VERY LOW MASS MICROCABLES FOR THE ALICE SILICON STRIP DETECTOR

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Abstract

The ALICE Inner Tracker silicon strip detector layers will use kapton/aluminium microcables (12/14 μm thickness) exclusively for all interconnections to and from the front-end chips and hybrids, completely eliminating traditional wirebonding. Benefits are increased robustness and an extra degree of dimensional freedom. Utilising a low-power, low temperature and low-force (10-15 grams) single-point TAB bonding process, aluminium traces are directly bonded through bonding windows in the kapton foil to bond pads on the chip, detector and hybrid. The same technique is also used to interconnect these microcables to create multi-layer bus structures with "bonded via's".

Working in close collaboration, the SRTIIM Kharkov and NIKHEF UTRECHT groups are involved in the design, production and testing of these cables, as well as research of positioning and assembly methods. A double-sided detector using prototype cables has been installed in the NA57 experiment in 1998.

1. INTRODUCTION

The ALICE Inner Tracker (ITS) [1] consists of six concentric layers of detectors. Layer 1 and 2 are equipped with pixel detectors, layers 3 and 4 with silicon drift detectors and layers 5 and 6 with silicon strip detectors.

Layer 5 has a radius of 390 mm. and consists of 34 ladders with 23 modules each, layer 6 (radius 435 mm.) has 38 ladders with 26 modules.

The Silicon Strip Detector (SSD) system consists of 1770 modules, 782 in layer 5 and 988 in layer 6. A front-end module consists of a double-sided (stereo) strip detector with 1536 strips and a double-sided hybrid on which the 12 (2x6) ALICE128C readout chips [1] ,[2] are mounted. The total number of channels is approximately 2.5 million.

Layer 5 ladders are 990 mm long, layer 6 ladders 1100 mm long, the ladders are carbon-fibre space-frame constructions and are connected to carbon-fibre end cones to form cylindrical shapes.

A freon cooling system consisting of two stainless steel tubes running along each ladder cools the hybrids. These tubes have diameter of 2 mm and the wall thickness is 40 μm.

On the ladders detectors are mounted in "high" and "low" overlapping positions to eliminate the dead areas of the detectors in the Z direction (parallel to the beam). Alternate ladders are also mounted in "high" and "low" overlap positions on the circumference to eliminate these area's in the Rϕ direction.

Heavy-ion physics with particle multiplicities up to 8000 dictate a very low-mass design.

2. MICROCABLE TECHNOLOGY

The microcable technology described here was originally developed by the SRTIIM as a low-mass interconnect system for use in space electronics, with microcables with minimum pitch of 150-200 μm and bus assemblies with up to 10 layers.

For use in detector systems, the technology has been scaled down to a pitch of 88 μm with typical trace widths of 35-40 μm.

A microcable is made up of a kapton (polyimide) foil with aluminium traces. The cables are available in 12 μm kapton with 14 μm aluminium or 20 μm kapton with 30 μm aluminium.

Bonding windows are etched in the kapton foil, so as to be able to press the traces through these windows and bond them directly to the bonding pads beneath.

The technique is similar to Tape Automated Bonding (TAB) , but with several important differences.

In TAB bonding, traditionally gold bumps are used on the pads and all connections are gang bonded in one go with a thermode using heat and force.

A more recent development by Bull and Dassault, supported by the European Community ESPRIT program is bumpless single-point TAB bonding.

The kapton foils used are much thicker, typically 70 μm thick and traces are 17.5 μm copper covered with 1-1.5 μm gold.

Bond force is typically 20 grams for TAB bonding, compared to 10-15 grams for the microcables.

TAB bonding is an industrial high-volume process which utilizes a kapton foil with sprocket holes for fast and accurate positioning and handling, it is uncertain if it will be possible to use such a system for microcables which have much thinner foils and traces and so are much more fragile.

Also, automatic bonding machines often do not react kindly to trying to use bond forces of around 10 grams!

