ORION CONFERENCE

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Flip-Chip Assembly for Focal Plane Array

Jean-Stéphane MOTTET

SET CORPORATION S.A.

Smart Equipment Technology, France

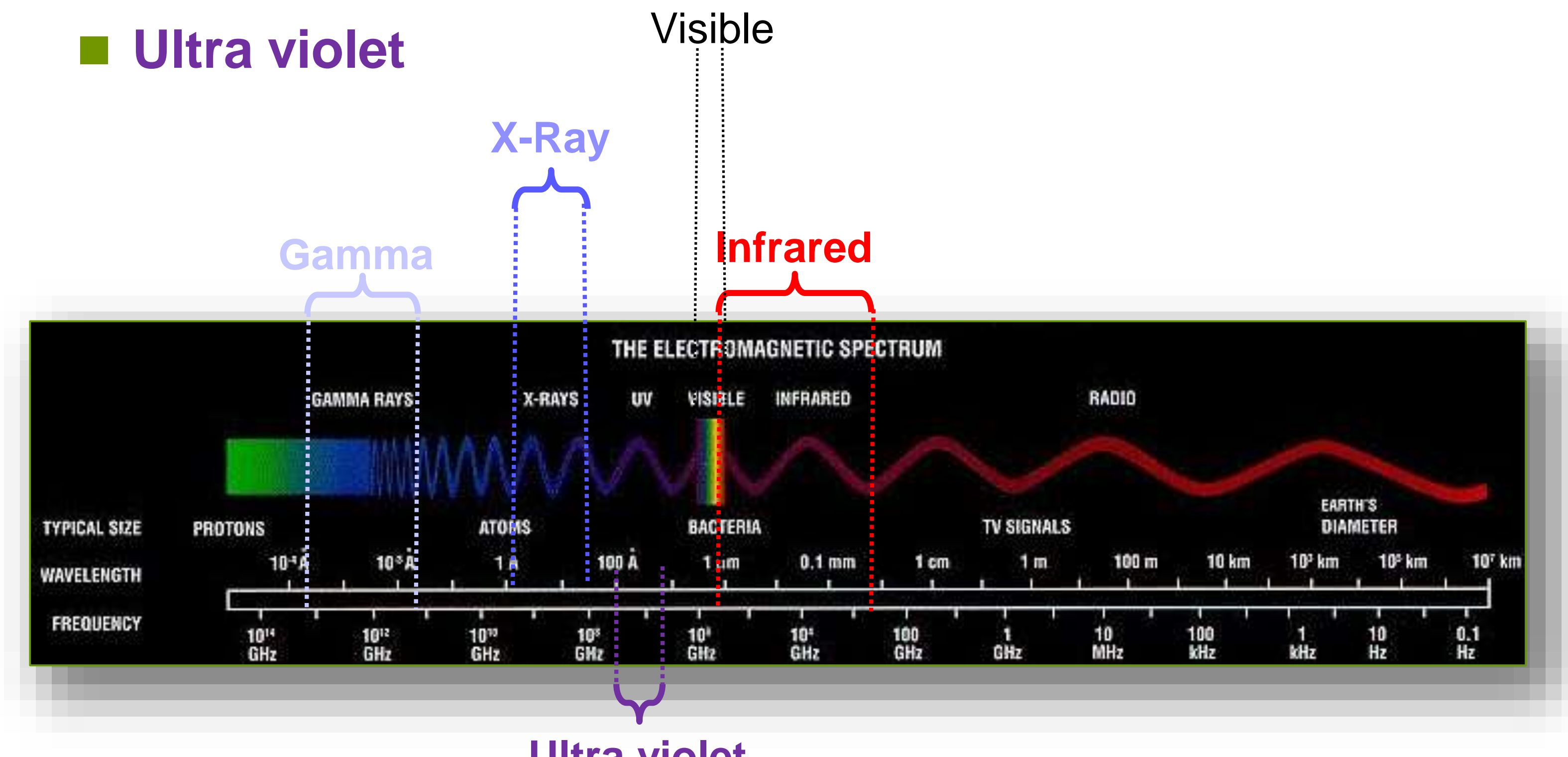
OUTLINE

Flip-Chip Assembly for Focal Plane Array

- Wave lengths
- Applications
- Materials
- Flip-chip assembly
- SET experience and solutions
- Conclusion

WAVE LENGHT

- FPA can detect different wave lengths:
  - Infrared
  - X-Ray
  - Gamma
  - Ultra violet



