Wire-bonding

Ingo Bloch

HELMHOLTZ
| ASSOCIATION
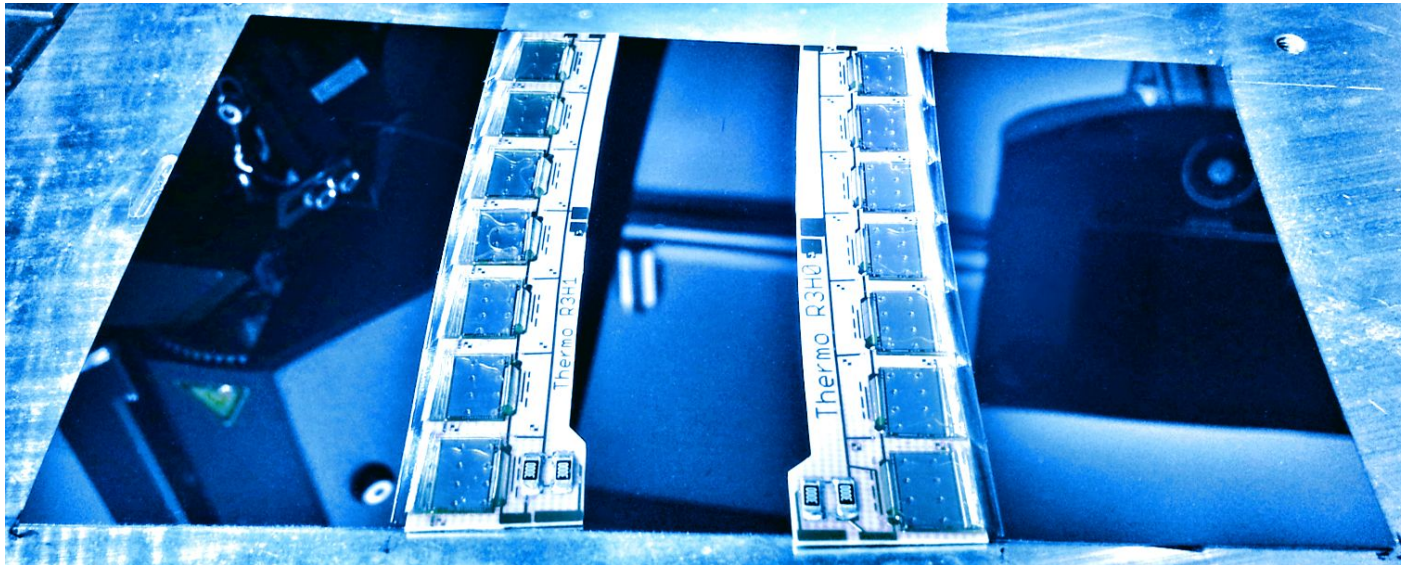
A plan for content - let's see how far we get

Intro - the long version… feel free to pick an item and ask about it

> Why bonds in the first place
>> What is the usual job of a bond
>>> ■ Connect what to what
>>> ■ Survive what
>> HEP default is Aluminium Wedge wire bonding - alternatives?
>>> ■ Gold ball about 5-10 times faster than Al-Wedge, but bond surfaces heated to T>125°C
>>> ■ Bump bonding: Expensive expert operation, yield can be challenging, potentially requires redundant connections
> Will focus on Aluminium Wedge Bonding
> Ask: What is the best focus otherwise?
>> ■ Rather focus *only* on how to wirebond?
>> ■ Or add focus on features where bond-aware design/layout is essential?

