The SSDBL FAQ

Alan Honma, EP/CMT

Introduction to the Solid State Detector Bonding Lab

- What, where, who?

A brief overview of wire bonding

- What is it?
- What types?
- How does it work?
- How does one test it?
- What alternatives are there?

Solid State Detector Bonding Lab

What is it?

- Historically, it's the "leftovers" from the OPAL silicon microvertex construction laboratory. After 1996, it became a general bonding facility for any experiment or project at CERN (and even outside of CERN). It is now part of the Divisional Silicon Facility (see Christian's talk).

Where is it?

- Currently occupies about 180m^2 in Bat 186-1-F03 (upper floor). Consists of a plastic tent "clean area" with laminar flow panels along one wall and limited air conditioning.

What do we do?

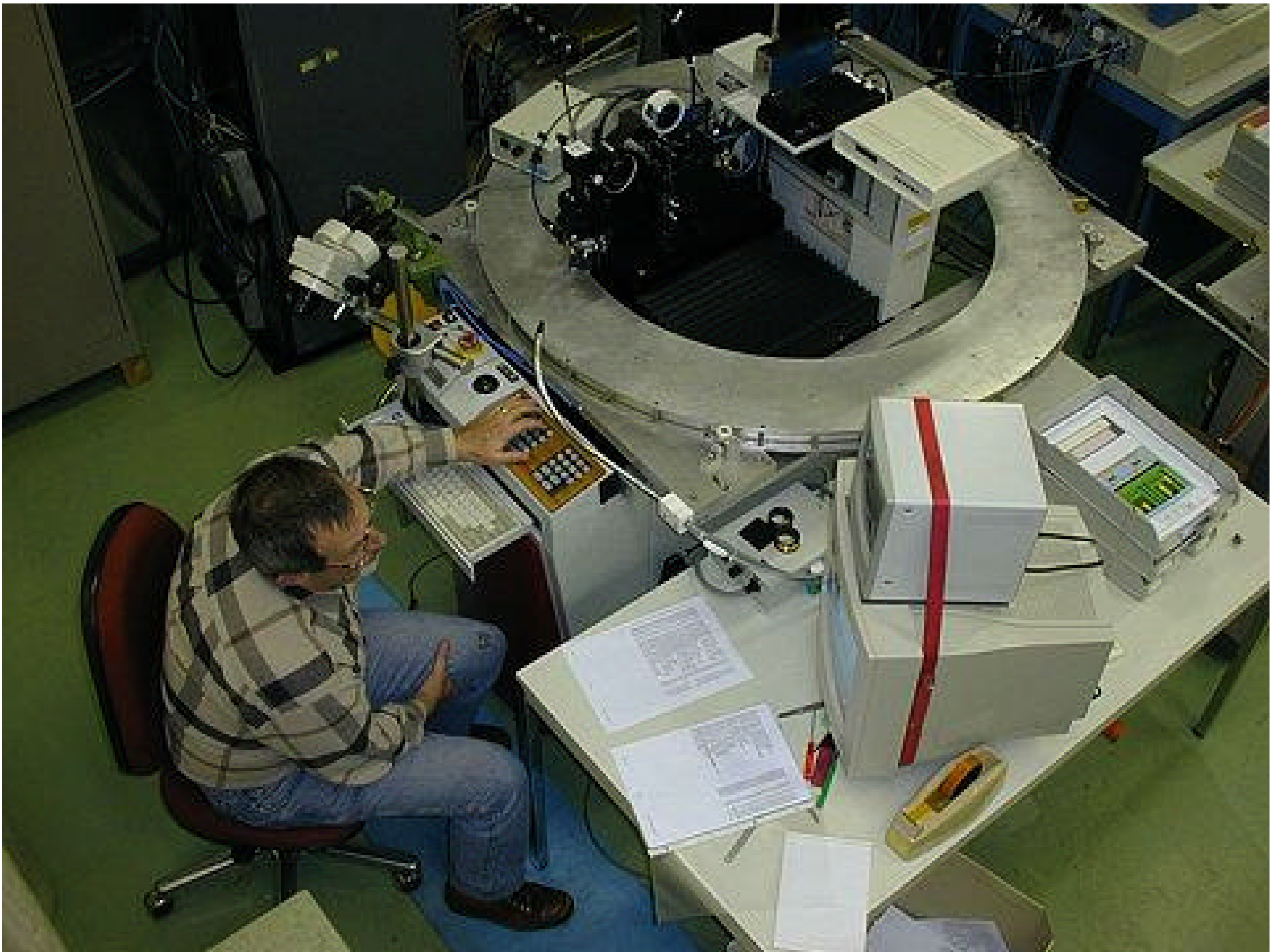
- The SSDBL provides wire bonding service to any CERN related experiment or project. In the past it was available to all comers on an informal basis mostly first-come first-served. From this year onward, priority will be given to the four LHC experiments silicon tracker projects but available capacity is open to other CERN projects which should be scheduled in advance as much as possible.

