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Manufacturing Experience and Test Results of the PS Prototype Flexible Hybrid Circuit for the CMS Tracker Upgrade

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The CMS Tracker Phase Two Upgrade for HL-LHC requires High Density Interconnect (HDI) flexible hybrid circuits to build modules with low mass and high granularity. The hybrids are carbon fibre reinforced flexible circuits with flip-chips and passives. Three different manufacturers produced prototype hybrids for the Pixel-Strip type modules. The first part of the presentation will focus on the design challenges of this state of the art circuit. Afterwards, the difficulties and experience related to the circuit manufacturing and assembly are presented. The description of quality inspection methods with comprehensive test results will lead to the conclusion.

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. Modern HDI circuits are essential to address the requirements imposed by HL-LHC. The upgraded CMS Tracker will use two main types of modules: the Pixel-Strip (PS) modules for the inner tracker and the Strip-Strip (2S) modules for the outer tracker. Both types of modules are based on flexible hybrid circuits folded and wire-bonded to the strip sensors and the Macro Pixel Asics (MPA). The front-end hybrid circuits host the binary readout ASICs and provide the interconnect to the sensors and other system elements.

A PS front-end hybrid circuit prototype was designed to exercise and test the flip-chip soldering technology, carbon fibre stiffener lamination, assembly procedures, production testing and module construction. The first part of the presentation will focus on the design practices, such as: HDI circuit design, design for testability and design for producibility. The circuit integration into the module and the tracker will be described.

Three manufacturer consortia produced the PS prototype hybrid circuits using different manufacturing processes and different assembly routines. Each manufacturer had various difficulties during the production (insufficient surface flatness, open and short circuits, thermal expansion coefficient difference). We will present the cause of difficulties and explain the available solutions in the design and production phases.

The quality of the produced hybrid circuits was inspected by X-ray, visual microscopy and cross section analysis. The electrical functionality was tested with a narrow pitch needle probe tester or a test connector interconnecting the hybrid circuits to the test system. A test interface printed circuit board (PCB) was designed to aid the measurements and host the needle probe tester and the test connectors. The feasibility of production testing was studied based on the test system designed for the PS hybrid circuit prototypes. The properties of the test interfaces (contact resistance, frequency response, cross talk between contacts, high-speed performance) were characterized in room temperature and in the cold. In addition, the hybrid electrical properties were measured (impedance characterization, via resistance). The reliability of the flip-chip bonding and the via structures were tested. We will present the various test results and show their relationship with the applied manufacturing and design techniques.

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