> Steps to bond single wires
>> Most relevant parameters
>>> ■ Xy coordinate setting for both bond feet for each wire, Z height setting for both, Bond force, US power, "Slow" range before touchdown
>>> ■ Loop height, shape, height/length correction
>> Most frequent bond failures
>>> ■ Lift off: Bad support, Contamination, Bad surface quality
>>> ■ Heel break: Bad support -> force too high, Bad surface, e.g. bonding in vicinity of old bond feet
>>> ■ Leaning wires / short circuits: Uneven surface, Torsion on wire in wire spool, contaminated wedge
> Steps for programs
>> Very brief, just define
>>> ■ Source "chip", target "chip" wires connecting 2 chips
>>> ■ Xy auto-adjust with pattern recognition
>>> ■ Height measurement at each chip
>>> ■ Never do:
>>>> > Define reference pictures on surfaces that can change when bonding (e.g. avoid bond pads), such that one can re-adjust when need for re-bonding comes up
> Environment / Behaviour
>> Preparation for work item (cleaning, jigs, bond plan)
>> Behaviour / cleanliness
>>> ■ Consequences for failure to work cleanly
> Usual non-day-to-day items
>> Change wire
>> Change tool/wedge
>> Calibate xy "Spider"
>> Infrastructure check
>> clean!
> Typical difficulties - transition to Q&A
>> Bond plan - which wire goes where? Documentation!
>> Avoid Contaminations - action to reduce existing contamination
>> ASIC/die related
>>> ■ Design ASIC bond pads (size, placement)
>>> ■ Design connectivity layout: few bond head turns, similar length, first short than long...
>> Hybrid/Package related
>>> ■ Design target bond pads (size, etching, placement, surface quality,...)
>>> ■ SMD placement
>>> ■ connector placement
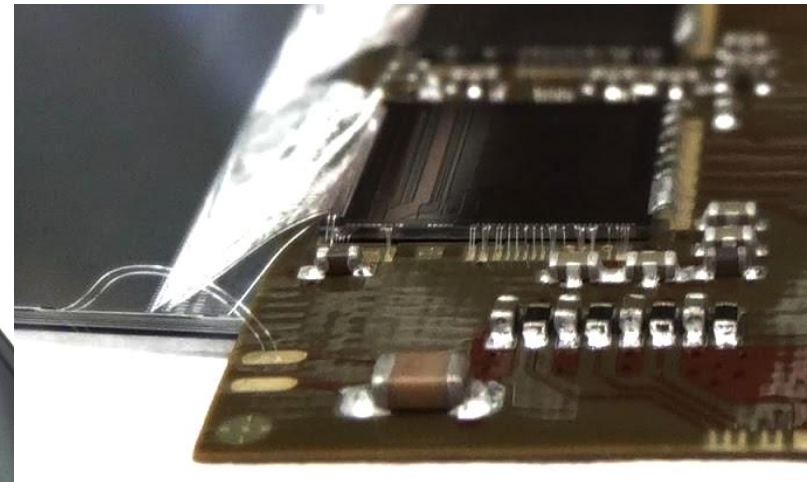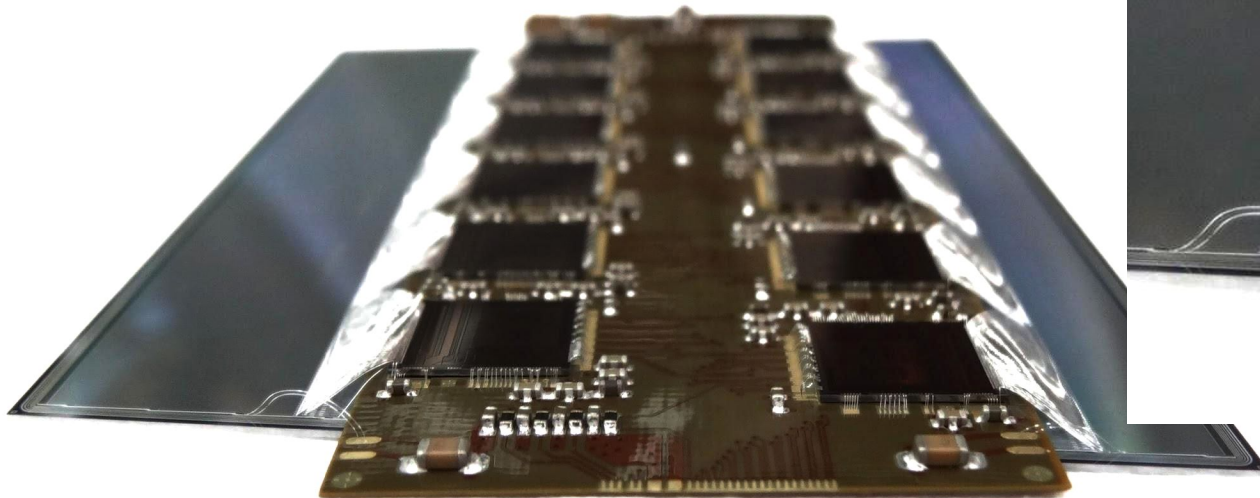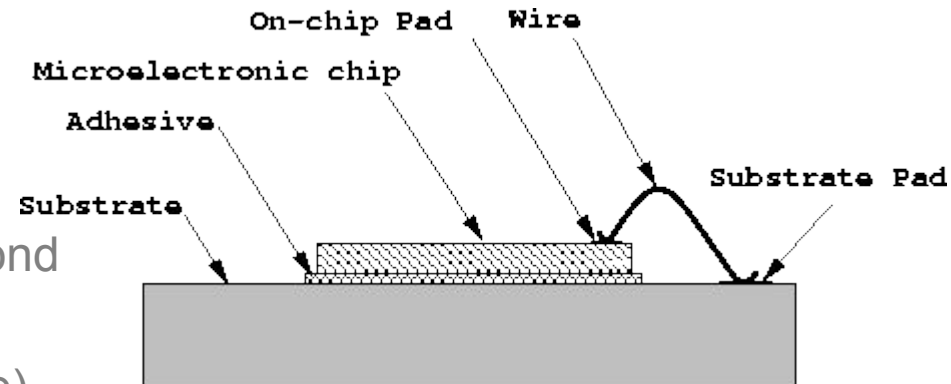>>> ■ Fiducials
>>> ■ Mechanical support

Plan

Parts of the session

> brief intro to wire bonding

> followed by discussion of wire bonding events

Intro

> Why bonds in the first place

>> What is the usual job of a bond

- Connect what to what
- Survive what (next page)

On-chip Pad   Wire
Microelectronic chip
Adhesive
Substrate Pad
Substrate

HL-LHC ATLAS Upgrade ("Phase II")

ATLAS tracking detector Upgrade (only Si-strip part here)