- We also provide assistance in designing detector modules as regards bonding issues as well as in designing and construction of bonding jigs (support tooling).

- We provide basic gluing facilities and limited assistance in gluing of read-out chips and detectors.

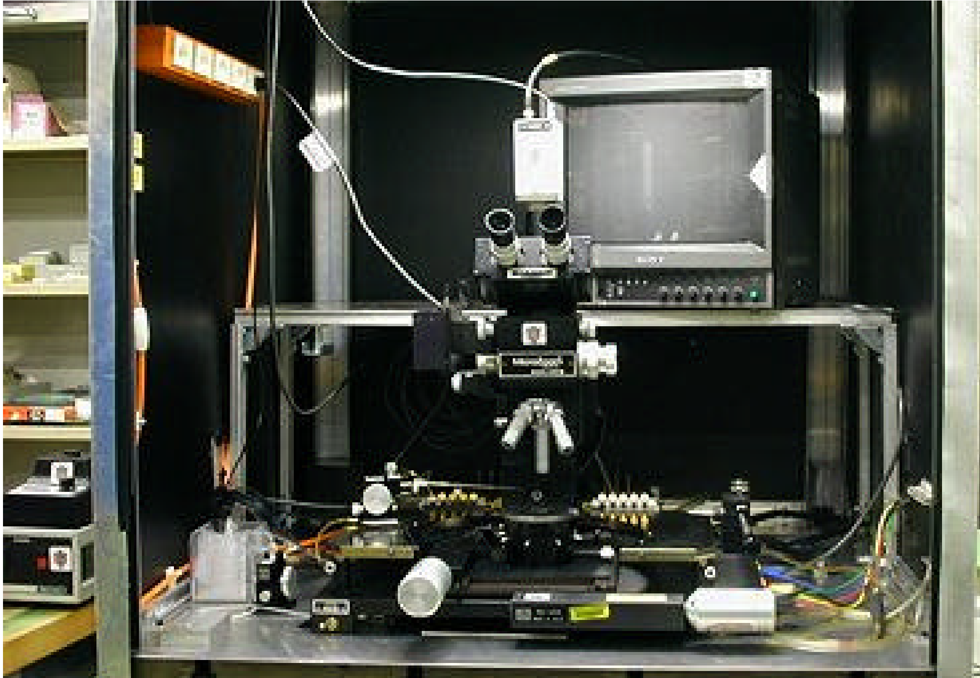
Current equipment of note:

- 2 Delvotec 6400 automatic wedge wire bonding machines (one is brand new, the other is 2 years old)



- 2 Hughes 2470-II deep access wedge wire bonding machines (both >10 yrs old and no longer supported).

- 1 precision Alessi manual probe station with motorized high magnification microscope



- 1 simple Alessi manual probe station
- 3 inspection stereo microscopes

- assorted glues and gluing equipment including 2 ovens

- ultrasonic PCB cleaning machine
- plasma oven
- UV oven
- basic bond test equipment
- basic electronics test equipment
- several long thick steel tables

- 2 Macs for documentation and communication

Manpower:

- Kaspar Muhlemann - full time bonding technician
- Ian McGill - full time bonding technician to start 1 May
- Alan Honma - lab supervisor and occasional bonder

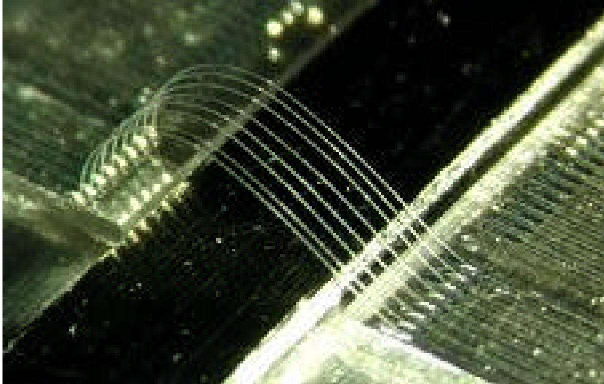
Experience (some of the bigger projects) :

