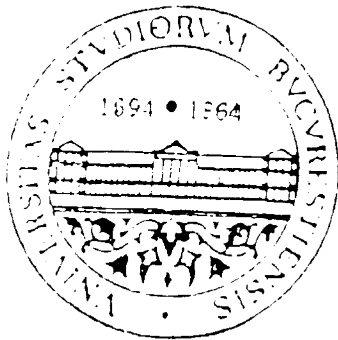

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MANUFACTURING PROCESS OF A SILICON HALF-LADDER MICROVERTEX DETECTOR

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Abstract

The Silicon Microstrip Detector (SMD) has been installed at the inner most position of the central tracker of the Luminosity 3 (L3) experiment at the CERN LEP storage ring (Large Electron Positron). The SMD (see figure 1) allows a two-dimensional measurement of charged particle tracks over the polar angle region $22° < \theta < 158°$ and over the full azimuthal region, improving the L3 impact parameter resolution, momentum and z coordinate measurements [1].

In this paper, after a brief review of the SMD general design characteristics we are presenting the main steps of the manufacturing process of one half ladder - the basic functional unit of the SMD.

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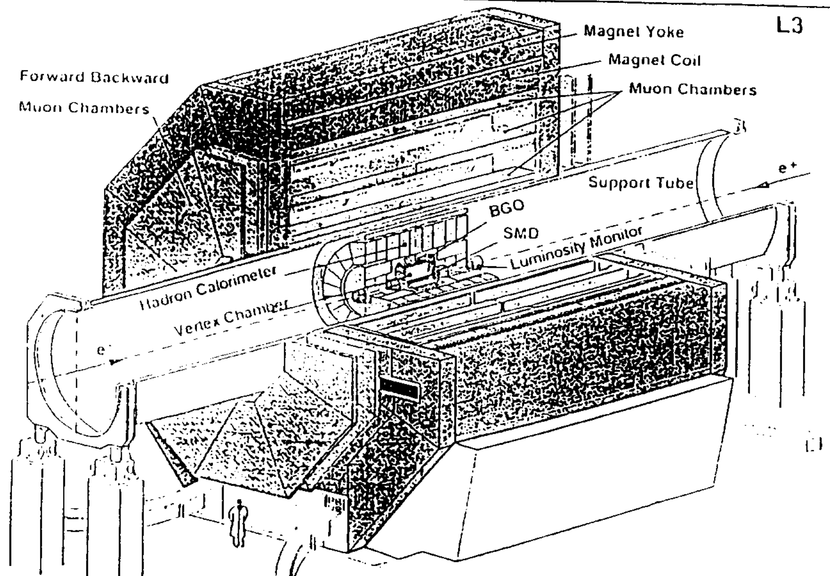

Figure 1.

1. General Design Features

The reduced size of LEP vacuum pipe (from 8.0cm to 5.5cm) gave the L3 the possibility to upgrade its central tracking capability. Given the constraints on space between the smaller beam pipe and the outer TEC detector (Time Expansion Chamber), the SMD design consists of two cylindrical layers with a radius of 6cm and 8cm, formed from 11 respectively 13 ladders (see figure 2)