> Current Si-strip detector (SCT) manages to
>> measure until ~600 fb^{-1} are reached
>> differentiate pile-up up to ~<60> events
> Does not agree with HL-LHC parameters
> **Strip-tracker-Upgrade** - targets
>> Radiation hardness up to 3000 fb^{-1} resp. $2*10^{15}$ neq/cm^2
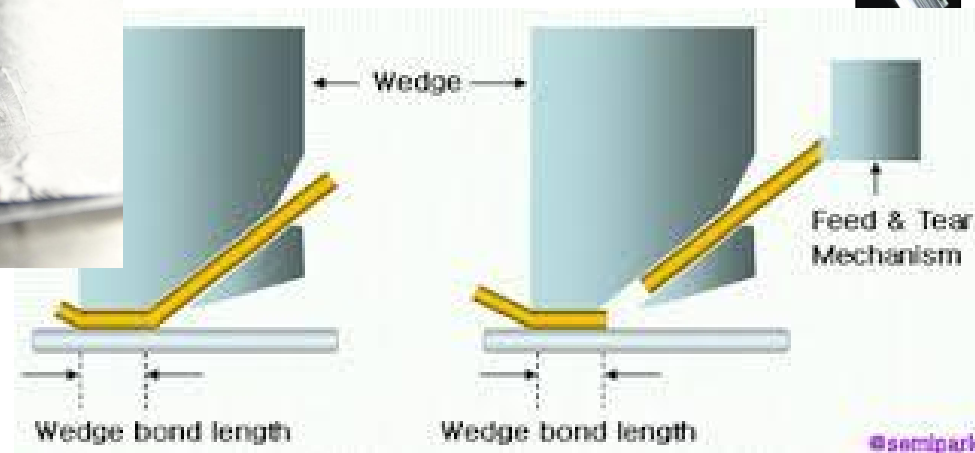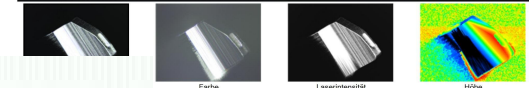>> Granularity about 4x finer than current SCT
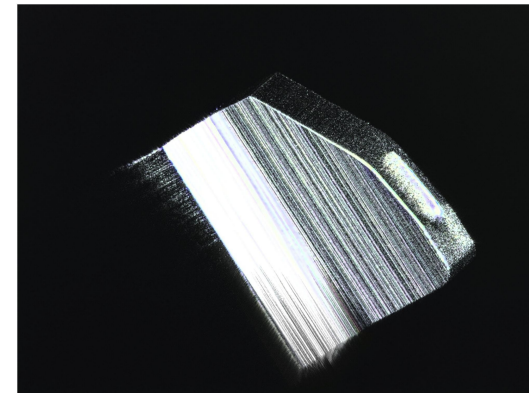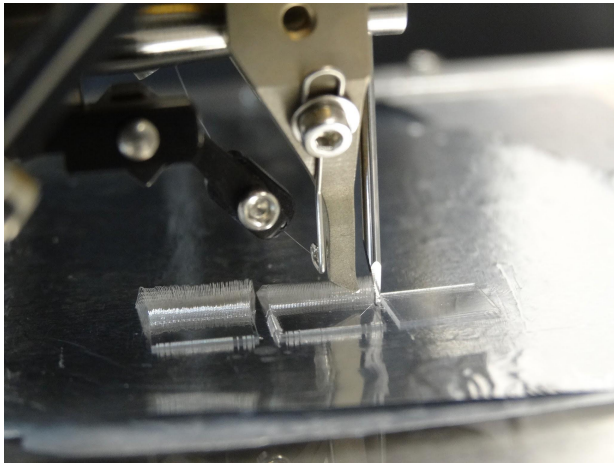>> Track-Trigger, less material, ...
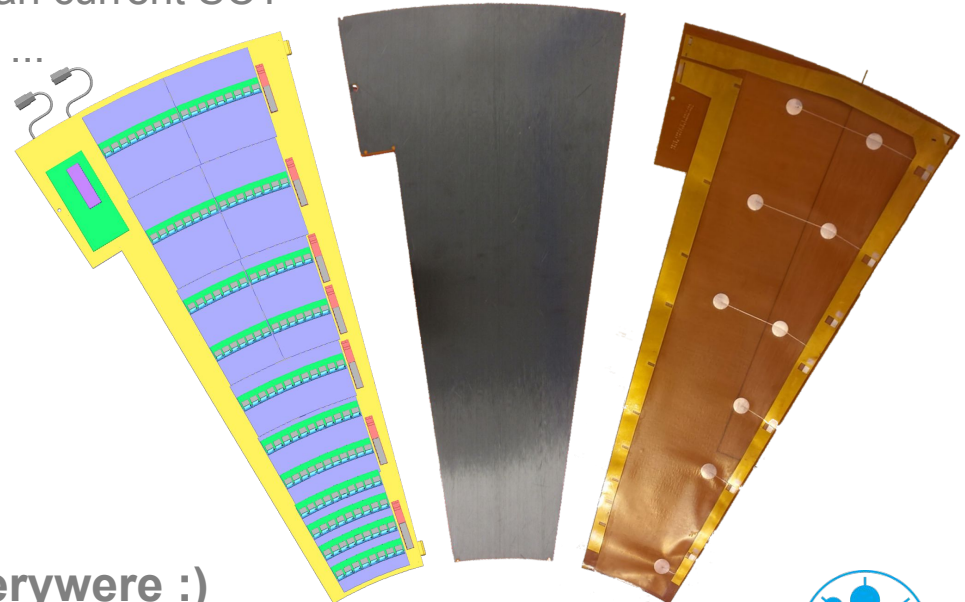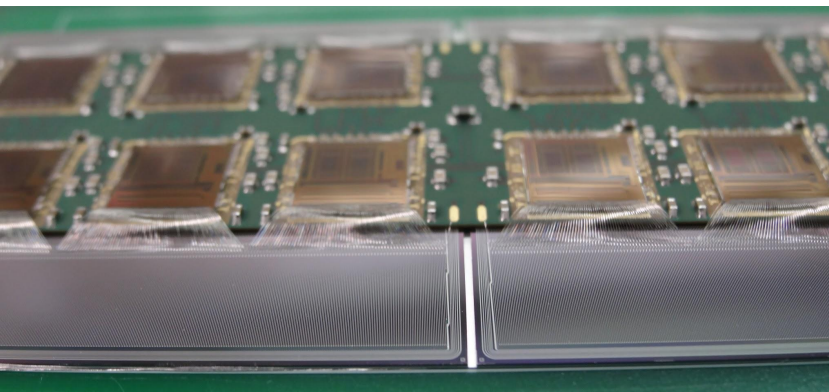
> **Wirebonds everywere :)**