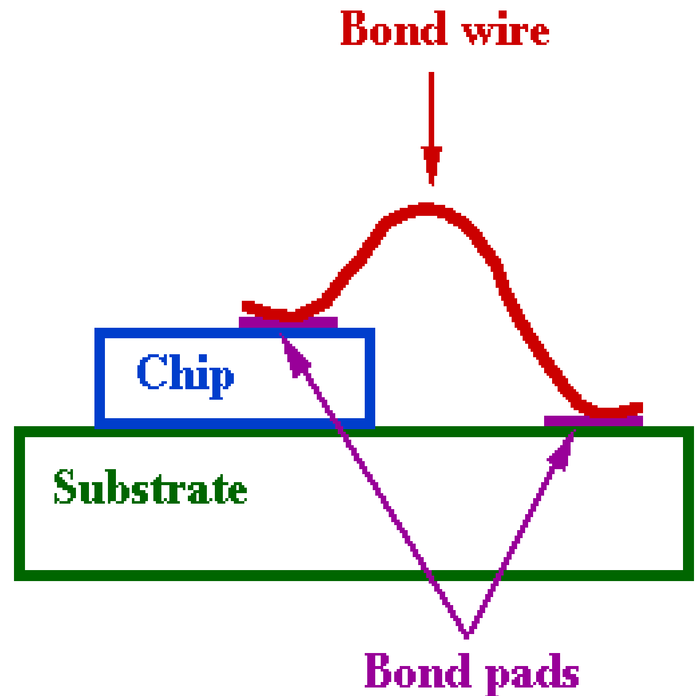
- OPAL silicon microvertex and silicon-tungsten calorimeter
- NOMAD
- GEMs R&D
- HERA-B
- COMPASS
- ATHENA
- ATLAS
- CMS
- ALICE
- LHCB

And a large number of smaller user groups at CERN.

Introduction to Wire Bonding

What is wire bonding?





For physics applications, to make electrical connections:

- Control signals
- Detector signals
- Bias voltages
- Chip power

This is a "mature" technology, about 40 years old!

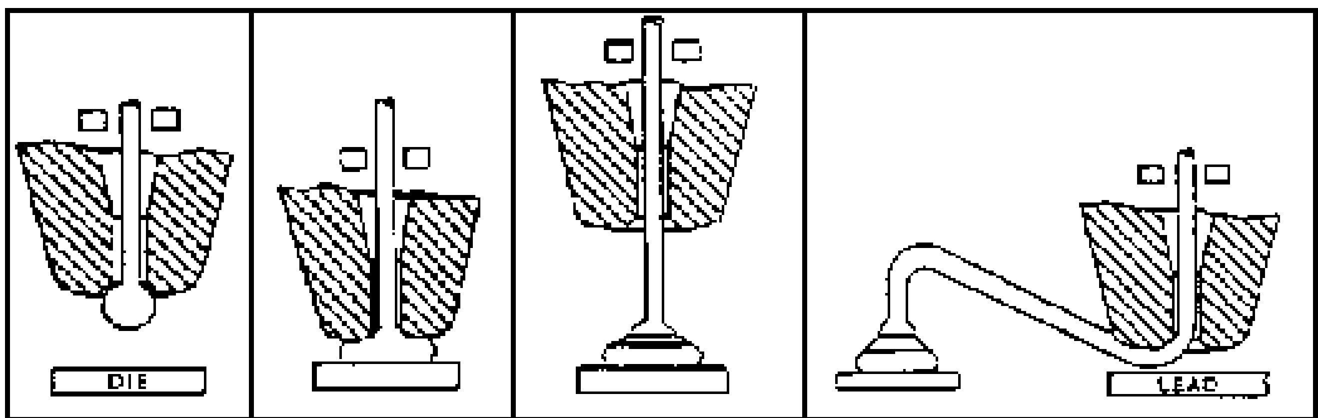
So why not just use a connector?

The typical physics applications are connections of integrated circuit die to circuit boards and connection of fine read-out pitch (< 500 μm) detectors to their electronics. These pitches are normally too small for standard connector technology.

What types of wire bonding exist?

1) Thermocompression/thermosonic ball bonding (gold wire)

Fastest, up to 10 Hz
very strong first bond
excellent reliability on gold pads
but needs heating of substrate and wire



2) Thermosonic wedge wire bonding (gold wire)

Slower, up to 5 Hz
excellent reliability on gold pads
needs moderate heating of substrate

3) Ultrasonic wedge wire bonding (aluminium wire)
Slower, up to 5 Hz
excellent reliability on aluminium pads
room temperature

At the SSDBL we do only ultrasonic wedge wire bonding.