The TAB direct bonding technique is being investigated by the Strasbourg and Nantes groups and is used in the STAR silicon strip detector [3]. Also the possibilities to modify this industrial process using aluminium instead of copper is under investigation.

In this paper we describe solely the Utrecht/Kharkov aluminium microcables designs.

3. INPUT CABLES

A front-end module, see Fig.1, consists of a double-sided strip detector and a double-sided hybrid on which the 12 (2x6) 128 channel readout chips are mounted. The detector and the hybrid are decoupled mechanically, the detector is mounted on the ladder with high accuracy while the hybrid is connected to the cooling pipes running along the ladder. These pipes are loosely coupled to the ladder structure except for one fixed point in the middle to accommodate differences in thermal expansion.

The hybrids are mounted in a different plane than the detector, so the connection between the chips and the detector must be made with flexible microcables, at the same time eliminating the need for fan-outs, as this can be done in the cables.

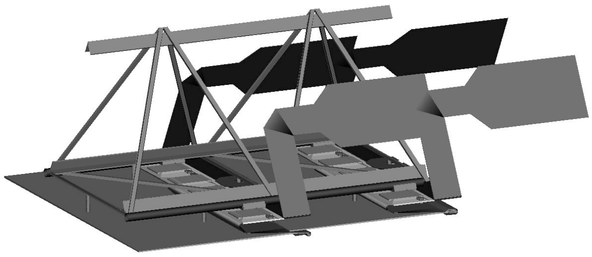

Figure 1. Front end modules on ladder structure.

The input cables, shown in Fig. 2, are made of 12 μm thick kapton foil with 14 μm thick aluminium traces, width 40 μm and 88 μm pitch on the chip side and 95 μm on the detector side. The traces are directly bonded to the bonding pads through bonding windows in the kapton foil with specially designed bonding wedges. The kapton foil is glued to the silicon surface to increase the mechanical strength. As the chip input pitch of 44 μm is too small for the cable design, half the traces run straight from the first row of bondpads and the other half folds around to connect to the fourth row. The cable also includes the output connections of the chip to the hybrid, this side of the pattern has a fan-out which fits in a 22 pin ZIF connector. In this way it is possible to test bonded chips before mounting them on the hybrid.

After testing of the chip, the test fan-out is removed, leaving only the pattern to be bonded to the hybrid.

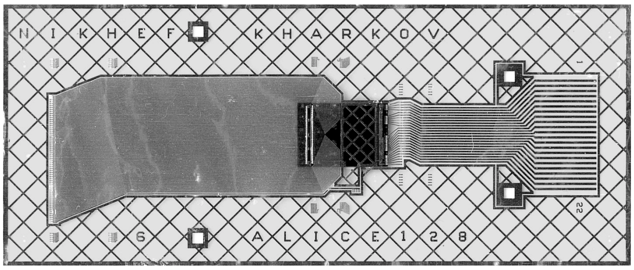

Figure 2. Input cable within template.

4. HYBRID BUS CABLE AND LADDER CABLE

The double-sided hybrid is 0.3x10.5x68 mm, just big enough to fit 12 chips and associated SMT components and the two cooling clips connecting the hybrid to the cooling pipes. On one side of the hybrid the front-end chips of the P-side are placed, on the other side the chips of the N-side.

To save material the read-out and power bus connecting the chips and components consists of a multi-layer microcable. This part does not have to be supported by the hybrid, allowing reduction of the hybrid to the minimum size needed to support and cool the chips. Fig. 3 shows a prototype of the hybrid and bus cable assembly including chips with input cables.

The via’s in this cable are made by bonding traces in different layers directly to each other through bonding windows in both cable layers.

The layers are glued together after the bonding process.

Here the kapton foil is 20 μm thick and the aluminium 30 μm and trace widths range from 70 μm to 2 mm.