Wire-Bonding - Thermo-Mechanical Module
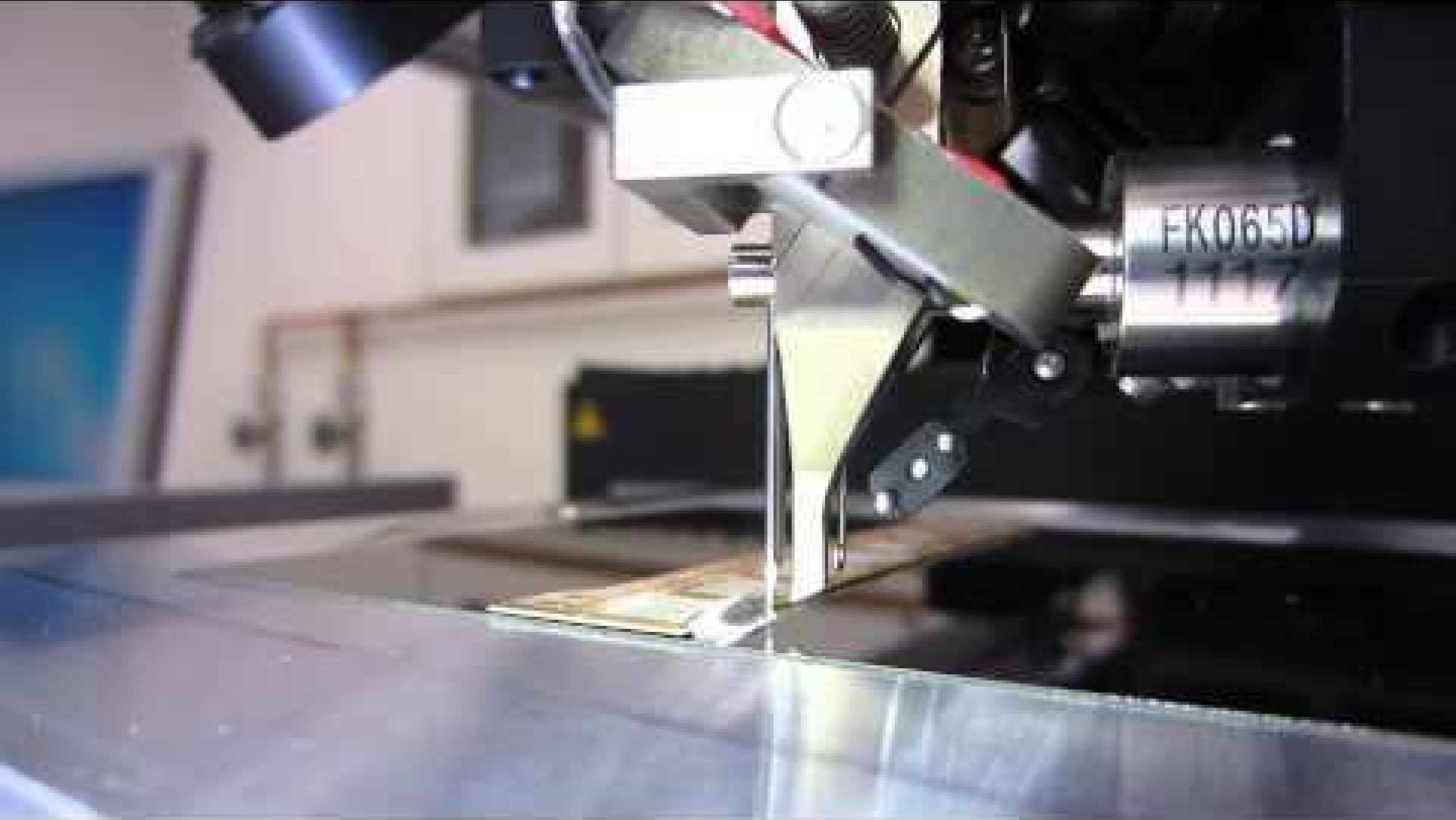
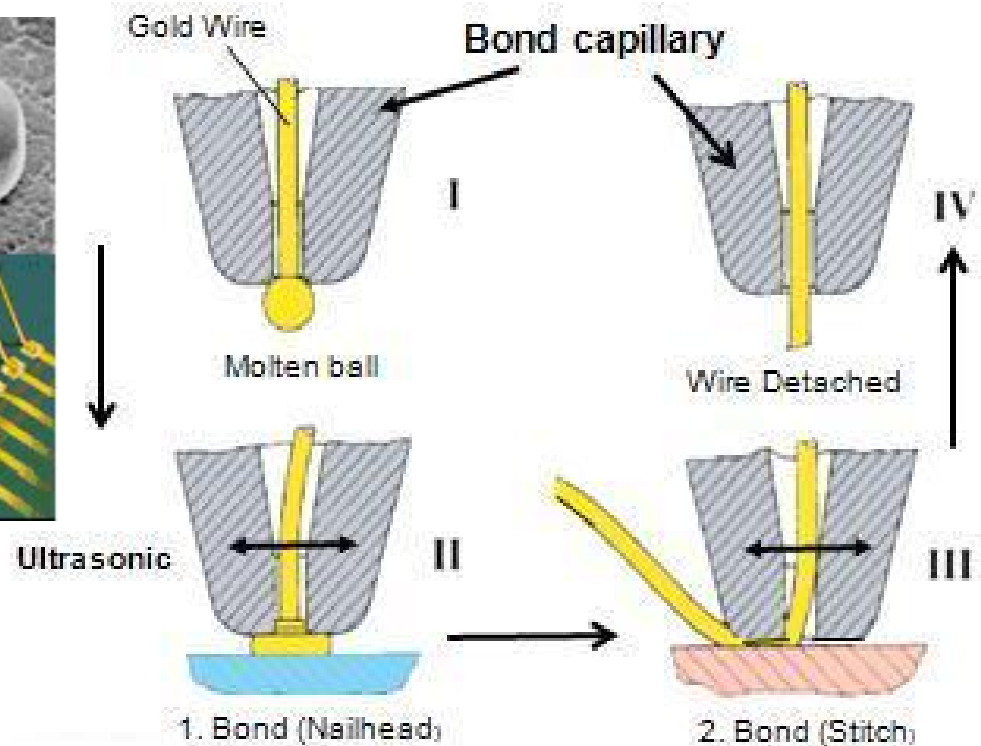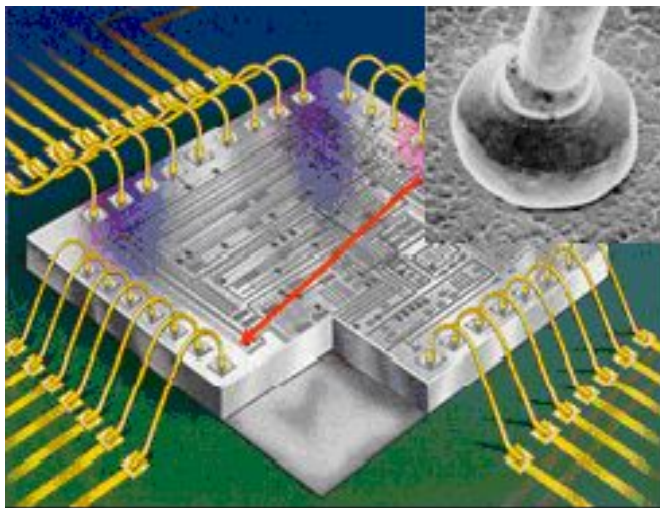# Bonding types: Aluminium wedge