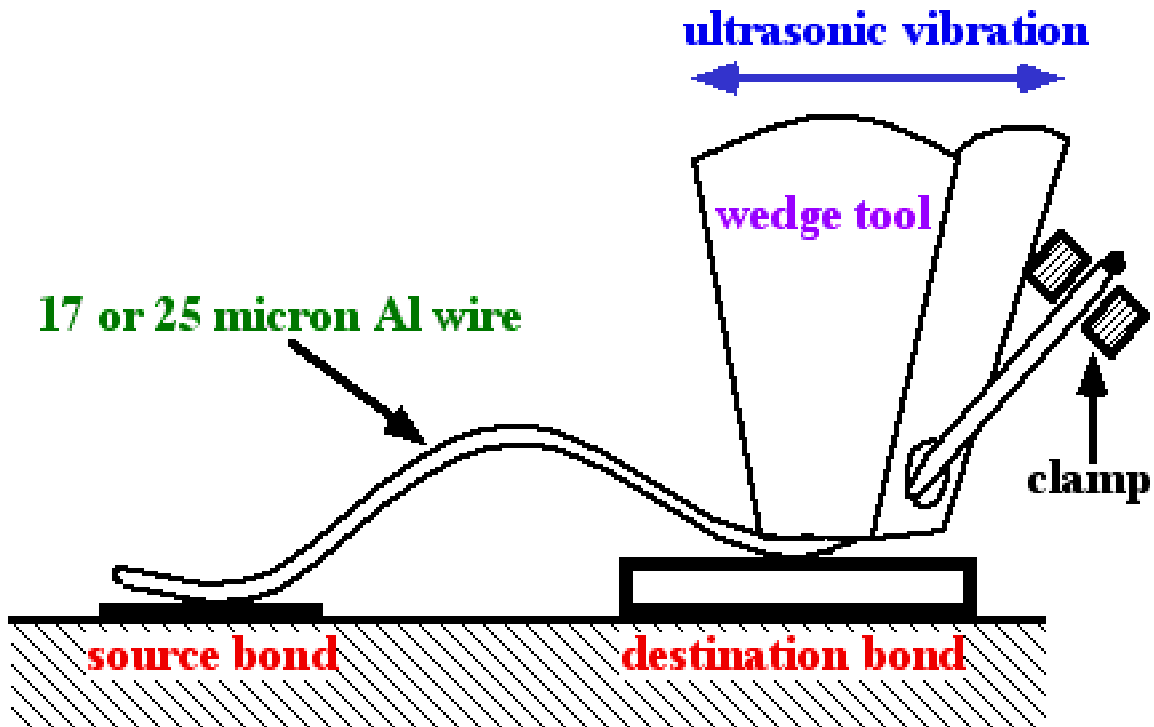
What are the typical applications of wire bonding?

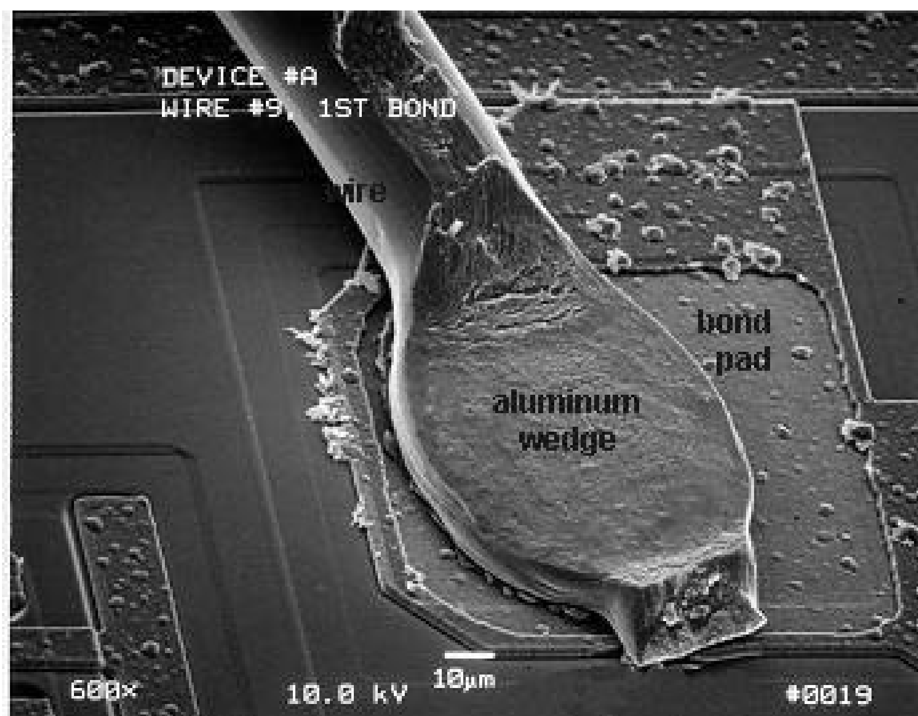
For industry:
multi-chip modules (MCM) or single packaged chip

