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# Reliability test results of the interconnect structures of the front-end hybrids for the CMS Phase-2 Tracker Upgrade

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High Density Interconnect (HDI) hybrids are being developed for the CMS Tracker Phase Two Upgrade for the HL-LHC. These hybrids are carbon fibre reinforced flexible circuits with flip-chips, passives and connectors. Their operational lifetime is determined by the reliability of the solder joints of the surface mount components (flip-chips, passives, connectors) and the copper traces and vias in the hybrid substrate. Specific test coupons were exposed to accelerated thermal stress cycles, aiming to test the reliability of the solder joints, vias and traces. Results from different suppliers and technologies will be evaluated and compared.

## 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 2S modules contain two parallel strip sensors of 10 × 10 cm2 and two front-end hybrids interconnected with a service hybrid. The PS modules contain a strip sensor and a macro pixelated strip sensor of 5 × 10 cm2 and two front-end hybrids interconnected with a power and a data service hybrid. These modules require state of the art HDI front-end hybrids hosting the fine pitch flip-chip front-end ASICs and connectors.

The target lifetime of the modules is approximately 15 years and all the components must operate correctly during this period. Therefore, the reliability of the front-end hybrids is a key aspect for the correct operation of the modules. Failures might affect bump bonds of the front-end ASICs, traces and vias of the flexible circuit, solder joints of passives and connector contacts.

Detailed literature exists about the reliability of bump bonded components and standard printed circuits. However, limited or no information is available about the reliability of the bump bonding of large flip-chip ASICs and carbon fibre reinforced HDI flex circuits. Test coupons were designed with daisy chain flip-chips, via daisy chain and fine line test structures. They were manufactured on the hybrid circuit production panels with three different suppliers. Three sets of coupons were assembled with eutectic solder alloy and one set was assembled using lead-free solder alloy. Additional test coupons were designed to qualify the reliability of the connectors proposed for the data and power interconnection. All the test coupons are mounted on carbon-fibre stiffeners similarly to the front-end hybrids construction. Some of the coupons were irradiated to investigate the effect of radiation damage on the reliability of the structures.

The test coupons were exposed to more than 1000 thermal cycles from -35℃ to 65℃ representing the environment in the CMS Tracker. The condition of the test structures were monitored actively through the monitoring of their resistance. In addition, via and flip-chip structures were monitored with a resistance transient counter in order to record fast resistance transients.

The proceeding will describe the design of the test coupons, their manufacturing challenges and the test setup developed for the reliability tests. The evaluation method and criteria will be explained together with the interpretation of the results. The reliability of the irradiated and non-irradiated samples will be compared. The reliability of the lead-free bump bonds will be compared to the eutectic lead-tin bump bonds. The expected lifetime of the assemblies will be estimated based on the test results.

**Author:** KOVACS, Mark Istvan (CERN)

**Co-authors:** ALLONGUE, Bruno (CERN); ANDRE, Florian (Telecom Physique Strasbourg (FR)); BLANCHOT, Georges (CERN); GAJANEC, Rafael (Slovak Technical University (SK)); GADEK, Tomasz (CERN)

**Presenter:** KOVACS, Mark Istvan (CERN)

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