Rework of Flip Chip Bonded Radiation Pixel Detectors

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Outline

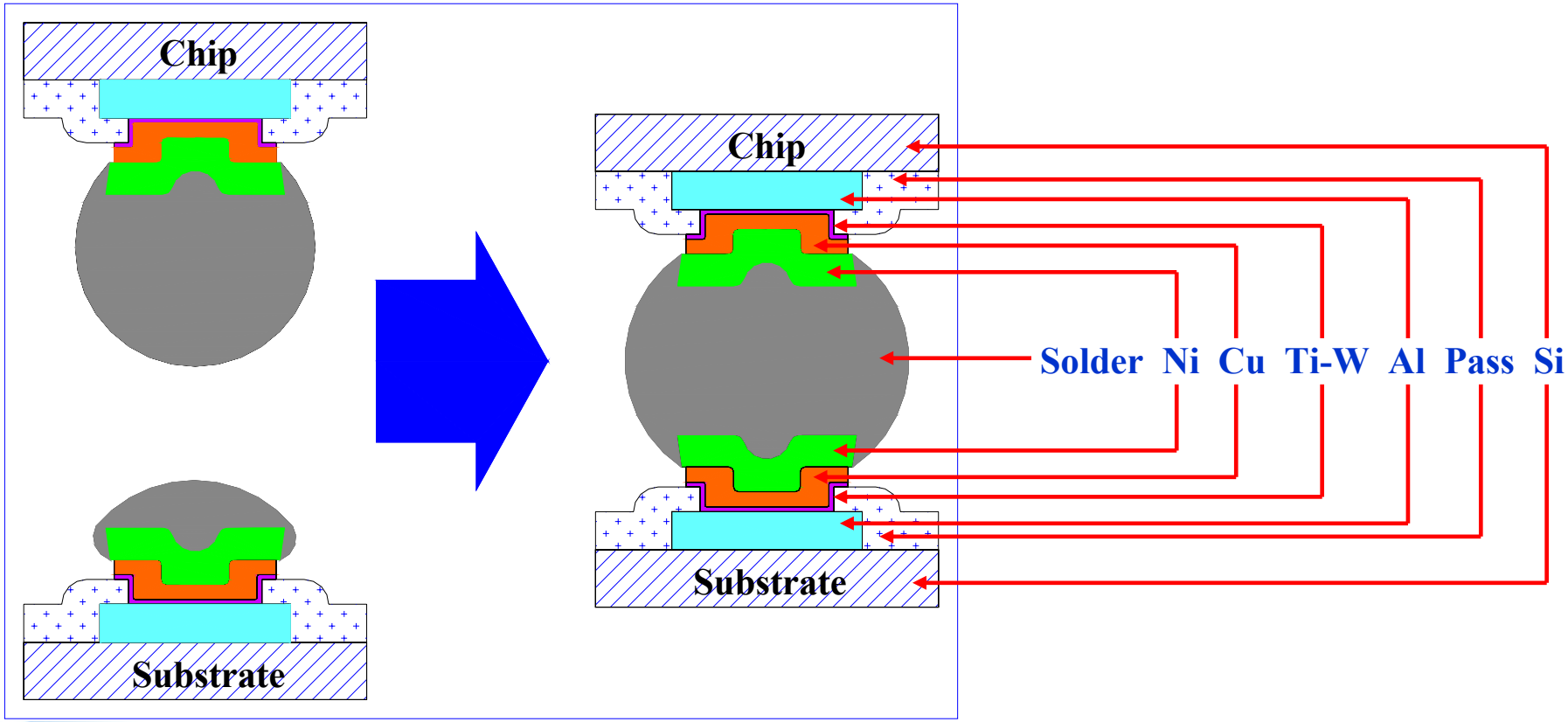
- Introduction
- Solder Bump Structure
- Rework Procedure
- Rework Yield (Case: ALICE ladders)
- Summary

Introduction

- **Rework = removal of bad flip chip bonded chip from substrate, and replacing it with new, operational, chip.**
- **High accuracy flip chip bonding is slow and, consequently, expensive.**
- **As the number of flip chip placements increases on single substrates, the probability of a flaw or failure in the multichip device increases.**
- **Therefore, rework is motivated by time and financial considerations.**

