Development and Test of Micro-Cables for Thin Silicon Detector Modules in a Prostate Probe.

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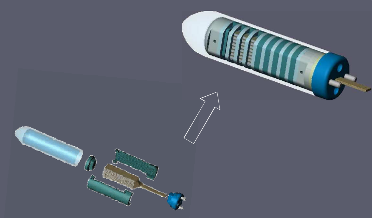
Introduction

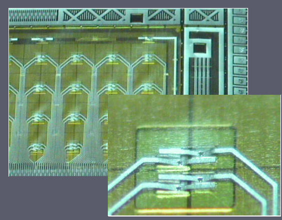
- Silicon probes can considerably improve the performance of imaging devices in Nuclear Medicine
- Diagnosis
  - ✓ Compton cameras
  - ✓ Compton prostate probe (shown in the picture) by improving both the sensitivity (due to the near field operation) and the spatial resolution considerably (G. Llosa et. al. Nuc. Ins. Meth. A Vol 527, 58-61 (2004))
  - ✓ PET magnifying glasses to provide enhanced resolution in regions of interest
- Therapy
  - ✓ An add-on to a conventional InBeam PET for light ion and proton therapy which would increase the sensitivity by detecting prompt gammas when operating the PET and the probe on compton camera mode



- The silicon probes are built as densely packed stacks of silicon pad sensors and packaging is a very important issue
- TAB (Tape Automated Bonding) is a possible technology that we are exploring
- Both silicon sensors and their readout chips VATAGP3 from IDEAS[1] have been TABed to their corresponding cables and measured

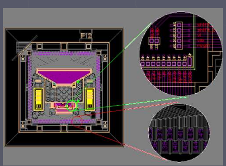
Micro-Cable Technology

- The micro-cable technology was developed by SRTIIM for use in space electronics.
- It connects (via ultrasounds) the pads of a device (ASIC, silicon detector) to aluminium printed traces on the micro-cable.
- The micro-cable on a flex support (Kapton) carries signals between pads of two different devices.
- Bonding windows etched through the Kapton to allow for pressing the Al traces through and bond them directly to the pads beneath.
- Typically
  - ✓ minimum pitch ~100 µm
  - ✓ thickness: Al 14 µm, Kapton 12 µm
  - ✓ bus assemblies (up to 10 layers)
- Similar to standard TAB technology
  - ✓ it is bump-less
  - ✓ very thin
  - ✓ bond force required is small (10-15 grams)

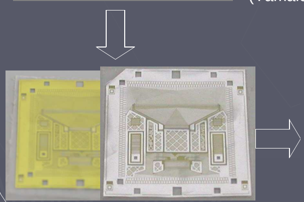


- Elegant solution for
  - ✓ flexible and compact interconnection between ASICs and sensors
  - ✓ stacking silicon sensors to form a detection volume filled with more than 90% of active detector.
- The use of a polyimide layer of 70 micron thickness was essential to reduce the load capacitance of the traces at the input of the amplifier to acceptable values.

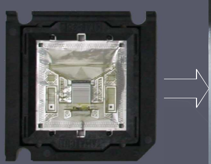
Setup of the ASIC module

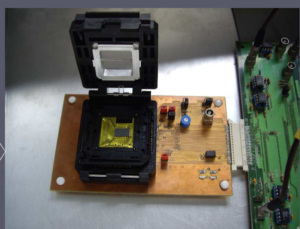


- A chip cable was TABed to VATAGP3 readout chips with 128 channels. This chip has already been used in prototype Compton probes to readout the signal of the silicon pad sensors.
- The chip cable was tested using a standard socket IC51-4364 (Yamaichi, Japan).
- TABed chips were mounted on a supporting frame, as shown on the picture below. The frame was in turn mounted on a clamp which was mounted on an intermediate board and the latter connected to the DAQ board in charge of generating the readout sequences.



Chip cable

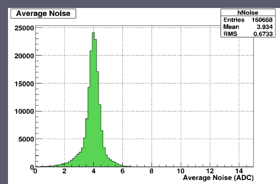


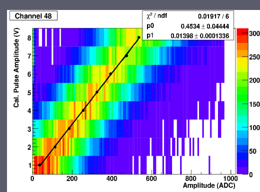


Results of the ASIC module

To check the functionality of the front-end ASIC we used a calibration pulse which was generated by an external pulse generator and injected on the calibration pad of the chip.