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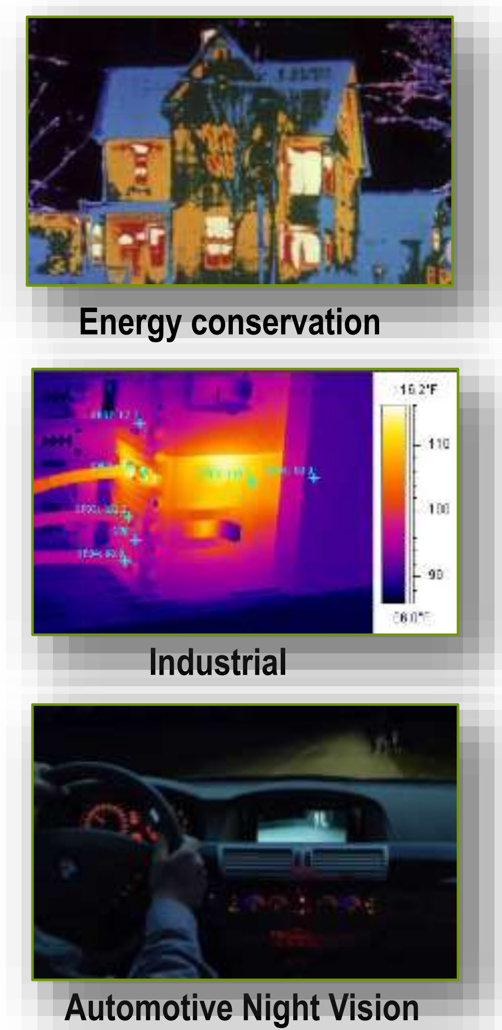
SOME APPLICATIONS

- **Infrared is the radiation of heat energy, related to the temperature of objects**