For physics experiments:
chip (read-out or control or monitoring) on hybrid PCB
read-out chip to detector
signal routing via pitch adapter
daisy-chaining of detectors
cable to hybrid PCB connections

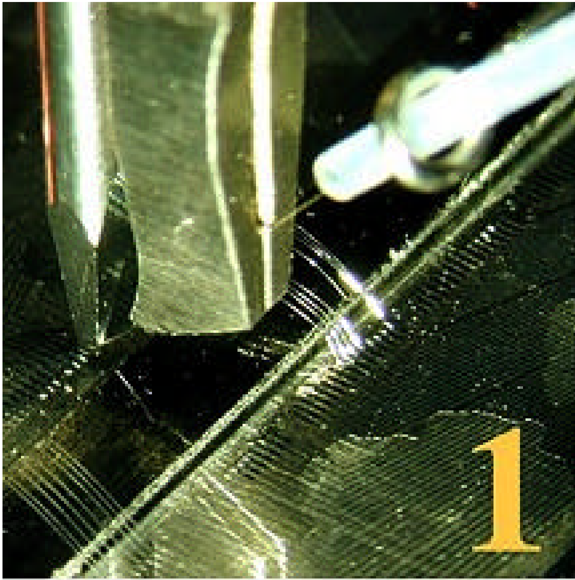
How does ultrasonic wedge wire bonding work?

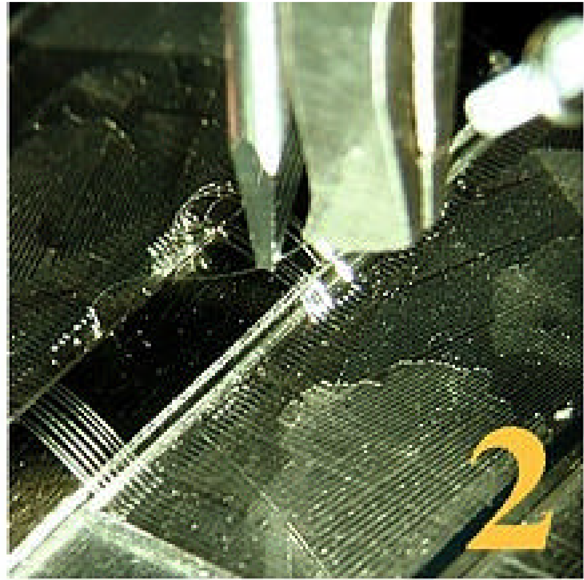
- Ultrasonic transducer vibrates wedge shaped bond tool
- Oscillation of wire on substrate heats contact surfaces
- Weld forms at interface and wire is compressed by tool
- Clamp opens, tool lifts, wire passes through hole
- Tool moves to destination bond for second weld
- Clamp closes and pulls to break wire, tool lifts