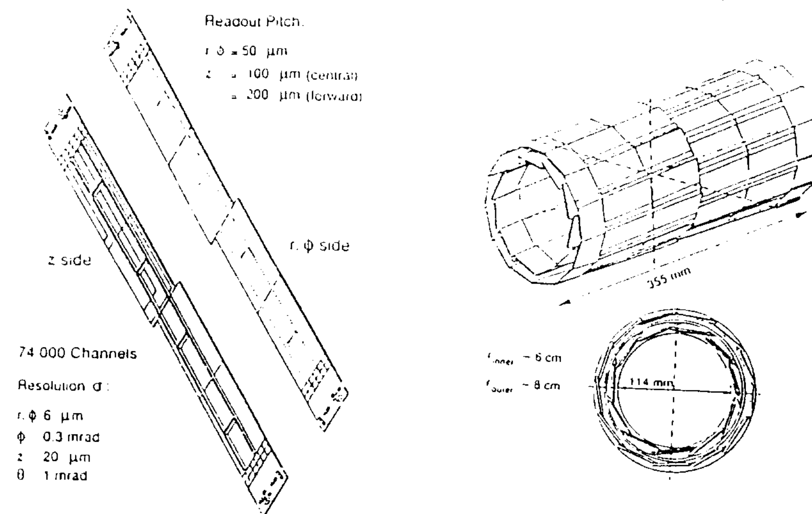

Figure 2

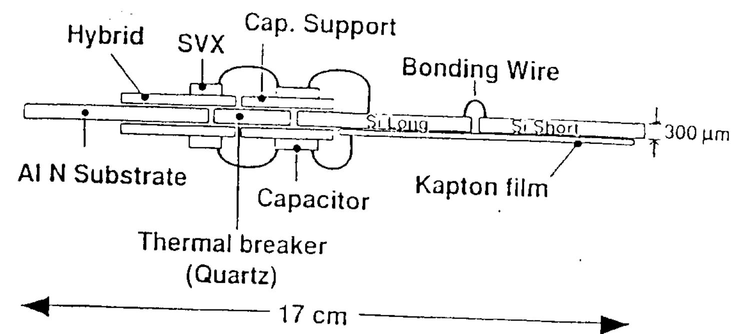

Figure 3

Each ladder contains four rectangular double-sided n-type high resistivity silicon sensors, 300μm thick, of $7 \times 4 cm^2$ each. The p-type strips on the junction side of the sensor are parallel to the beam, allowing the R-φ coordinate measurement, while the n-type strips on the ohmic side are orthogonal, allowing the Z coordinate measurement. Each of the 24 ladders is built from two

separate "half ladders". Each half ladder is, in turn, built from two electrically and mechanically joined double-sided silicon sensors, a special low mass kapton router cable glued to the Z side of the sensor pair and two front end readout electronics (see figure 3).

Each technological operation involved in the half ladders' manufacturing process requires careful monitoring of multiple geometrical parameters, at micron level, as well as a large number of microbonds for electrical interconnection. The following section describes the assembling operations' sequences for a half ladder manufacturing process.

2. Assembling Process Sequences

The half ladder is the basic functional unit for the SMD system. Each half ladder is manufactured using the following subunits: 1) a double-sided silicon sensors pair with its kapton router cable; 2) two front end readout electronics; 3) an aluminium nitride and a quartz thermal breaker plates for structural support.

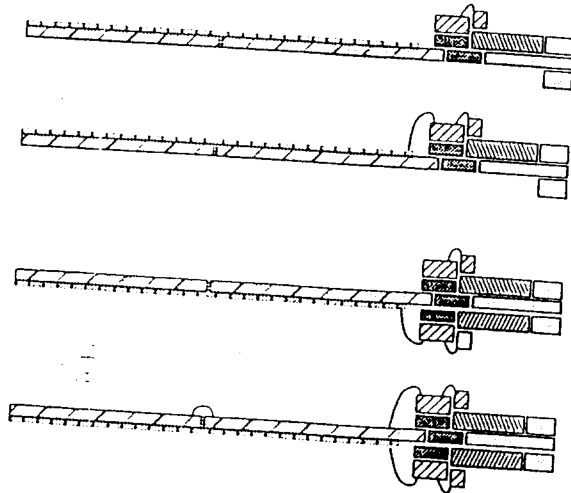

Figure 4.

The silicon pair subunit is assembled using the following procedure:

- Alignment and gluing edge to edge of two silicon sensors;
- Kapton router cable gluing to previous done silicon sensor pair;
- Wire bonding of silicon strips pads to kapton cable pads;

For assembling a readout electronic subunit the following steps must be done:

- Isolation capacitors chips alignment and gluing to a quartz support;
- Alignment and gluing of the previous done capacitor module to the hybrid module;
- Wire bonding of capacitors pads to IC amplifiers pads.

All the above operations, as well as the following which will be presented are monitored in dedicated data sheets.

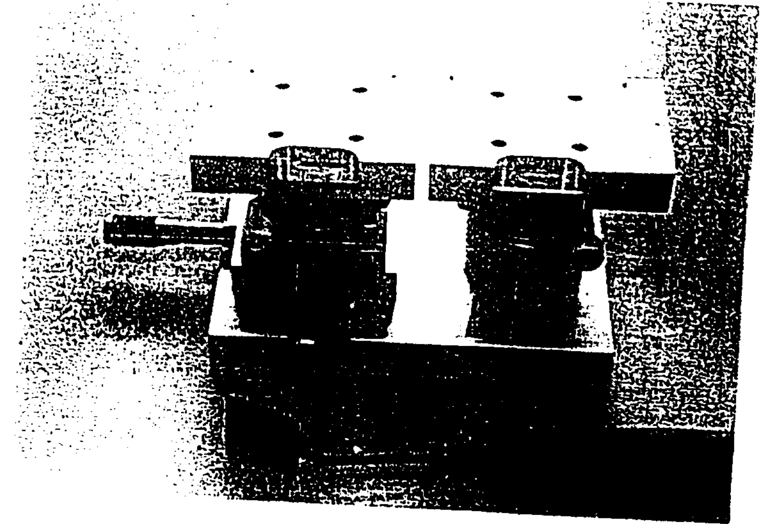

Figure 5.