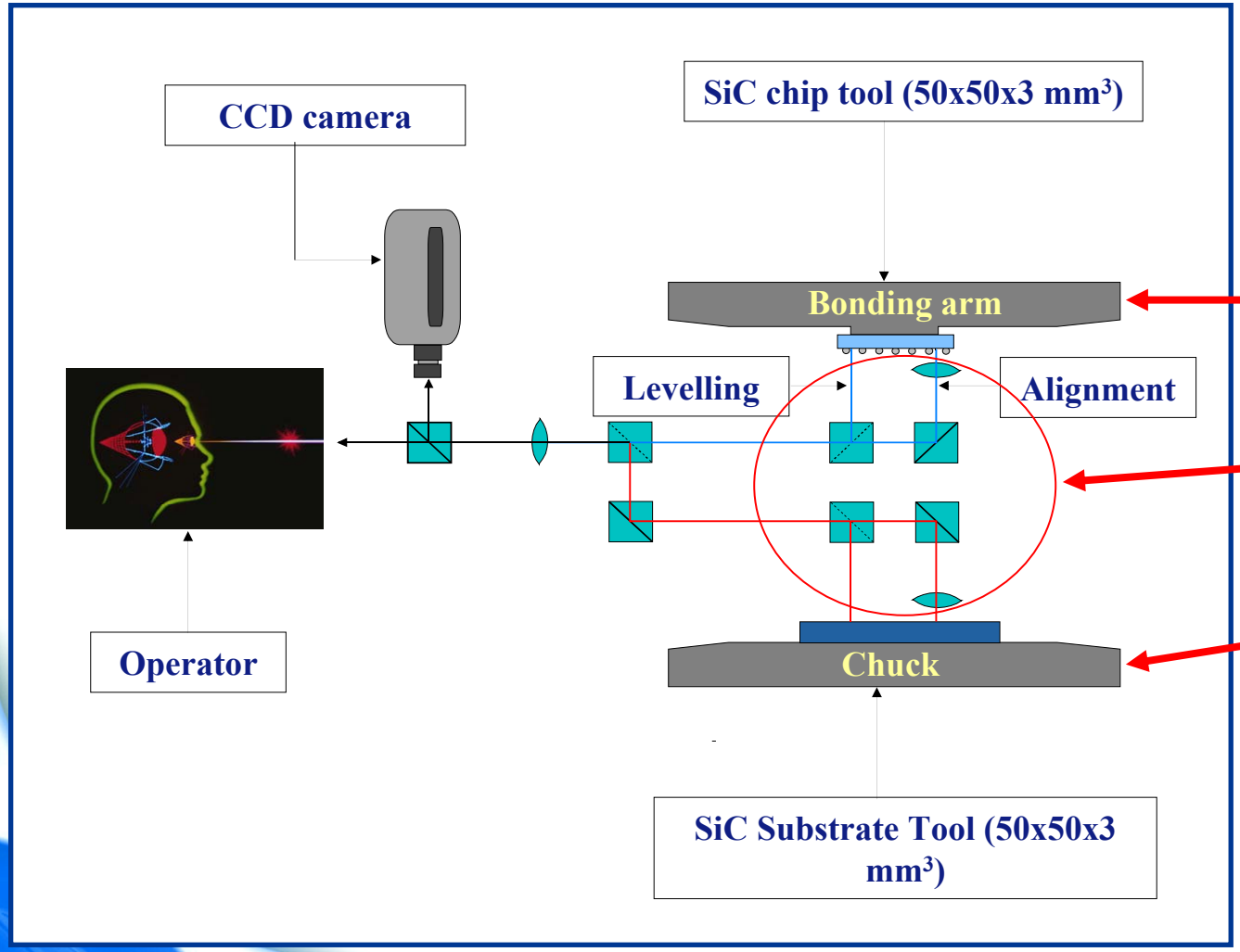
Solder Bump Structure

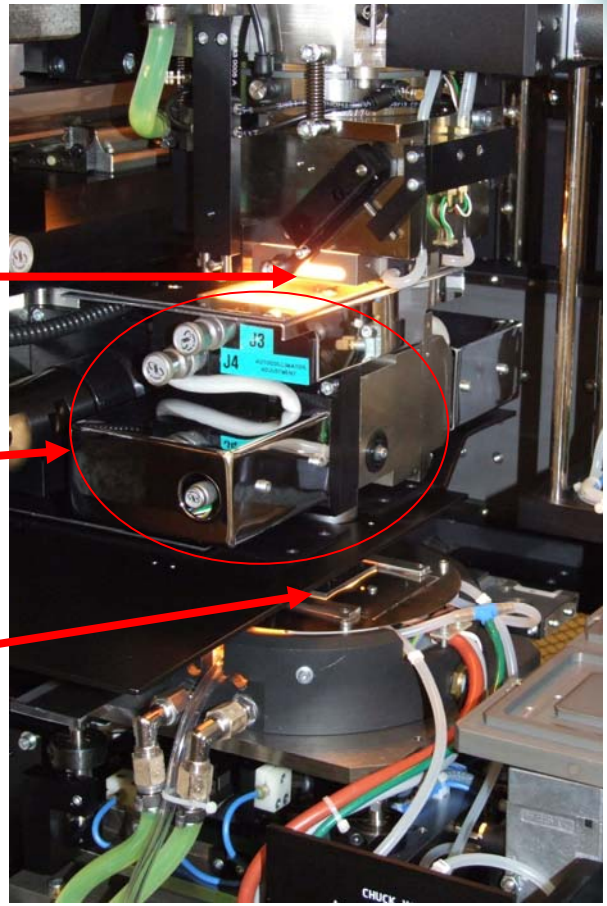
- From flip chip point of view, structures are identical on chip and substrate side, except for solder volume.
- Ti-W & Cu are sputtered seed layers; Ni & solder are electroplated layers.



Equipment: Flip Chip Bonder

- **Faulty readout chip is removed using flip chip bonder.**

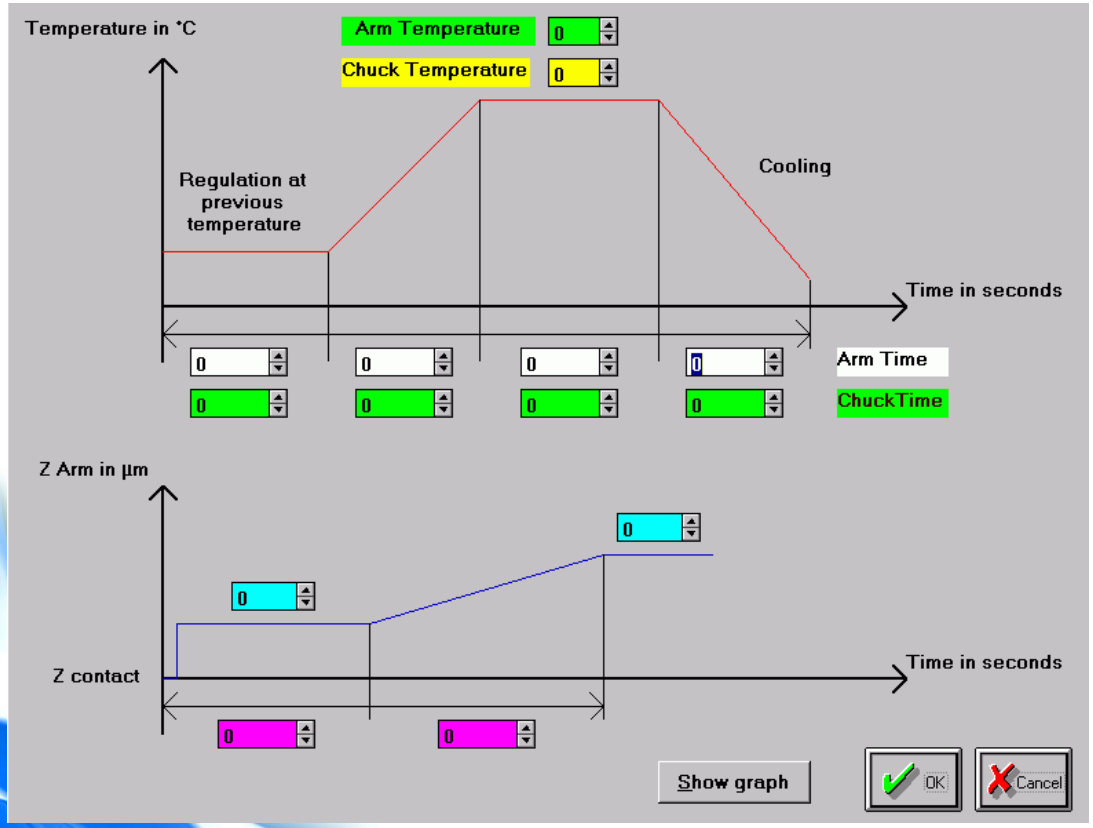


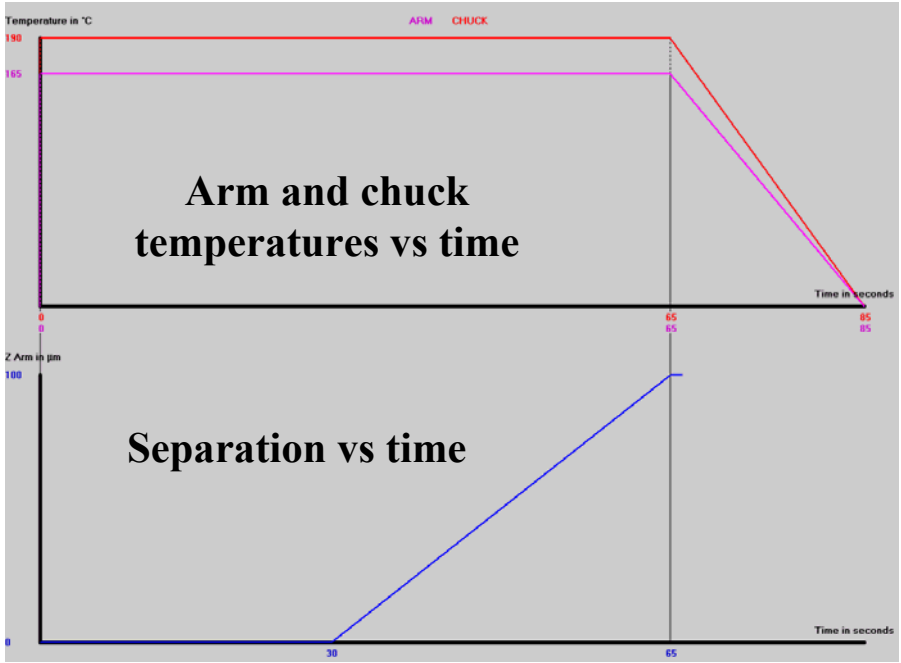


Rework Parameters on Flip Chip Bonder

Flip chip bonding and rework operations are done with same bonders:

- **Different temperatures can be set for arm and chuck.**
- **Two-step pulling-apart distance and rate of separation can be programmed.**
- **Heating and cooling times can be controlled.**





Rework Steps

Step 1: Select suitable candidate for rework.