> HEP strip detector default is "Aluminium Wedge wire bonding"
>> Just saw the video
>> Uses a tungsten carbide wedge
>> Usually using 25 (or 17) micrometer AlSi (1%) wire
>> Press wire down (Bond-Force) and vibrate (ultrasonic power) to heat and weld to substrate
>> Go to target, repeat, rip rest of wire off, done

Farbe   Laserintensität   Höhe

Wedge

Feed & Tear Mechanism

Wedge bond length

Wedge bond length

@semipark.

Bonding types: Alternatives

> HEP strip detector default is "Aluminium Wedge wire bonding"
>> Alternatives?
>> **Gold ball bonding**: about 5-10 times faster than Al-Wedge, but bond *surfaces have to be heated to T>125°C*

# Bonding types: Alternatives

> HEP strip detector default is "Aluminium Wedge wire bonding"
>> Alternatives?
>> **Bump bonding**
>>> ■ Expensive expert operation with yield issues
>>> ■ Potentially requires redundant connections
>>> ■ Good for limited area, high density (e.g. pixel detector)
>>>> Not ideal and too expensive for large area strip detector
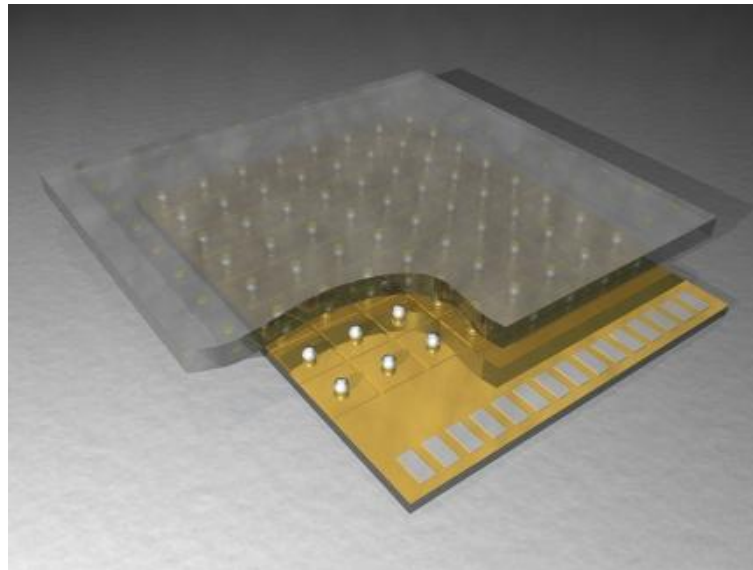
> Will focus on Aluminium Wedge Bonding

Bond steps for a "single wire"