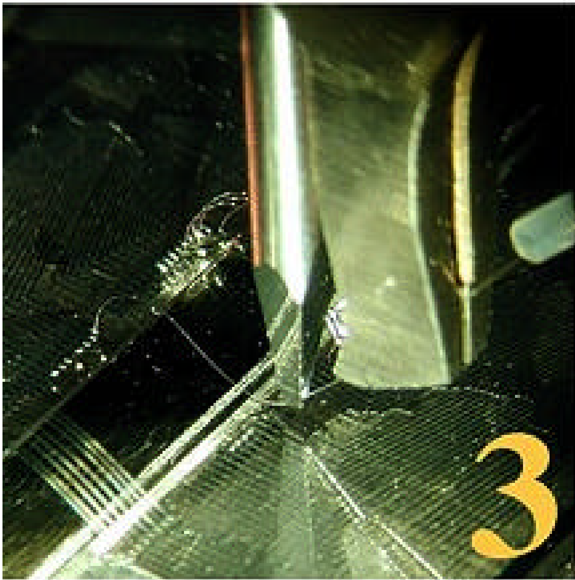


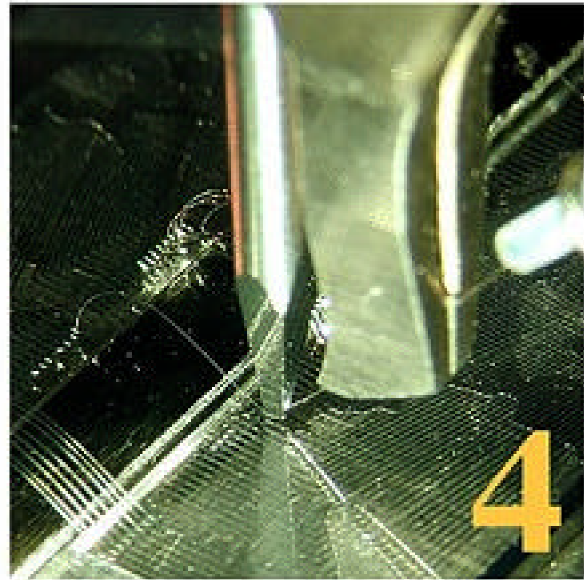


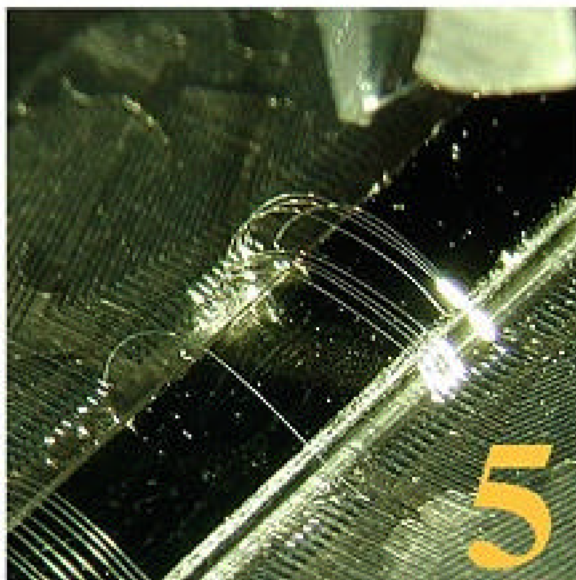
Scanning electron microscope 400x photo of bond foot
http://www.eccb.org/pbps/tg/wirebond.htm


1


2


3


4


5

What are the main parameters for obtaining a good weld?

- Ultrasonic power
- Bond tool force (20-30g)
- Time (typically 10-30 ms)

What wire and substrate substances are possible?

Wires: Al, Au, Cu (with difficulty), 17.5 - 75 μm diameter
We normally use 17.5 μm diameter Al (w/1% Si) wire whereas 25 μm is "standard". Done for repair reasons.

Substrates: Al, Au, possible but problematic: Cu, Ag, Fe, Ni

What types of ultrasonic wedge bonding machines are there?

Level of automation:

- Manual
- Semi-automatic (program wire locations and parameters)
- Fully automatic (pattern recognition and part indexer)

Other sophisticated features:

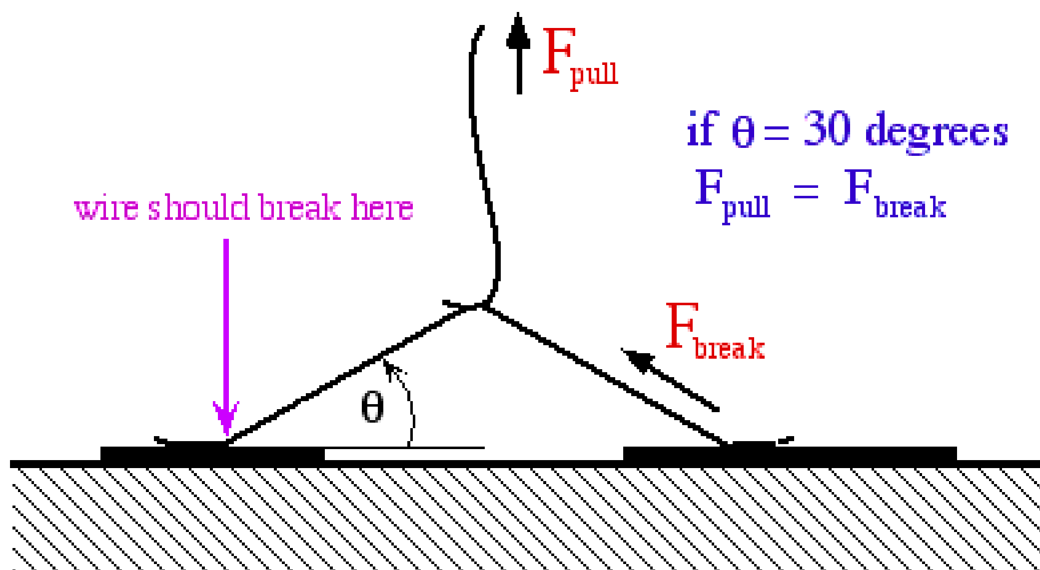
- Wire feed (despooling) control
- Touchdown sensor
- Bond process control (wire deformation feedback)
- Loop form control

Our Delvotec 6400 has all the above-mentioned features.