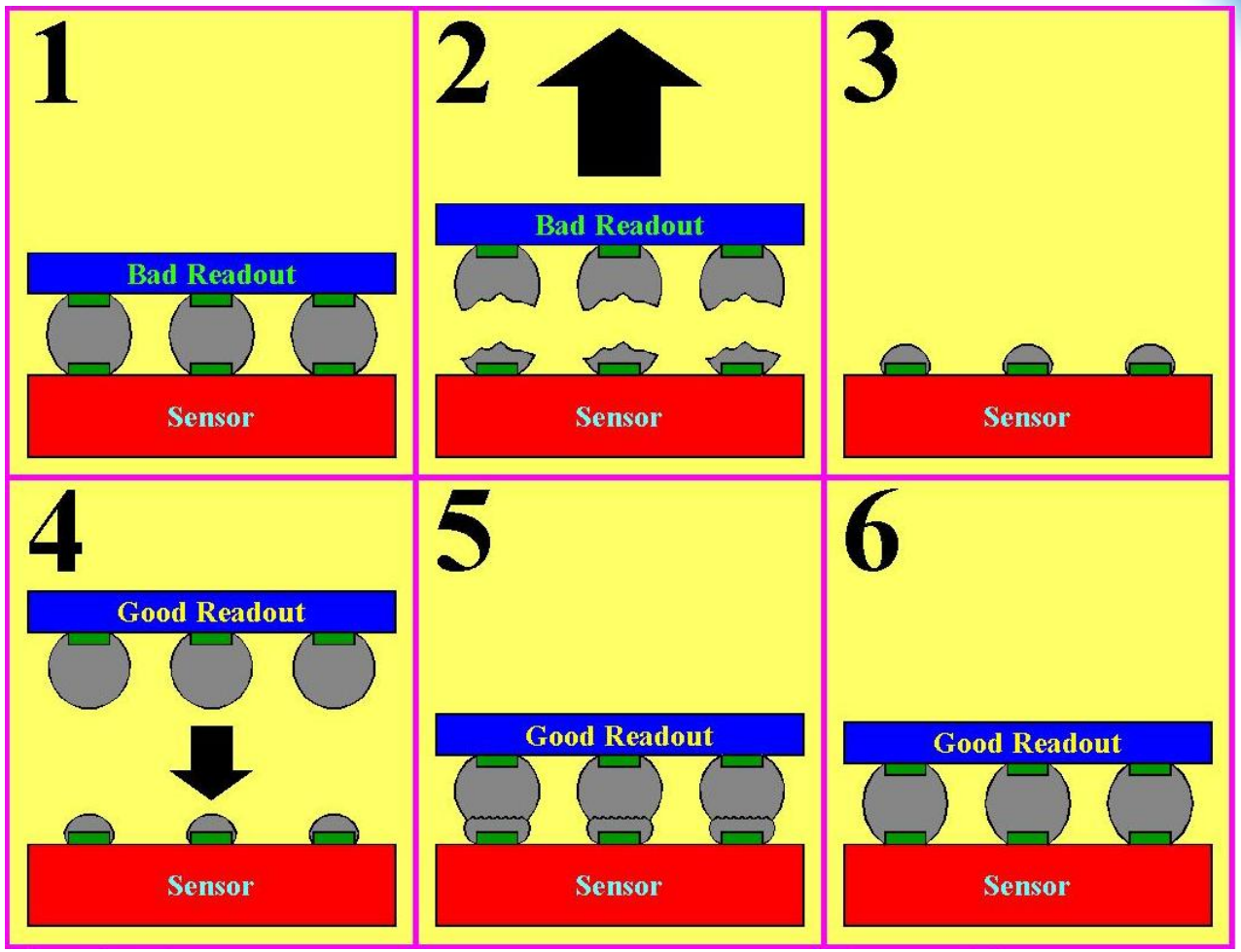
Step 2: Remove bad chip.

Step 3: Do reflow for sensor.

Step 4: Align replacement ROC.

Step 5: Tack bond replacement readout chip.

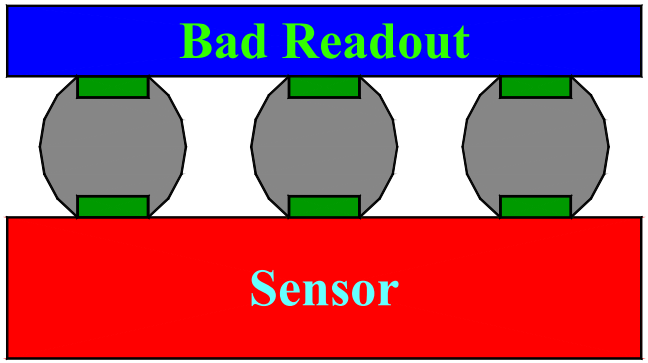
Step 6: Do assembly reflow.



Rework Procedure: Step 1

Step 1: Starting Point

Bad readout chip has been identified, and needs to be replaced.



Typical reasons for replacement:

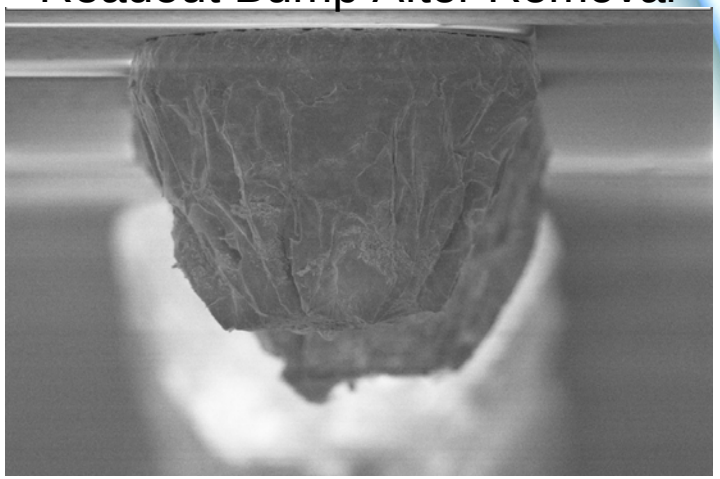
- Too many bad bump contacts in chip area – open contacts and / or shorts.
- Malfunction of readout chip.

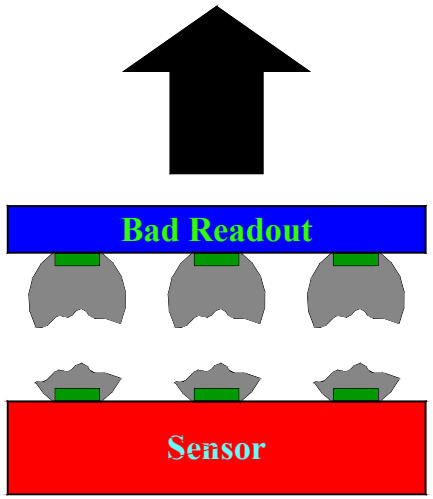
Rework Procedure: Step 2

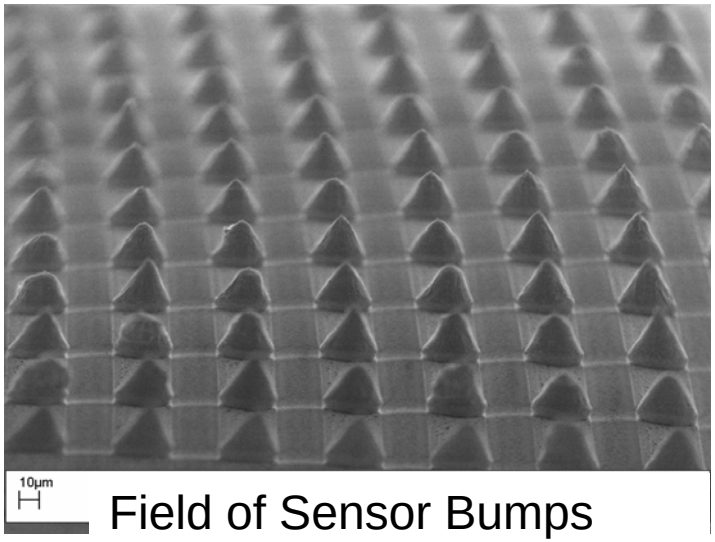
Step 2: Removal of Bad Chip
Bad readout chip is pulled apart from sensor in controlled manner on flip chip bonder. Heating is applied to sensor and readout chip to facilitate proper division of solder volume at separation.