> Steps to bond single wires
>> Set parameters (main ones...):
>>> ■ Xy coordinate setting for both bond feet for each Wire
>>> ■ Z height setting for both
>>> ■ Bond force
>>> ■ US power
>>> ■ "Slow" range before Touchdown
>>> ■ Loop height, shape, height/length Correction
>>> ■ Bond
>>> ■ Check
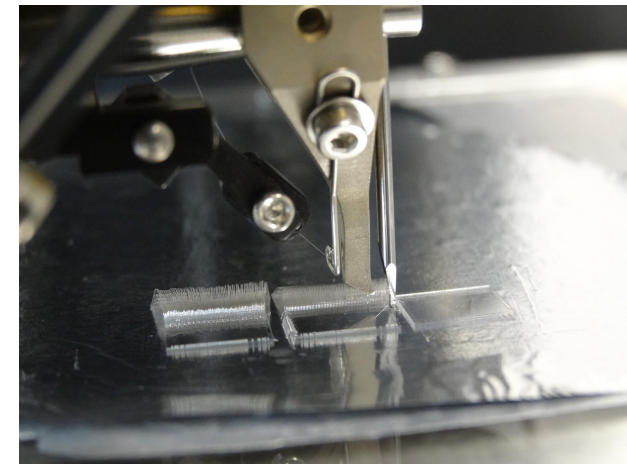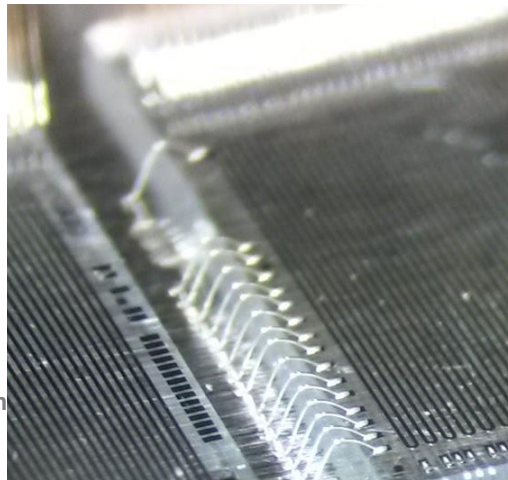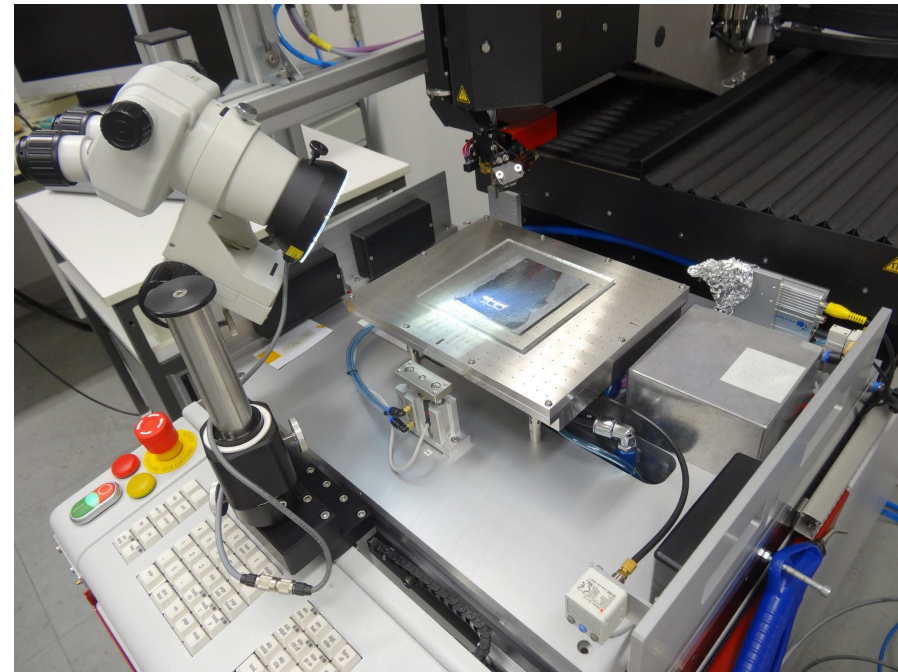
Bond failure modes

> When checking, one mostly discovers all is fine (ideally >99.9% of the time)

> If bond failure, most frequent bond failures are

- Lift off of one of the bond feet. Possible causes:
  - Bad mechanical support
  - Contamination of pads or wire
  - Bad surface quality
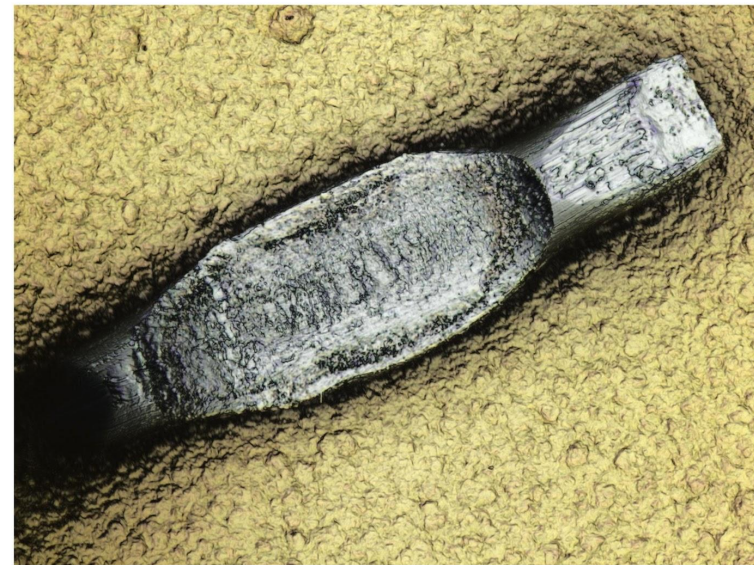- Heel break in one of the wires. Possible causes:
  - Bad support -> force too high
  - Bad surface, e.g. bonding in vicinity of old bond feet
- Leaning wires / short circuits. Possible causes:
  - Uneven surface
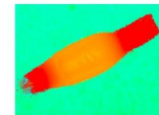 - Torsion on wire in wire spool
  - Clogged or contaminated wedge
- ….