What are the methods for testing bond quality?

- Visual inspection (best with ~40x stereo microscope)

- Pull testing (destructive or non-destructive): uses manual, semi-automatic or automatic wire pull dynamometer to measure breaking strength of wire loop. Typical bond breaking strength for 25 micron diameter wire is ~8g.



Non destructive pull test is similar but a fixed maximum pull force is applied which should be at the minimum required strength.

- "Touch" method: touch wires lightly with a needle to dislodge weak bonds

- Air jet method: shoot compressed air at wire to dislodge weak bonds

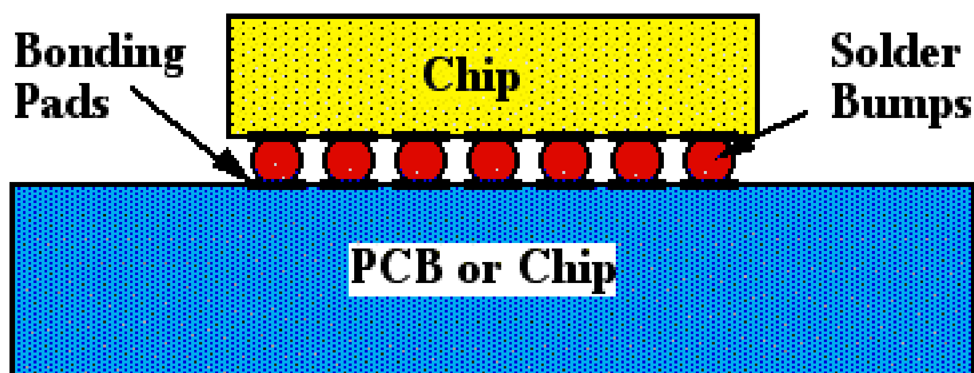
What other possibilities are there for fine pitch connections?

Bump or “flip-chip” bonding

TAB (Tape Automated Bonding)

Bump bonding:

schematic:



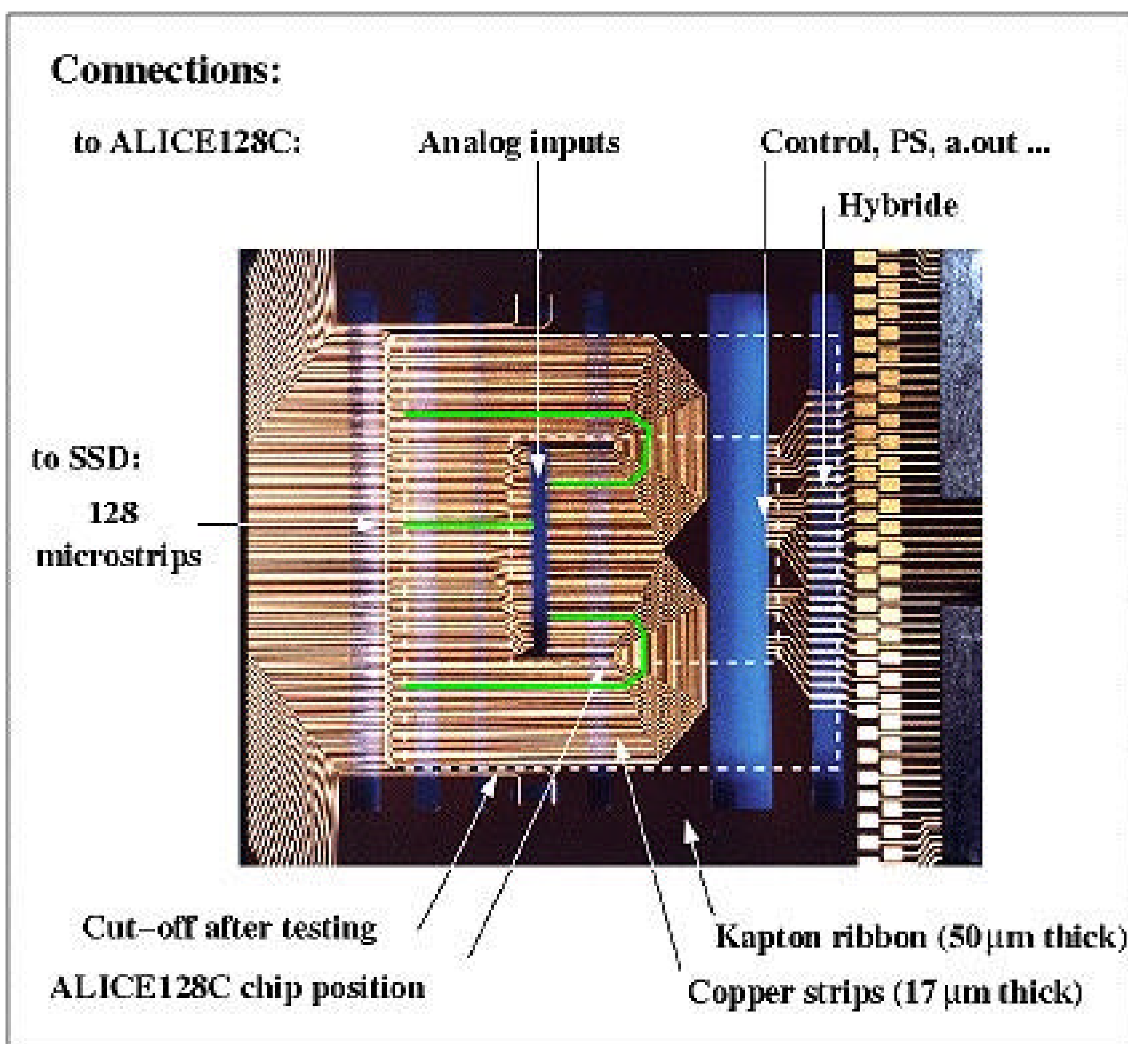
In place of solder (often indium), one can use conductive adhesives. Either heating of the joint or curing (or both) is needed.