This is the most critical step in rework process. If the UBM layers come off with the bumps from either side, the pixels will be lost in the final detector.

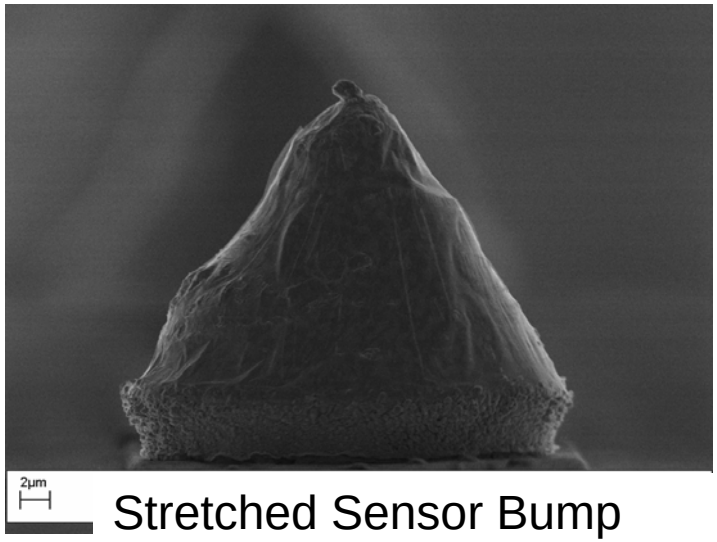
Readout Bump After Removal







Field of Sensor Bumps



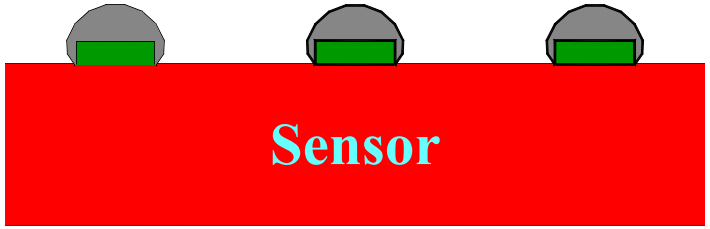
Stretched Sensor Bump

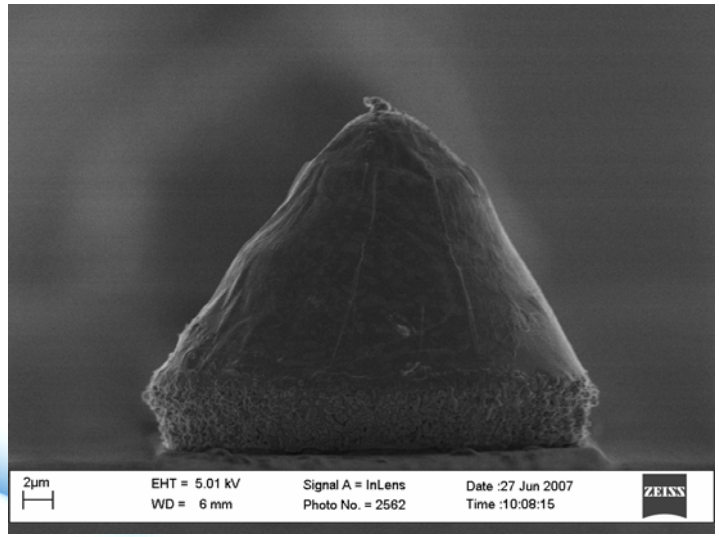
Rework Procedure: Step 3

Step 3: Sensor Reflow

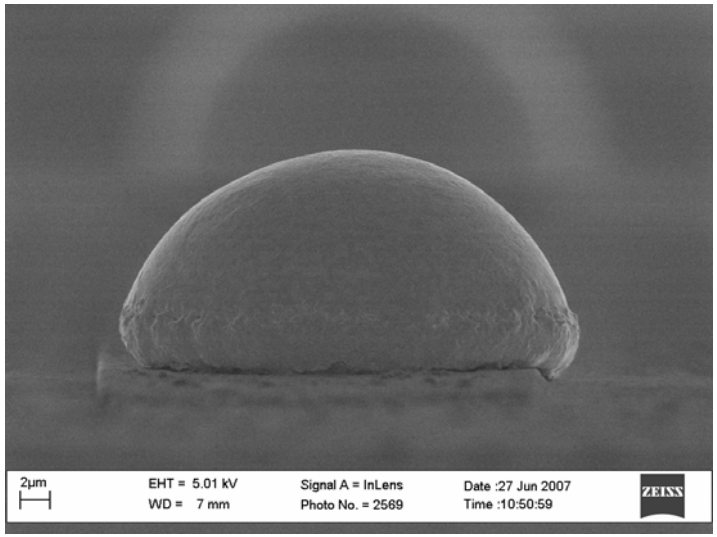
After bad readout chip has been removed, sensor is run through reflow in Ar/formic acid ambient.

Formic acid reduces oxides on bump surfaces and their shape changes back into hemisphere again. Formic acid decomposes around 200 °C and leaves no visual residues on wafers