Only the part of the cable containing the bondpads for connecting the chips and the solder/glue pads for the SMT components is glued to the hybrid, the rest of the bus is floating free in the air. The bus has a short “umbilical string” on one side which is bonded to the ladder cable. This is a similar cable of variable length (depending on module position) which runs along the ladder to the endcap module at the end of the ladder. This cable end is bonded to a very small PC-board, which has a trace pattern that fits into a ZIF connector, so again a completed front-end assembly can be tested before mounting it on the ladder. To make assembly easier, the ZIF connector system is also used to connect the ladder cable to the end-cap electronics.

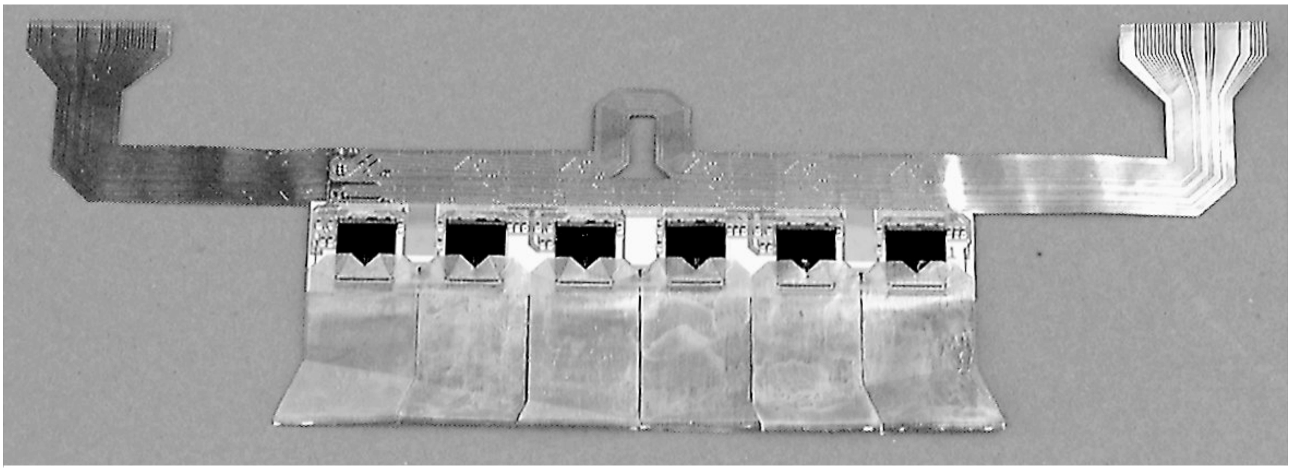

Figure 3. Alice doublesided hybrid with input cables and output bus cables.

5. TEST RESULTS

5.1 Introduction

Bond tests and bond pull strength tests have been done and are still ongoing. Also research has been and is still done on several subjects: glue pull strength for the input cables, tests using different bond wedge foot profiles, bonding and assembly methods and jigs to accomplish them

This is necessary, as there is little or no industrial know-how concerning this kind of cables. Bonding these cables looks deceptively easy compared to traditional wire bonding, but one has to realize that to make a reliable bond connection, now not only the workpiece (chip,detector, hybrid) has to be held stable in position, but the microcable template as well. The cable must be held absolutely flat and tension-free against the surface to be bonded to get reliable, consistent results.

Also visual inspection of the bonds is not easy, it is difficult to discern any difference between a successful bonding and a total failure!

5.2 Results

For a typical input cable the pull strength of the aluminium trace with 40 μm width has been measured, a consistent value of 6 grams was found.

Also for the input cable, the glue strength of a narrow glue strip (200-300 μm) was determined, values of 40-60 grams were found. The glue pull strength is much larger than the total weight of a single module, about 7 grams, so that it can effectively protect the aluminium traces during handling of the module.