Figure 4 details the assembling steps from the subunit level to the completed half ladder, as follows:

- Silicon pair subunit (with kapton side up), quartz thermal breaker and aluminium nitride plates alignment and gluing with the electronic subunit. This operation is called "first side gluing".
- Wire bonding of kapton cable pads to capacitor pads;
- Reversing upside down the whole structure using appropriate jigs;
- Alignment and gluing of the second electronic subunit (second side gluing);
- Wire bonding between silicon strips pads and capacitors pads;
- Wire bonding between the two silicon strips pads.

The precise alignment and gluing of the various elements are done under microscope using a coordinate measuring machine [2]. The positional accuracy of the various elements of the half ladder is typically better than 10μm.

Two glues are used to construct the SMD ladders. Araldite AW106 (hardener HV953U) is used for most of the structural joints and for all applications involved with the microbonding [3]. A good thermal conducting glue, Stycast2850FT (hardener 24LV) is used to join the pieces of aluminium nitride to readout electronics subunits. This glue ensures a good thermal path between readout electronics and the cooling provided on the support structure. The quartz support of the capacitor chips and the quartz piece between the aluminium nitride support plate and the silicon sensor thermally isolate the silicon sensors from the rest of the ladder. Particular care was taken during the gluing operations to control the thickness and the uniformity, both of which are vital for the microbonding and for achieving the final precision of the half ladder dimensions. This was accomplished due to the high precision of the assembling jigs (a planarity tolerance <5μm) and the use of a pressurised automatic glue dispensing system [4].

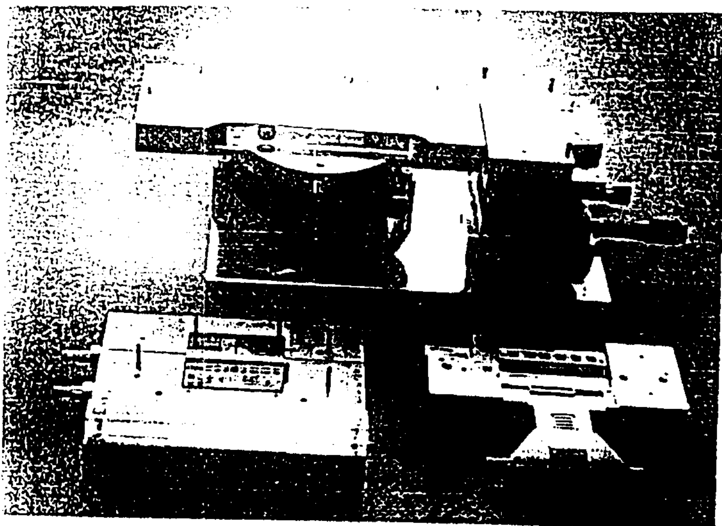

Figure 6.

Figure 5 shows the jig used to edge glue the two silicon sensors of the half ladder and figure 6 shows the jigs used for the first side gluing. The latter includes a positioning jig for the readout electronic assembling (foreground left), a readout electronic transfer jig (foreground right) and the half ladder first side gluing jig (background centre). The first jig position the electronic subunit with respect to the transfer jig. After application of the glue, the electronic subunit is placed, using the transfer jig, on the half ladder gluing jig, thus joining together the sensor pair, the electronic, the quartz thermal breaker and the aluminium nitride pieces.

A total of 4564 microbonds are needed to make the electrical connections on each half ladder. We used 25μm Al1%Si wire and a ultrasonic bonding machine [5]. Figure 4 shows the location of the microbonds between capacitor chip pads and IC amplifiers pads, between the silicon wafer output pads (R-φ side) and capacitors input pads, between the two silicon wafer strips pads (R-φ side), between the kapton router pads (Z side) and capacitor input pads and between silicon wafer strip pads (Z side) and kapton router pads. A second series of vacuum jigs was constructed to support the half ladder and the different subunits on the bonding machine.

3. Conclusions

We have described the main steps involved in the SMD half ladder assembling process. Each assembling operation requires careful monitor of multiple geometrical parameters, at the micron level, for each constitutive part as well as for the whole detector. An analyse of the experimental results obtained during half ladder assembling process will be done in a following paper. The SMD was constructed and is operating successfully at CERN LEP on the L3 experiment.

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[3] Araldite AW106 (HV953U), Ciba-Geigy SA, CH-4002 Bassel, Switzerland.
Stycast 2850FT (24LV), W.R.Grace Co., 77 Dragon Ct., Woburn, MA, USA.
[4] Model 2000XL, EFD Inc., 977 Waterman Avenue, East Providence, RI 02914, USA.
[5] Model 4123, Kulicke & Soffa Industries Inc., 507 Prudential Road, Horsham, PA, 19044, USA