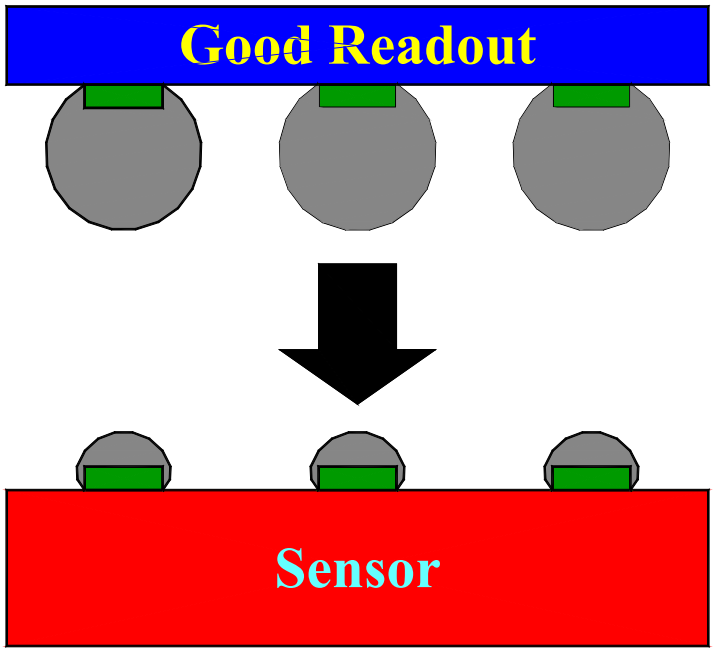
Reflow

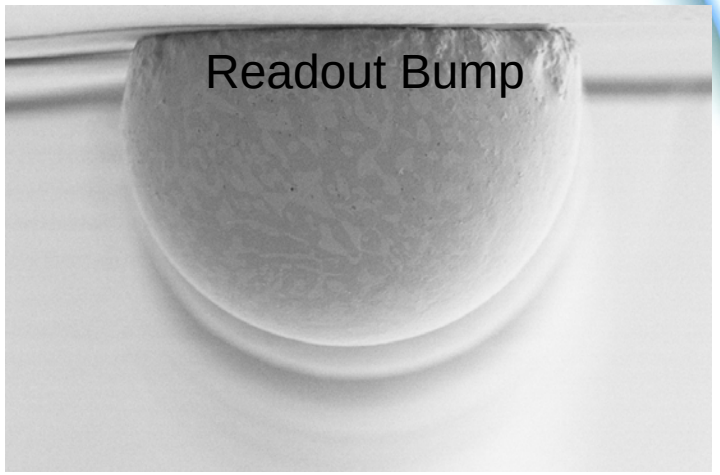


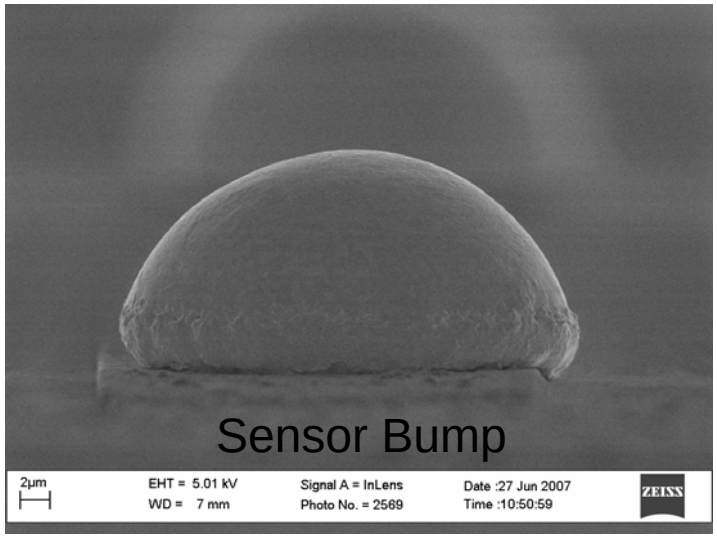
Rework Procedure: Step 4

Step 4: Alignment of New ROC

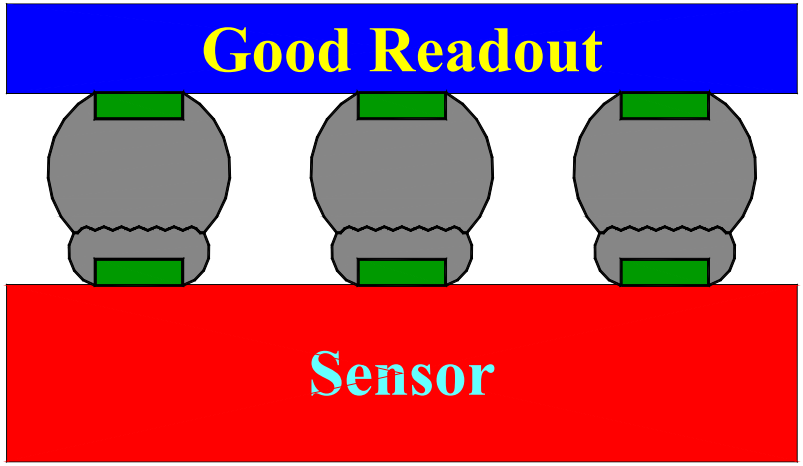
New (replacement) readout chip (with bumps) is aligned and set parallel to sensor on flip chip bonder.





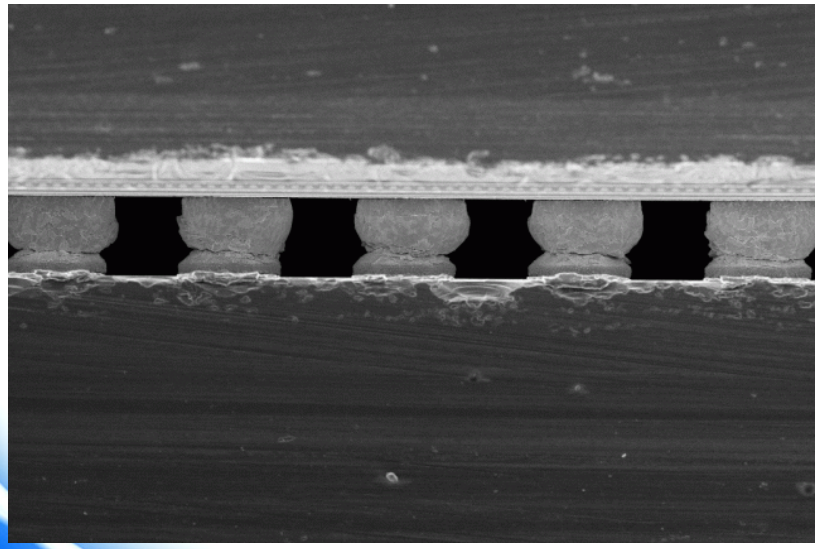


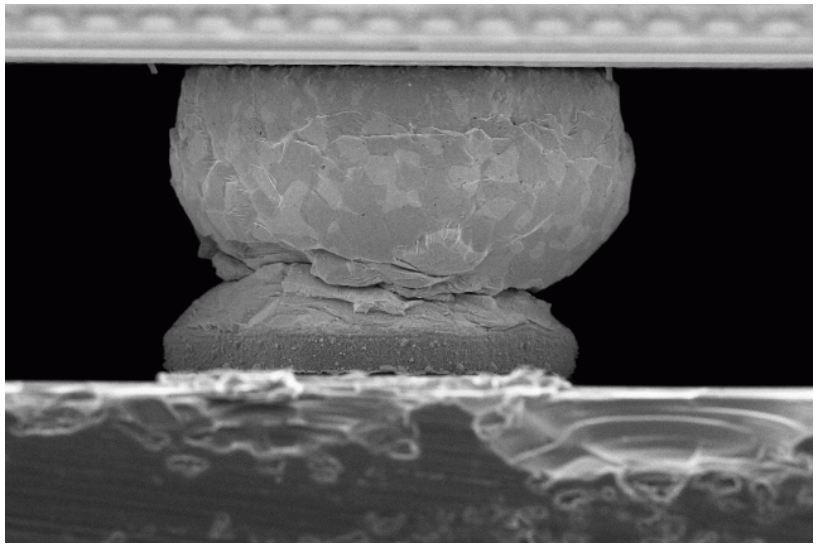
Rework Procedure: Step 5



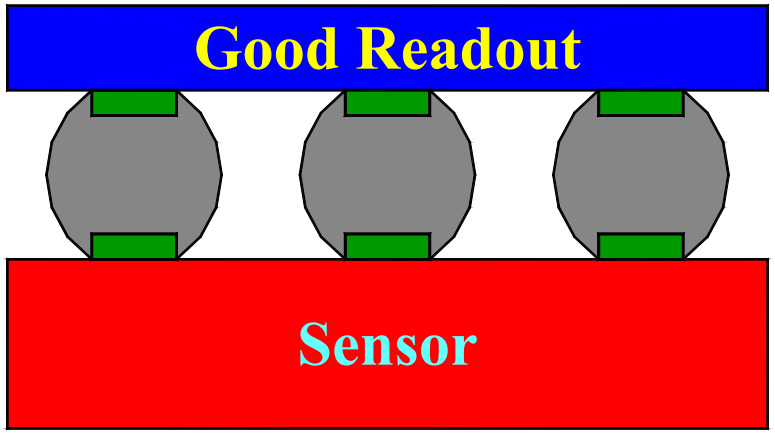
<u>Step 5: New ROC Tack Bonded onto Sensor</u>

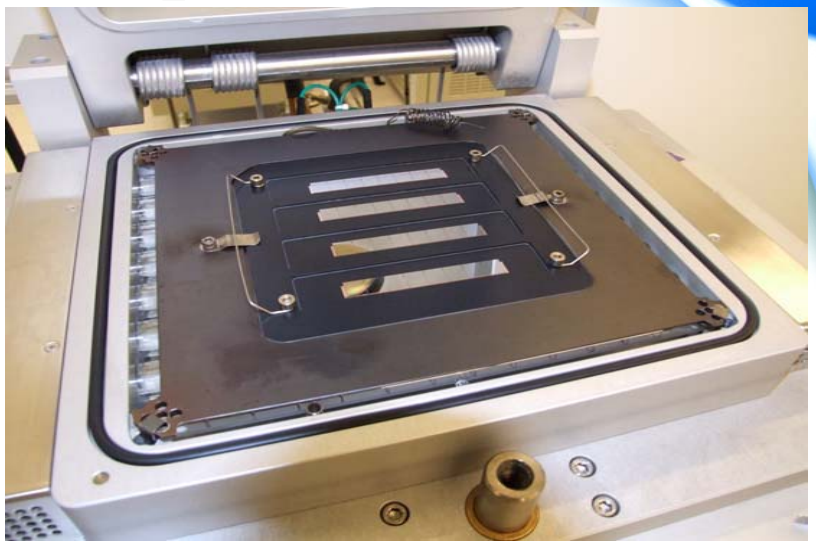
New (replacement) readout chip is tack bonded onto sensor to replace bad one.





