ROSA, Alessandro (CERN); PORRET, David (CERN); ZOGRAFOS, Angelos (National Technical Univ. of Athens (GR)); BARON, Sophie (CERN); KULIS, Szymon (CERN)

Presenters: BLANCHOT, Georges (CERN); RASEVIC, Nikola

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