INFRARED APPLICATIONS



Energy conservation

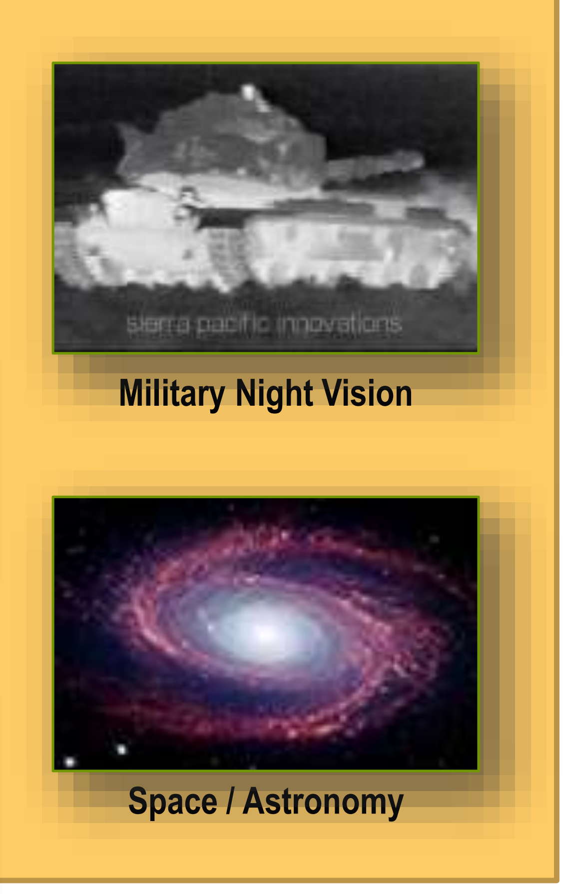
Industrial

Automotive Night Vision

Weather Satellites

Security/Law Enforcement

Medicine



Military Night Vision

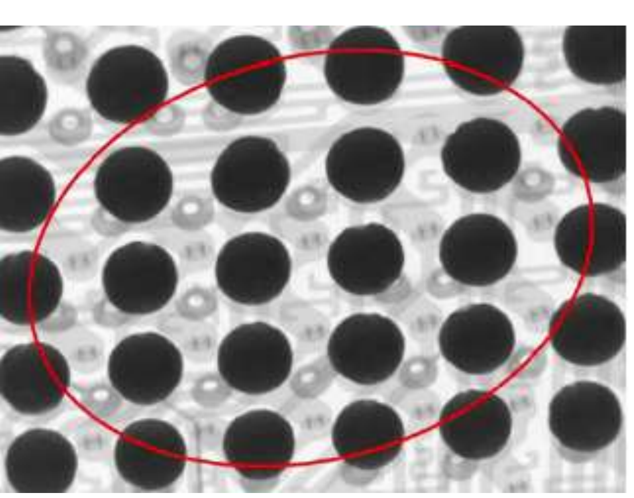
Space / Astronomy

X-RAY APPLICATIONS

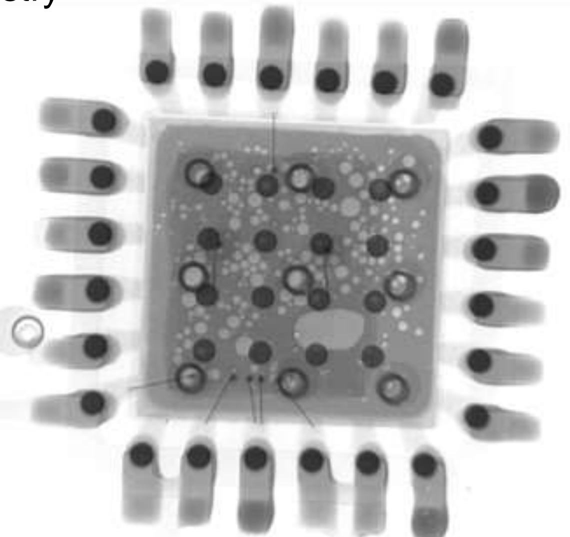
Medical

- **Cameras for dentist/medical applications**
- **In the industry for assembly analysis**

Industry



Shorted vias in a 3D package

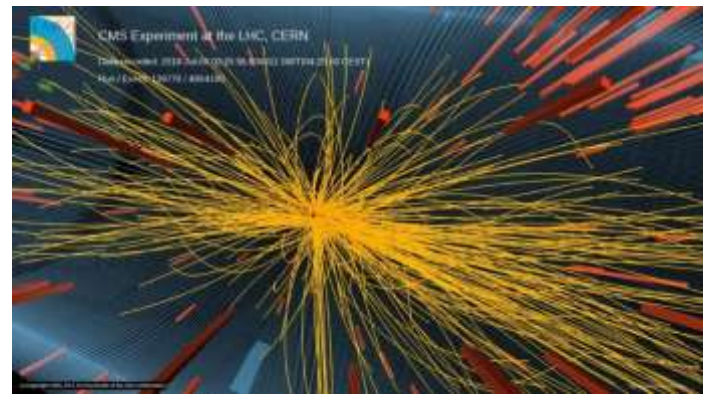


Voids on a glued BGA

GAMMA AND UV APPLICATIONS

- **Research for scientist experiences**
- **Aerospace applications give higher inspection capacities**

Research



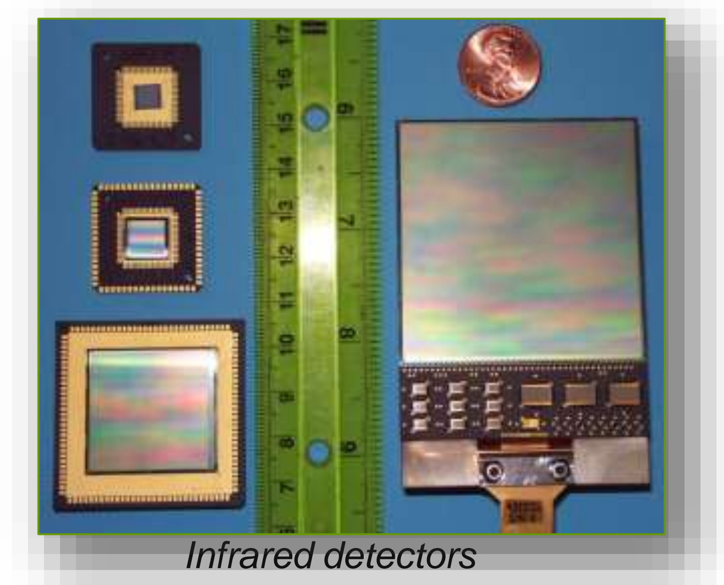
CERN (Switzerland): Higgs boson

Aerospace

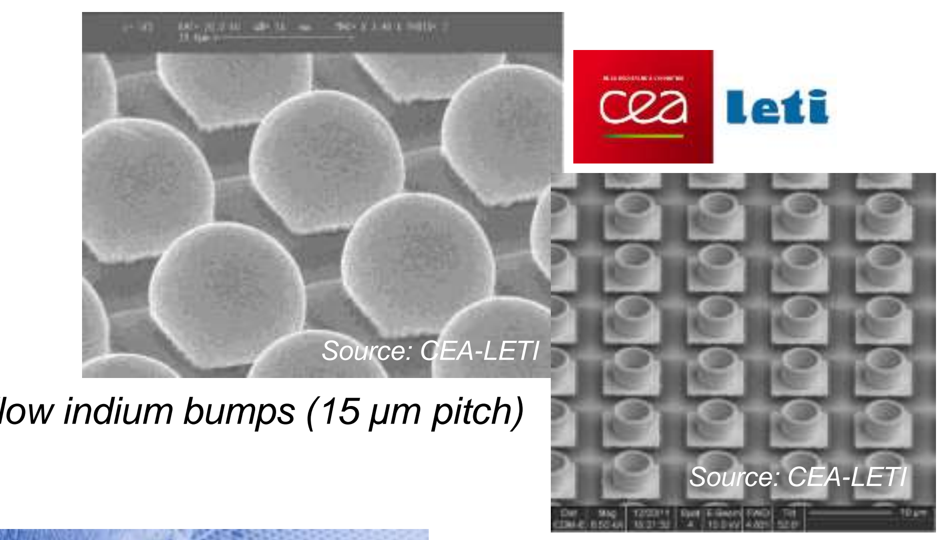
Andromeda galaxy (UV picture)