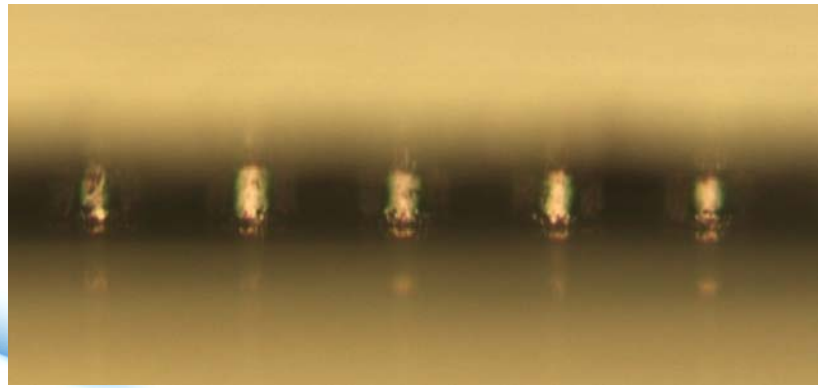
Rework Procedure: Step 6

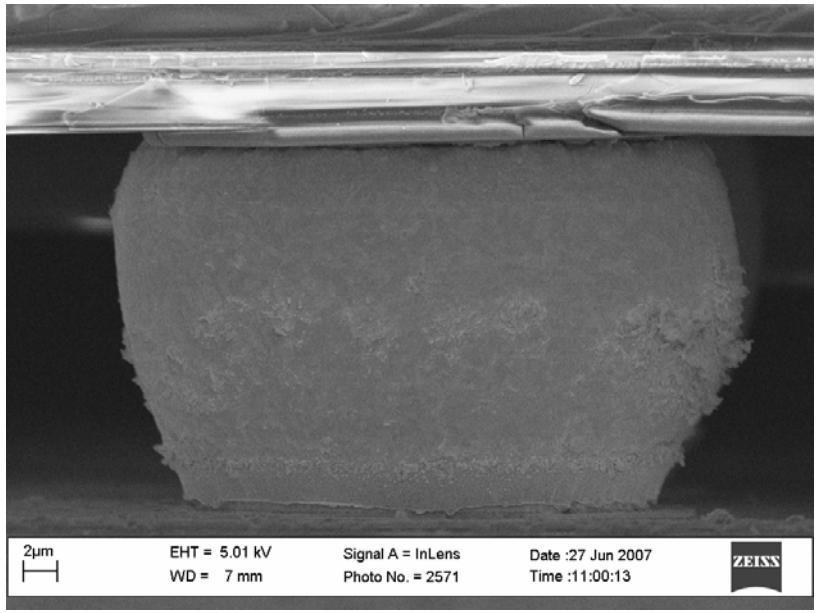




<u>Step 6: Final Assembly Reflow</u>

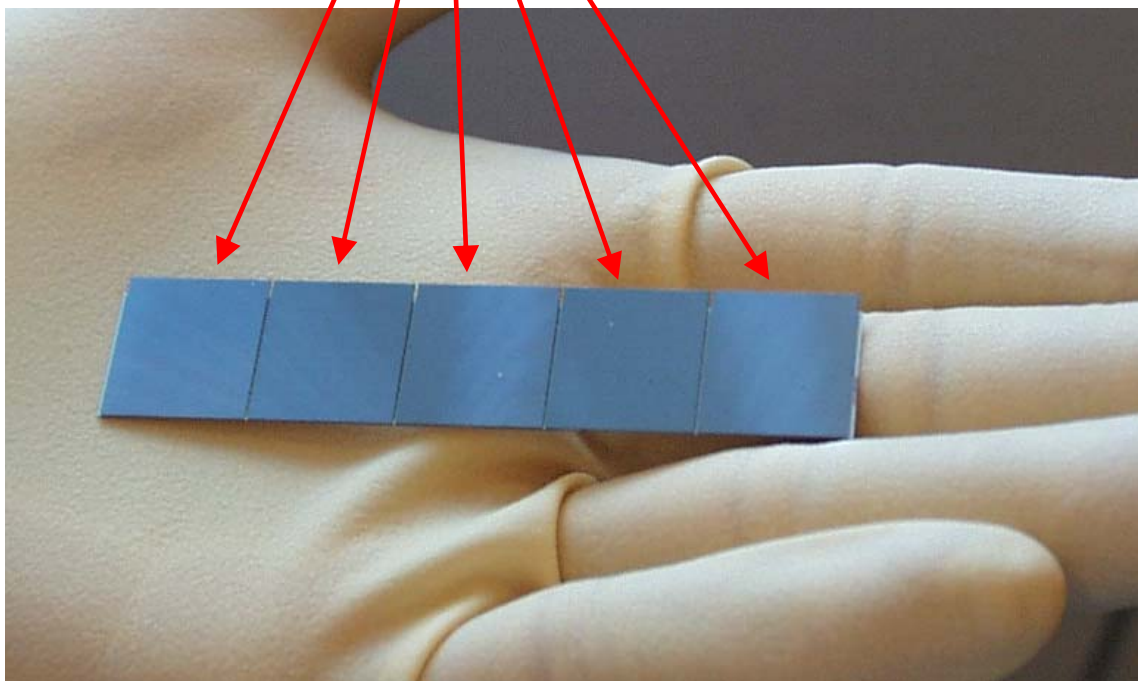
After tack bonding, assembled detector is run through final Ar/formic acid reflow.





