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Nuclear Instruments and Methods in Physics Research A 551 (2005) 285–289

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Development and large-scale production of ceramic PCBs for the preshower detector of the CMS experiment

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Received 25 May 2005; received in revised form 24 June 2005; accepted 25 June 2005
Available online 20 July 2005

Abstract

Fabrication of printed circuit boards (PCBs) in high-radiation areas requires new technologies. The CMS detector in the CERN Large Hadron Collider will have portions in high-radiation environment. The preshower detector in front of the endcap electromagnetic calorimeter is such an area. During the past several years, the emphasis has been put on the research and development of individual components of the preshower detector. Several prototypes of PCBs were manufactured on ceramic substrates. The final prototype was a high-quality product with the ceramic board meeting all specifications, including the adherence of metallic pastes, the resistivity of the metallic lines and the precision of the laser cutting. The Yerevan Physics Institute in collaboration with the MARS Factory, Rubin L. Tech. JSC and Yerevan Telecommunication Research Institute made 4.500 units of the ceramics PCBs and are now being incorporated in the preshower detector. This article describes in detail the R&D for the technology of thick film printing on a ceramic substrate with different pastes and the precise cutting of ceramic plates by a laser.

PACS: 68.55.−a; 81.05.Mh; 85.40.Sz

Keywords: PCB; Ceramic; Thick film; Metallic paste; Silk-screen printing; Laser cutting

1. Introduction

The preshower detector is a part of the endcap electromagnetic calorimeter of the CMS detector [1]. It consists of 4300 identical modules, each

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.06.061

containing a 1.9 mm-pitch silicon strip sensors of $63 \times 63\,\text{mm}^2$ [2,3]. Fig. 1 shows the layout of such a module. The silicon sensors and the electronic hybrid units, including the front-end readout electronics, are mounted on a ceramic printed circuit board (PCB) [4] that provides the reverse bias voltage to the back plane of the sensor. The ceramic is composed of alumina (Al_2O_3) and has been selected primarily because of its excellent thermal conductivity and its flatness. The silicon sensor is glued to the ceramic and the heat generated in the sensor is removed through the substrate. The dimensions of the ceramic plates are $93.0^{+0}_{-0.2}$ mm in the direction parallel to the strips; $62.5^{+0}_{-0.2}$ mm in the perpendicular direction, and 0.63 ± 0.05 mm in thickness. Section 2 describes the thick film technology developed and used to deposit metallic pastes on the ceramic substrate by a silk-screen printing method, and the subsequent baking at high temperature. Section 3 describes the technology of the initial unsatisfactory mechanical cutting and drilling of the ceramic plates and ultimately using the laser for a more accurate cutting and drilling. Finally, the mass production is discussed in Section 4.

2. The development of thick film technology for ceramic PCBs using silk printing of metallic pastes

During the past several years, physicists at Yerevan Physics Institute (YerPhI), in collaboration with personnel at MARS Factory, have developed thick film PCB technology with a silk-screen printing method using various metallic (Au, Ag, Al, Au/Pt) and dielectric pastes, followed by baking (firing) at high temperature (650–900 °C). The high-temperature firing took place in a belt furnace (Simon-Carves Ltd., England) located in the MARS Factory. The furnace was operated at five temperature zones, with the maximum temperature at 1050 °C. The belt width is 230 mm and the belt speed can be varied between 76 and 457 mm/min. For the firing process to be successful, the critical parameters are the furnace airflow volume and the firing temperature profile. The firing process is performed in ambient air. A good airflow (oxidizing atmosphere) during heating process is needed to guarantee the burnout of the organic materials of the metallic paste. The firing profile is controlled by the belt speed. The typical total time of firing is about 18 min to heat from room temperature to the peak temperature, about 10 min at peak temperature, followed by 18 min cooling to room temperature for a total of 45 min. The optimum time for staying at peak temperature was found to be 10 min.

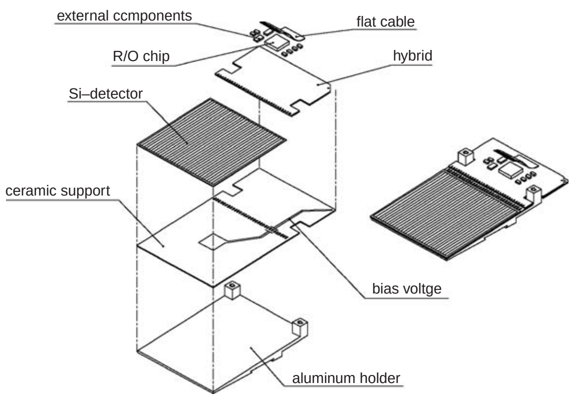

Fig. 1. Endcap preshower detector module.

2.1. The choice of the pastes and technology of their deposition on the alumina substrate

The choice of the paste depends on the application (either conductor or dielectric in multilayer systems). For this project, we used pastes from two manufacturers: DuPont Photomasks, Inc. and Electro-Science Laboratories, Inc. In the initial design of the preshower module, the silicon sensor was glued and wire-bonded to pads located on the upper side of the ceramic. The bias voltage was provided on the back plane of the silicon sensor via a special wire. The under side of the ceramic contained a large ground plane, insulated from the mechanical support and connected to the electronics by soldering. A three layer ceramic PCB was manufactured (see Fig. 2(a)) using two different metallic pastes (Au, Ag/Pt) and one dielectric, all fired at high temperature (850–900 °C). The bonding layer used a gold paste (ESL 8881B), the ground layer a silver paste (DuPont QS171) and the insulation layer a dielectric paste (DuPont QM42). These pastes are