Laser+Farbe   Farbe   Laserintensität   Höhe

Bond programs - beyond single wire

> Video-impression of a running program:
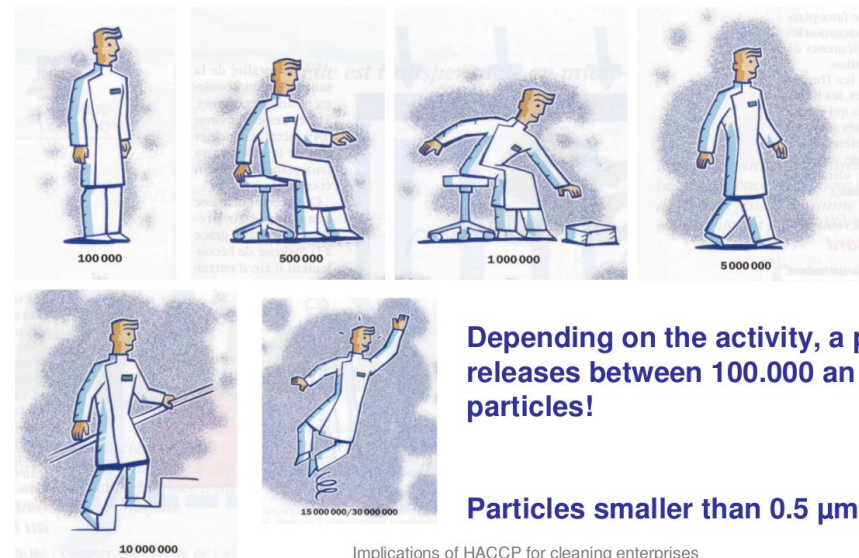
Bond programs - beyond single wire

> Steps for programming
>> Very brief
>>> - Source "chip", target "chip", wires connecting 2 chips
>>> - Xy auto-adjust with pattern recognition
>>> - Height measurement will take place at each chip's first wire
>>> - If long and short wires close by: bond short wires first
>>> - Never do:
>>>> - Define reference pictures on surfaces that can change when bonding (e.g. avoid bond pads), such that one can re-adjust when need for re-bonding comes up

Behaviour in Bond-labs - a few items

> Prepare environment and work cleanly and carefully
>> Preparation for work item (cleaning, jigs, bond plan)
>> Behaviour / cleanliness
>>> Many things have to be learned "on the job"
>>>> Move slowly, dress in cleanroom gear, don't touch bare skin...
>>>> Appreciate the delicacy of wire bonds
>>>> Learn to manipulate at micrometer scale
>>> failure to work cleanly leads e.g. to contamination
>>>> Either "only" a few missing wires
>>>> Possibly "rotting wires" once bonded object is subjected to high humidity (ATLAS IBL)

Humans are producers of particles

100 000   500 000   1 000 000   5 000 000

10 000 000   15 000 000/30 000 000

Depending on the activity, a person releases between 100.000 an 30 Mio particles!

Particles smaller than 0.5 µm per min

Implications of HACCP for cleaning enterprises
Module 4 - Cleanroom cleaning

# Transition to Q&A… List of possible items to talk on about

> Usual non-day-to-day items
>> Change wire
>> Change tool/wedge
>> Calibate xy "Spider"
>> Infrastructure check
>> clean!
> Typical difficulties - could be used as transition for Q&A
>> Bond plan - produce, use, iterate, improve
>> Contaminations
>> Bond-aware design: ASIC/die related
>>> bond pads (size, placement)
>>> few bond head turns?
>> Bond-aware design: Hybrid/Package related
>>> bond pads (size, etching, placement, surface quality,...)
>>> Obstacle placement (SMDs, connectors,...)
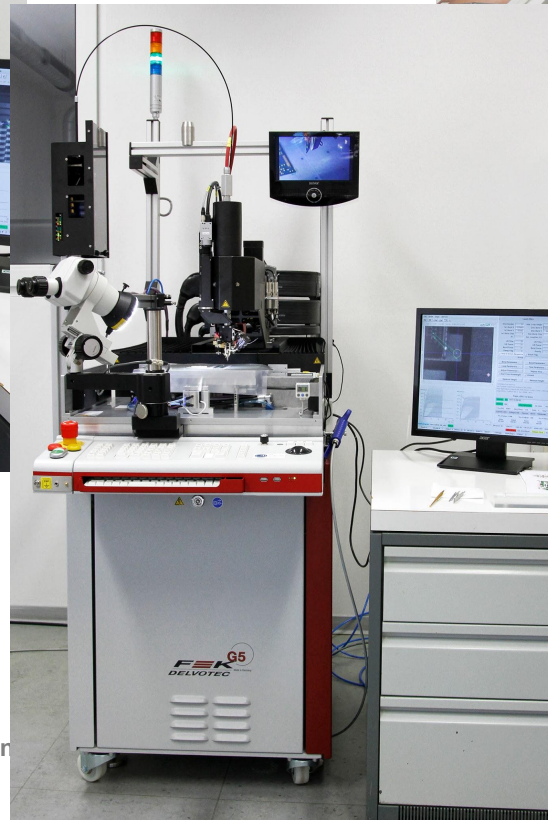>>> Fiducials
>>> Mechanical support of bond areas