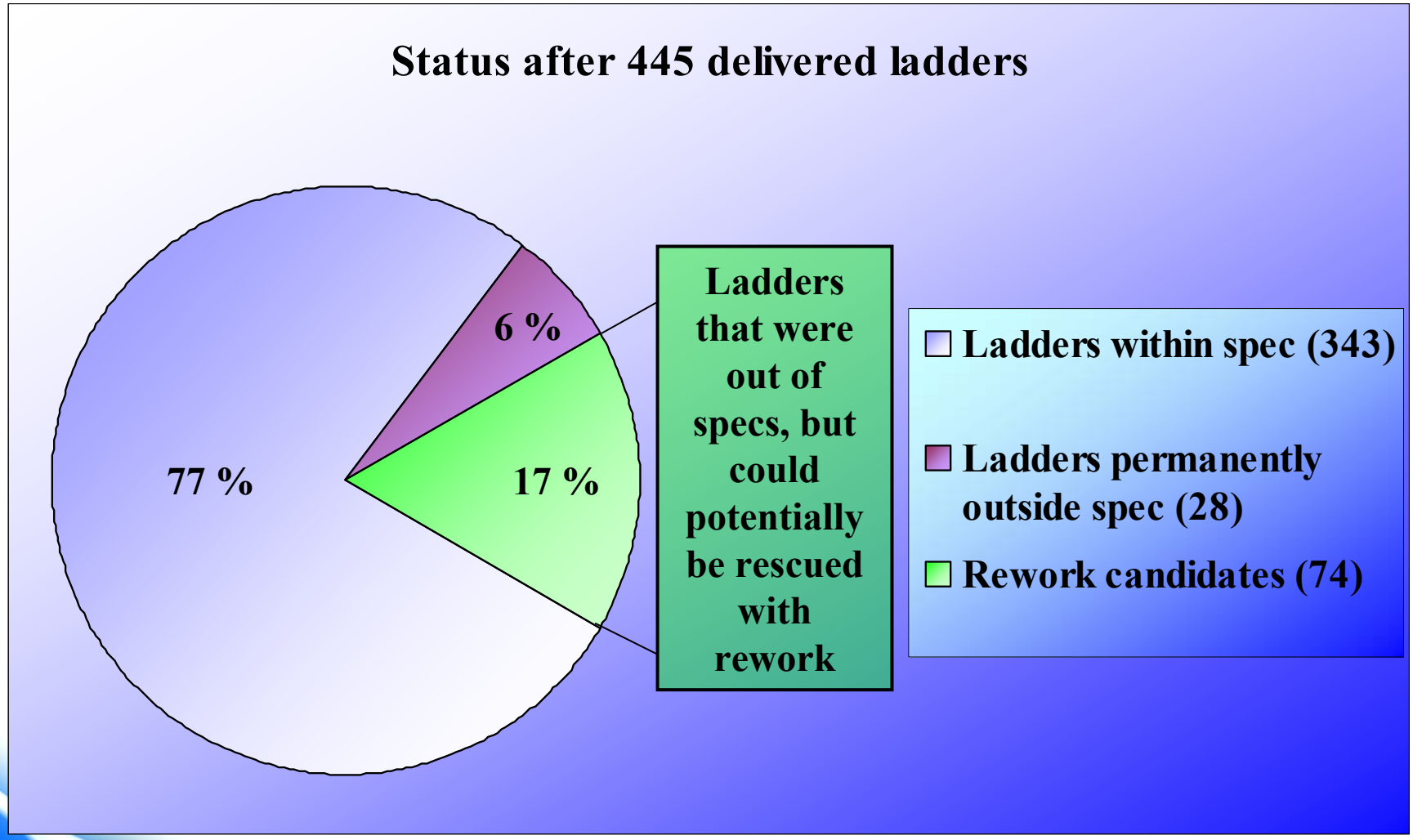
Case: ALICE Ladder Detectors

ALICE SPD consists of 240 1x5 'ladders' (five readout chips bonded onto single sensor chip).



- **Sensor chip size for each ladder is 70.7 x 13.9 x 0.200 mm^3.**
- **Readout chip size is 13.5 x 15.8 x 0.150 mm^3.**
- **There are 8,192 eutectic Sn-Pb solder bumps (32 columns x 256 rows) between each readout and the sensor.**

Rework of ALICE SPD 'Ladders'



Reworkable Defects

Rework may be useful if…

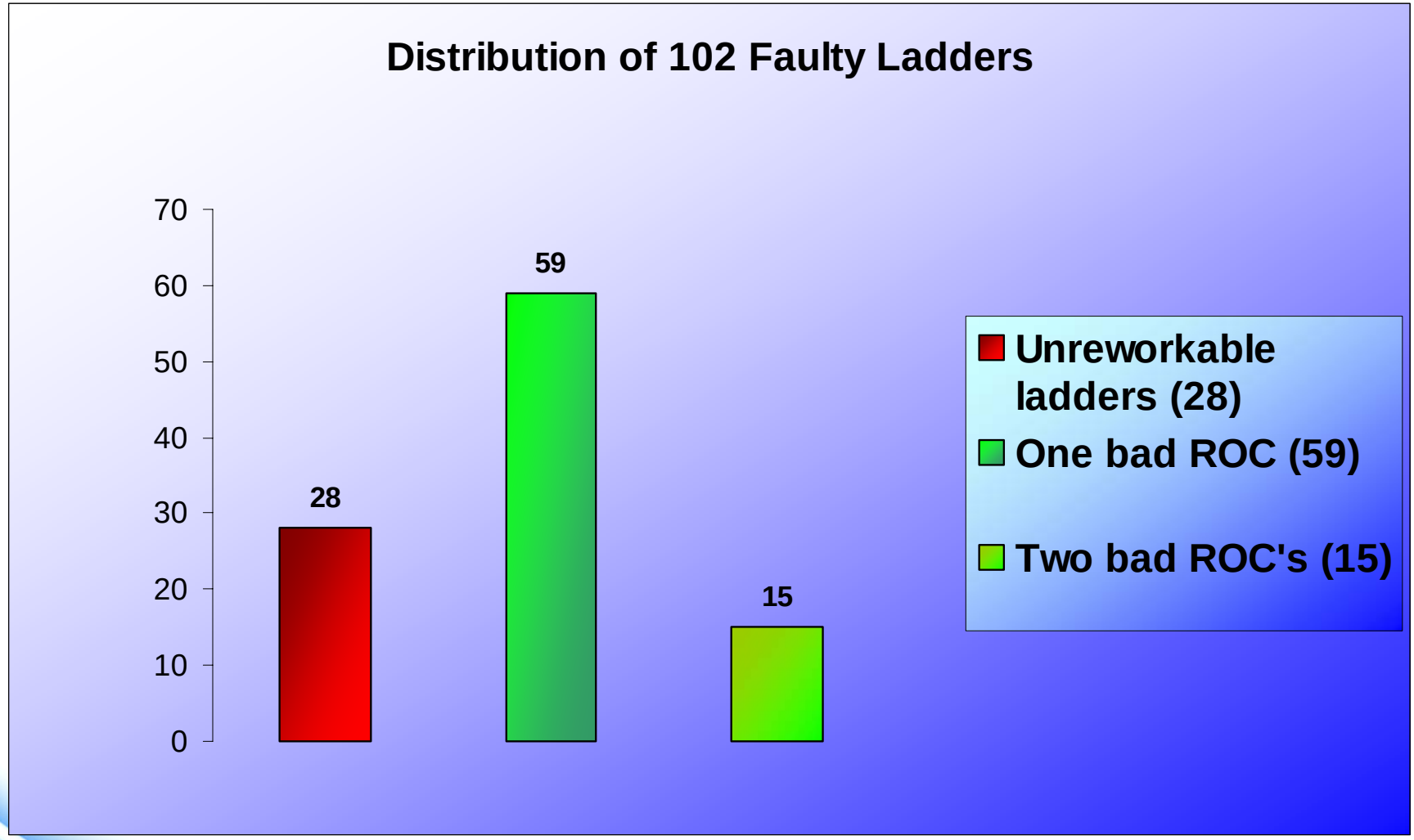
- **Replacing malfuntioning readout chips.**
- **Replacing bad bump bonds with readout chip – typically open bump contacts and/or shorts.**
- **Readout chip has some visible defects, e.g., destroyed probing / wire bonding pads.**