In Fig. 4 bond pull strength figures as a function of bonding energy for four different bonding wedge foot profiles are shown. The results are quite good, there is a sufficiently wide energy range in which acceptable bonds are realized. In nearly all cases the trace is pulled off the pad leaving a patch of aluminium behind, see Fig. 5, it does not tear off in the "heel" of the bonding. In wirebonding practice the conclusion would be that the bonding energy should be increased up to the point that this effect starts to appear. With microcables another parameter must be accounted for; if the bonding energy is increased too much the trace will smear out too much and with the small pitch the risk of shorts becomes very high. The hybrid bus cable and the ladder cable are produced using 20 μm kapton foil with 30 μm aluminium. Trace

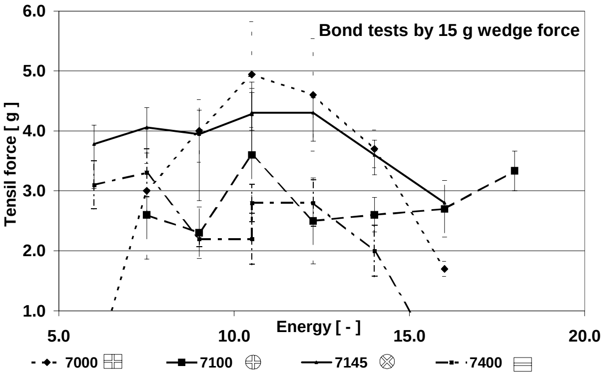

Figure 4. Bond pull strength tests for 4 different bonding wedges.

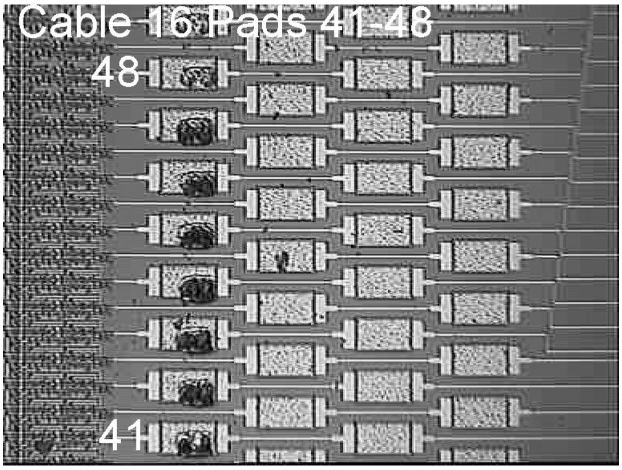

Figure 5. Footprint of good quality micro cable bonds.

widths vary from 100 μm to several mm for power lines, in the case of power lines several bondings are made in parallel, the trace width in the bonding window area is always 100 μm wide. Bond pull strength of these bondings is 18-20 grams.

6. CONCLUSIONS

The use of microcables gives the designers of front-end modules and inner tracker structures more possibilities; 3D freedom, longer interconnections, some relative movement allowed, robust and yet low mass.

Bonding on active surfaces is inherently safer compared to wire bonding, no lost wire bonding possible and low settings of bonding parameters.

Component qualification can be taken one step further, it is possible to do chip acceptance tests with bonded chips.

The SRTIIM institute and production facilities in Kharkov have much experience with large-scale use of this technology using minimum pitch 150-200 μm.

One should keep in mind that this is a new technology for this field, that there is –especially for small pitch cables- not yet very much experience. Also there is no industrial production know-how in industry here yet, although at the moment two firms (Selmic, Detexis) seem interested.

But we are convinced that without these microcables it would not be possible to assemble the inner tracker layers and get anywhere near the present specs concerning mass and coverage of active area.

7. REFERENCES

[1] ALICE ITS Technical Design Report CERN/LHCC 99-12

[2] Proceedings of Third Workshop on Electronics for LHC Experiments CERN/LHCC 97-60: L. Hebrard et.al.: ALICE128C: A CMOS Full Custom ASIC for the readout of Silicon Strip Detectors in the ALICE Experiment.

[3] Proceedings of Fourth Workshop on Electronics for LHCC Experiments: S. Bouvier: TAB: A Packaging Technology Used for Silicon Strip Detector to Front End Electronics Interconnection.