Some pics
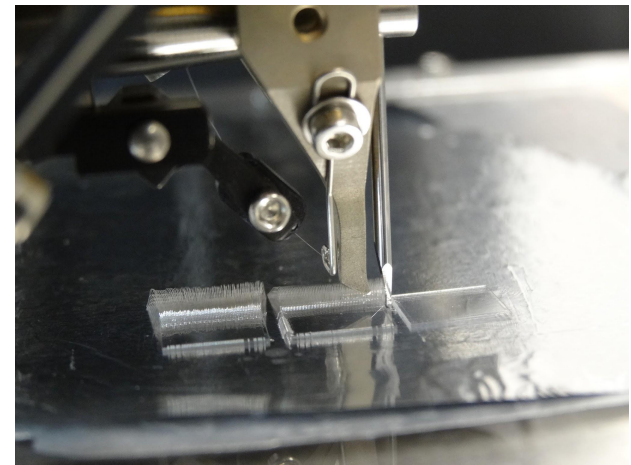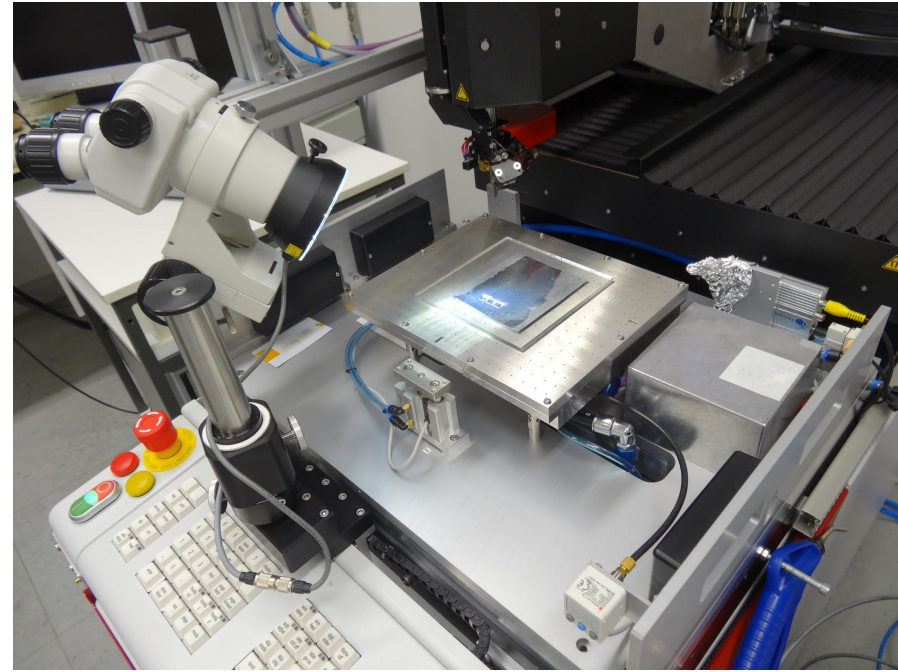
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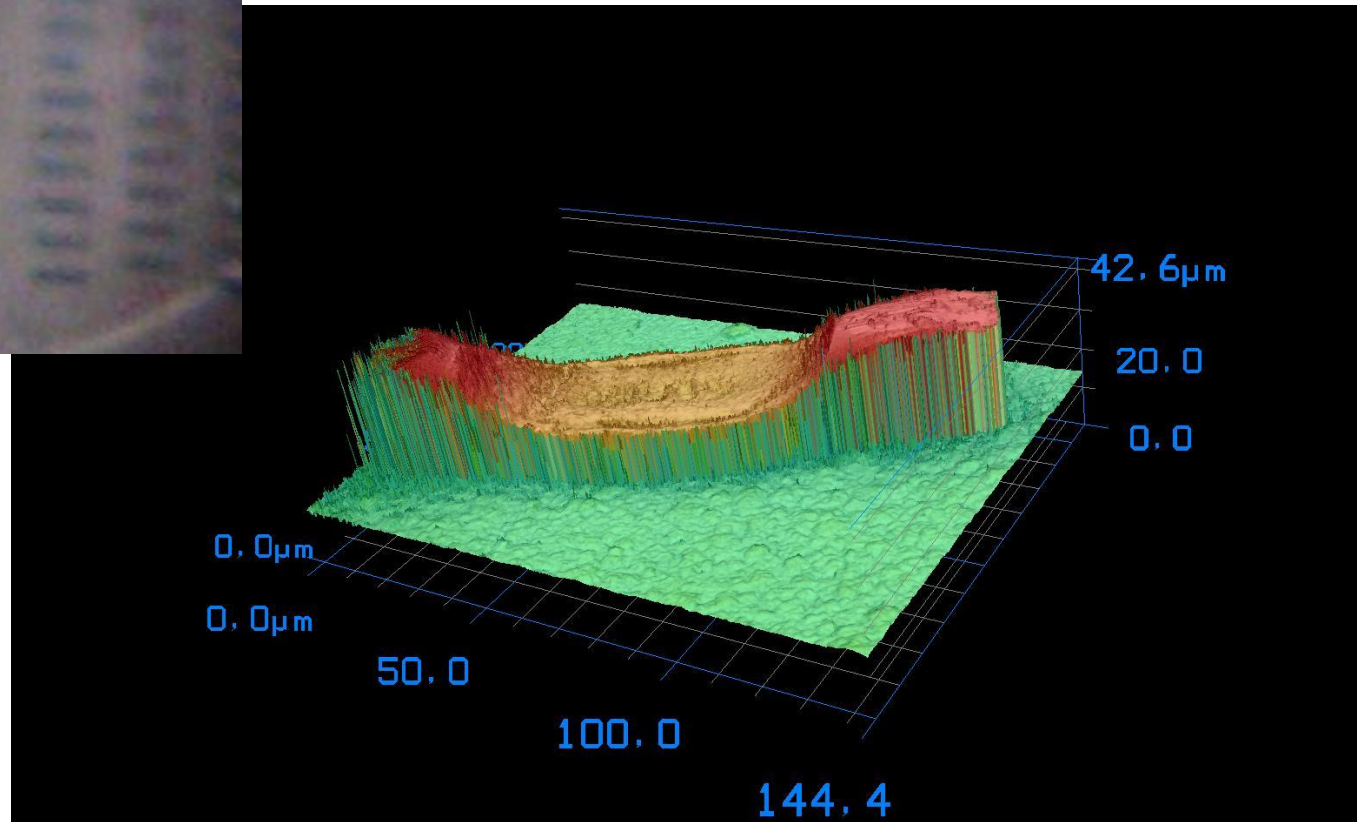
Some pics

Wire-Bonding - Prototype Module