Rework isn't worthwhile if…

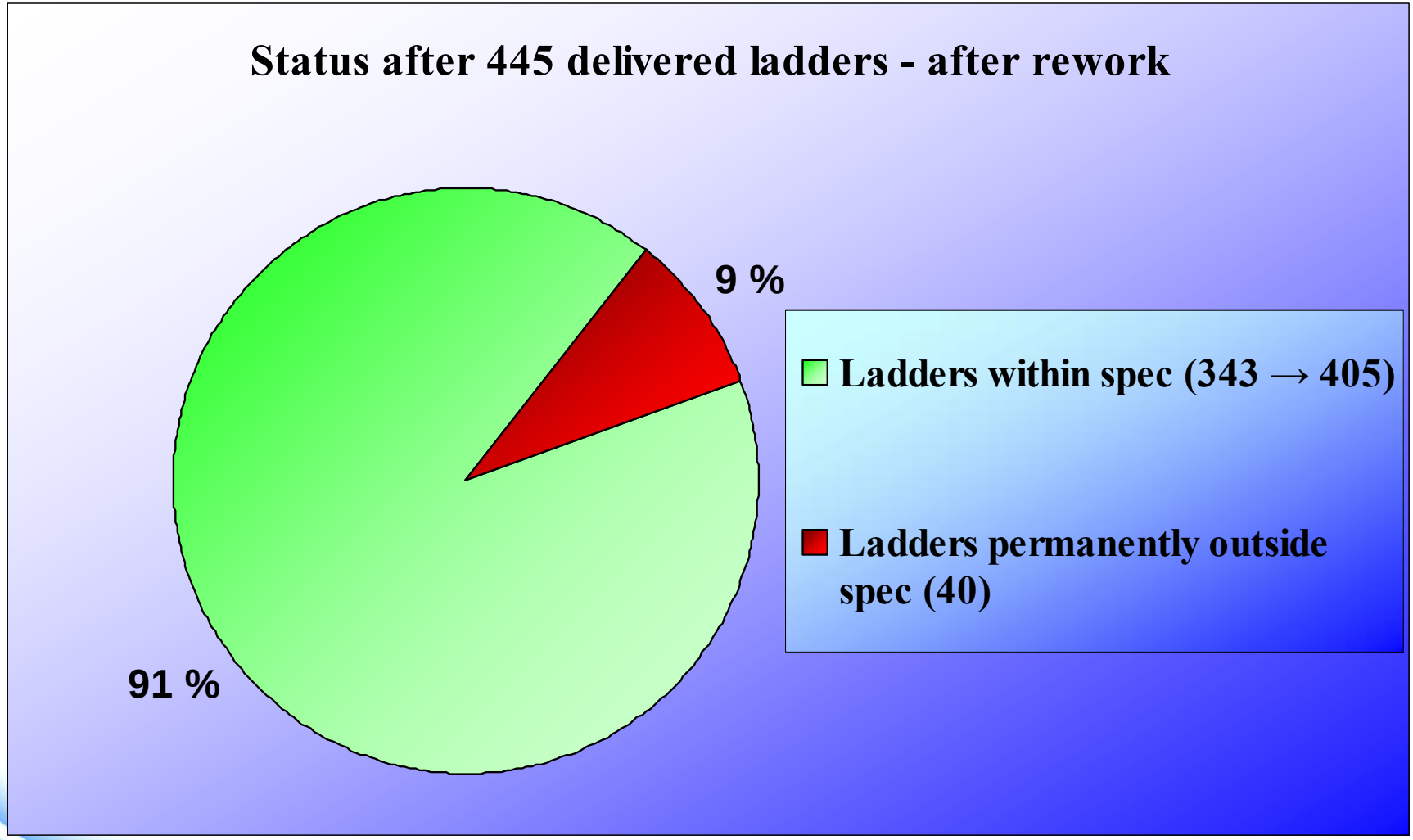
- **Sensor's leakage current is outside specs – replacing readout chip would provide no improvement.**
- **Sensor has been damaged somehow and it cannot be recovered.**

- **It was considered for ALICE project that it was worthwhile to replace one to two readout chips (out of five) on detector ladder. Three or more replacements, although possible, would almost represent more work than building new ladder from scratch.**

Rework of ALICE SPD 'Ladders'



Rework of ALICE SPD 'Ladders'

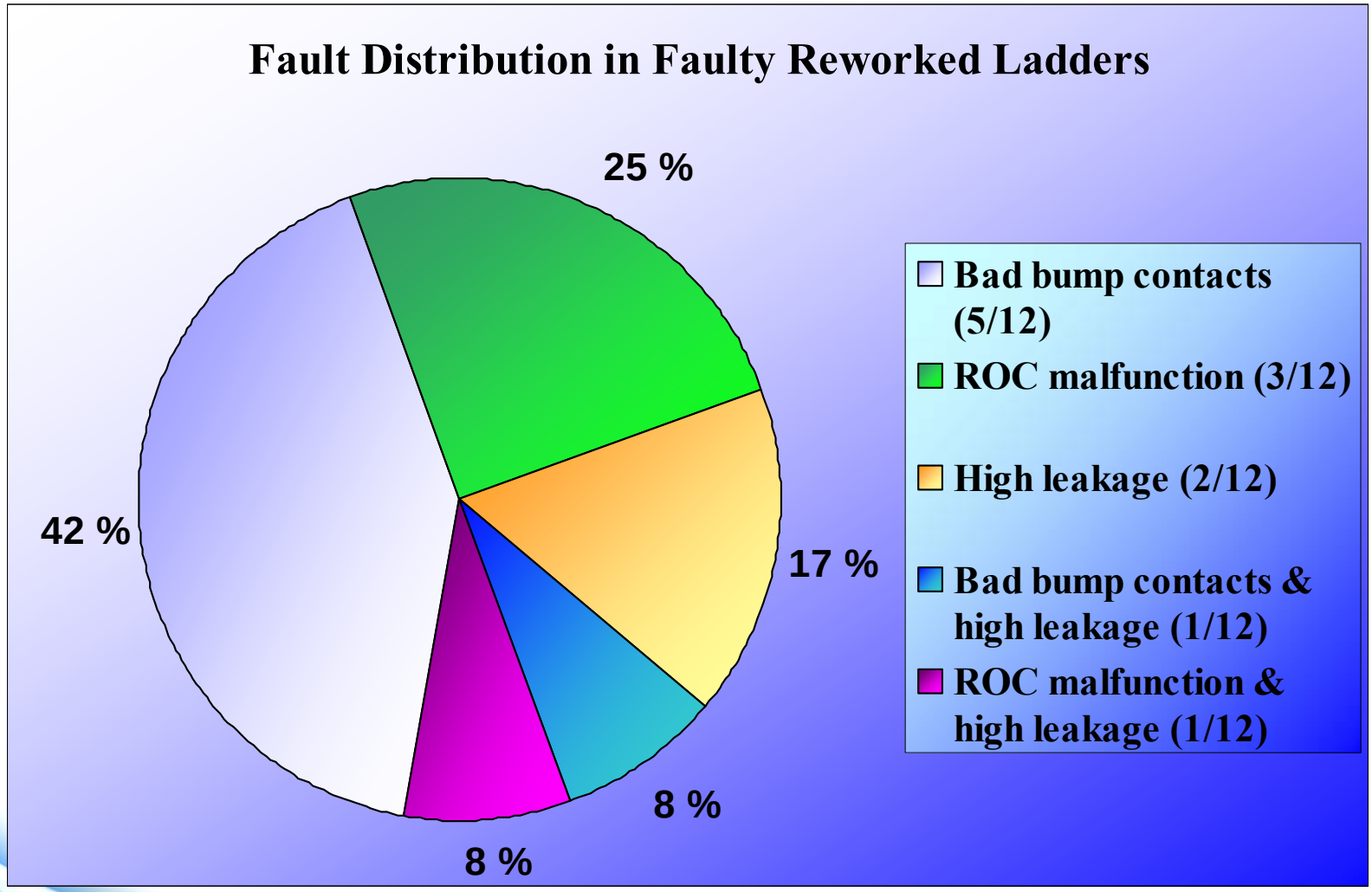


Rework Yield Numbers of ALICE SPD 'Ladders'

Yield of individual chip replacements:		
Number of ROC's replaced:	89	
Successful replacements:	80	
Unsuccessful replacements:	9	
Chip-level rework yield:	90	%
Yield of complete ladders:		
Number of ladders reworked:	74	
Successful ladder reworks:	62	
Unsuccessful ladder reworks:	12	
Ladder-level rework yield:	84	%

Post-Rework Fault Distribution

- 12 of the 74 reworked ladders were still 'bad' after rework.



Summary

- Background and motivation for rework was first introduced.
- Solder bump structure was described.
- Steps in rework procedure were explained.
- Data from ALICE ladder detectors was presented, giving chip-level and ladder-level rework yields of 90 and 84 per cent, respectively.
- Solder bump flip chip process without underfill has good potential for rework.
- The authors wish to thank Petra Riedler and Fadmar Osmic (of CERN) for providing test results, and for useful discussions.