- The chip response versus the test pulse amplitude is shown in the "gain curve" (figure below)

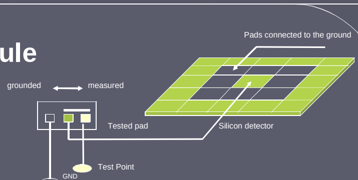




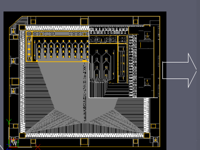
- The figure above shows the average value of the noise after common mode subtraction in units of ADC counts.
- Wire bonded VATAGP3 chips exhibit a similar noise performance.
- This result, therefore, demonstrates that TAB technology does not introduce any performance penalty.

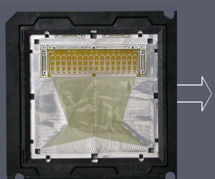
Setup of the Detector Module

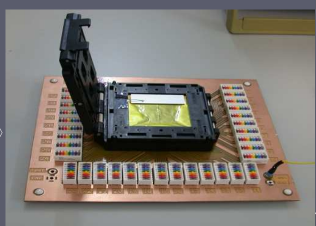
- Developed by SRTIM, Kharkov
- A silicon detector (46 mm long, 14 mm wide and 1 mm thick) was TABed and held in a supporting frame
- The frame was housed in a standard socket IC51 – 3244 (Yamaichi, Japan).
- The clamp was mounted on a custom designed board for the test of the detector cable
- Connecting one pad to the test point and all its neighbours to ground we measured the leakage current on that pad avoiding contributions from other pads.



- Each switch connects one pad either to a test output or to ground (as shown in the figure above).
- This method allowed the test of the 256 pads separately.

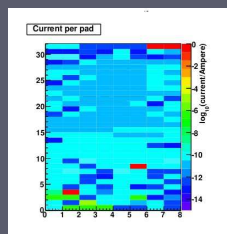


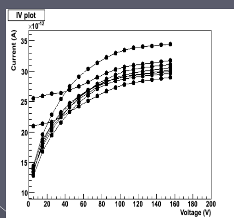


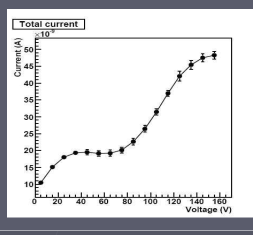


Results of the Detector module

- The measured current on the test output as a function of the bias (setting all the pads to ground and only one to the test output) produced the IV curve shown in the figure below.
- The current measured per pad was ~34pA at 150V bias voltage.
- The measurements were made at room temperature.
- The figure on the right represents the leakage current measured on each pad of the detector.
- Most of the pads produce a leakage current of about 34pA at 150V
- The number of pads drawing currents compatible with zero represent a small percentage and are concentrated on the periphery so we believe that failure is due to handling and mechanical stresses after the TAB process.

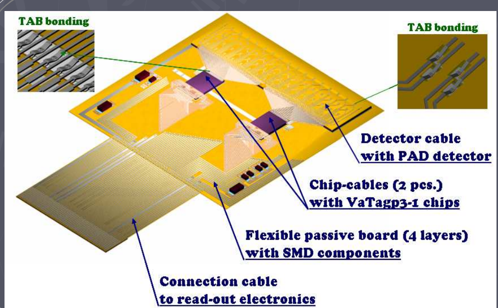




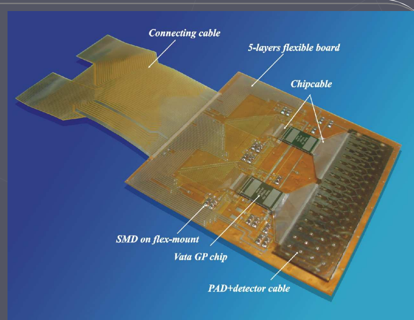


- The left figure shows the current measured in the HV return line. It therefore represents the total leakage current of the detector.
- The step at 60V is due to the guard current becoming more important for higher voltages.
- The curves show that the detector gets fully depleted at 150V.
- The total current of 50nA is compatible with 50–100pA measured per each pad.

Conclusions



- Silicon sensors and readout chips VATAGP3 from IDEAS[1] were TABed to their corresponding cables and tested successfully.
- A total of 256 interconnection pads from the silicon microstrip detector were connected to two readout chips.
- TAB does not deteriorate the electrical performance of the ASICs and we have proved that the yield of the connection of the detector pads is high (82%).
- Detector-cable and chip-cable assembly were TABed to a very thin PCB, being a Kapton cable soldered to the PCB for connection to the data acquisition system, achieving a total height of only 1.2 mm (shown on the right).
- The very high density packaging of silicon detector modules achieved is suitable to be employed in medical imaging modalities SPECT and PET.
- The use of micro cables gives the designers more possibilities like flexible, low mass and densely packed interconnections.
- TAB technology offers an elegant solution for a flexible and compact interconnection between the readout ASICs, the silicon sensor and the hybrid board.



[1] www.ideas.no

[2] www.sintef.no

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