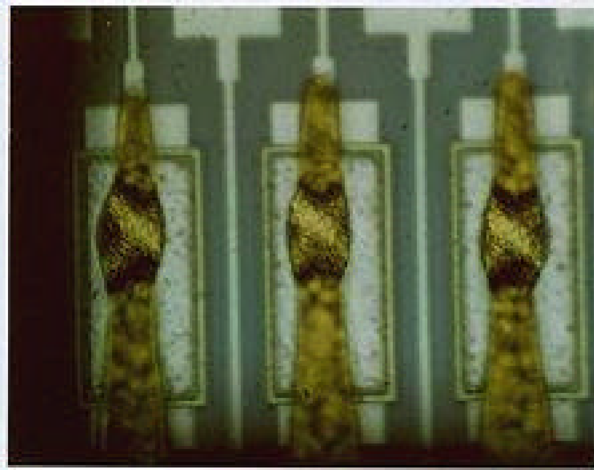
A web reference for bump bonding in high energy physics:
http://www.physics.purdue.edu/vertex/talks/lozano/index.htm

TAB bonding:

In TAB bonding, you place a thin kapton foil circuit ("tape") over the chip or PCB and use a bonding machine (often a wire bonding machine with a special TAB bonding tool) to weld the bond pads of the foil to the bond pads of the substrate.

Example of TAB bonding in high energy physics: **STAR**
http://star.in2p3.fr/STAR_documents/warsawJPC/index.htm





close-up of bonded tabs

Summary of the 3 connections methods

Connection Method	Advantages	Disadvantages
Wire bonding	Flexible Fairly easy to repair Visible Mature technology Can allow for CTE difference No heating or curing	Slower (higher cost) Higher resistance and inductance Fragile
Bump bonding	High density of connections Becoming industry standard Choice of connect material Low resistance, inductance Robust Cheaper in quantities	Only for chip to PCB Device specific pad layout high initial cost Differential CTE problems Heating or curing needed Accurate piece alignment Invisible joint Difficult to repair
TAB bonding	Low resistance, inductance Partly visible No heating or curing More robust than wire bonds Can combine with wire bonding (same machine) Less CTE worries	Only for cable to chip or cable to PCB Slower (higher cost) Device specific pad layout high initial cost Accurate piece alignment Difficult to repair

A web reference for all three connection methods:
http://www.eleceng.adelaide.edu.au/Personal/alsarawi/Packaging/packaging_www.html

In a future seminar (by our bonding techs):

- Examples of bonding jobs performed by the SSDBL
- Description of procedures involved in a typical bonding job
- Typical problems encountered
- Hints for successful bonding (for users and bonders)