Andromeda galaxy (visible light picture)

FPA DETECTORS AND BUMPS



Infrared detectors



Reflow indium bumps (15 µm pitch)

Microtubes (10 µm pitch)

Joint shaping on indium bumps (15 µm pitch)

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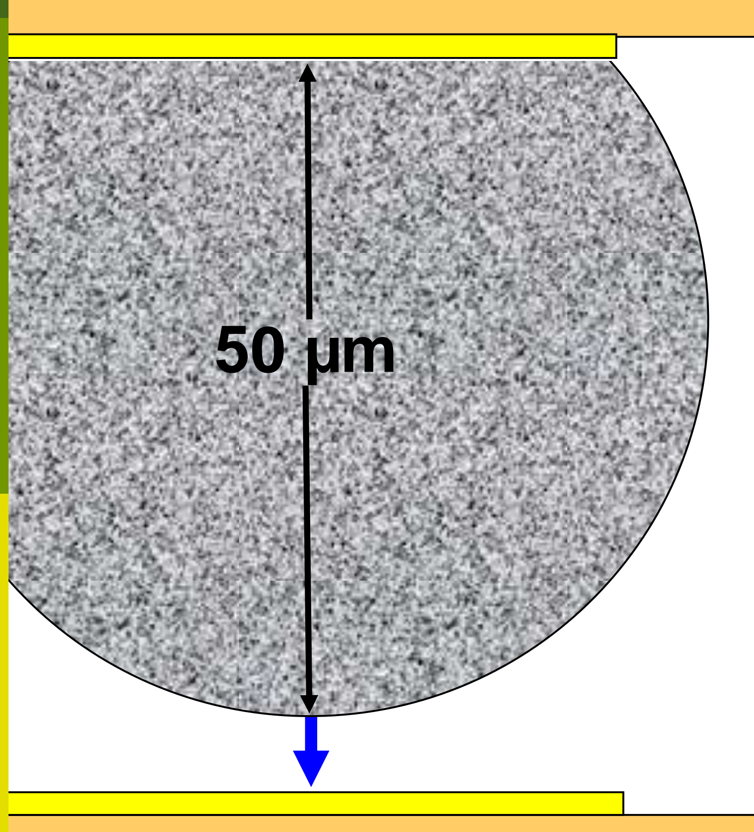
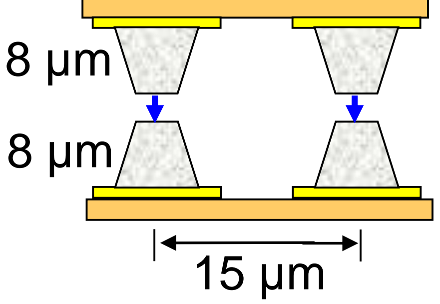
FLIP-CHIP BUMPS

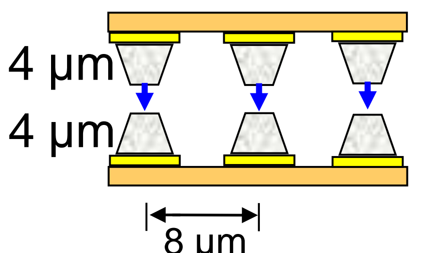
Conventional flip-chip solder ball



Indium-bumped FPA today

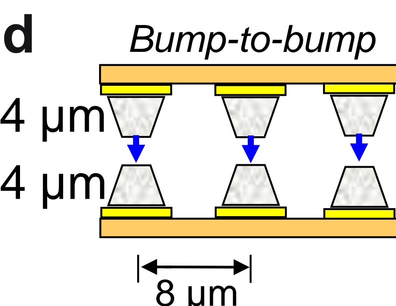


Indium-bumped FPA tomorrow

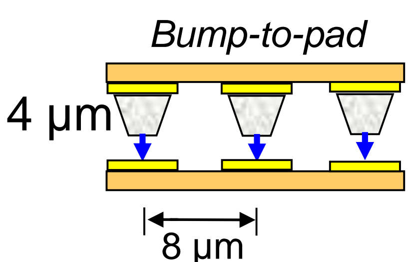


FPA CHALLENGES: SMALLER PIXEL & BUMP SIZE

- **2 different approaches with bump-to bump and bump-to-pad.**



- **Very important for FPA:**
  - Sub-micron alignment in XYϴ,
  - Guaranty parallelism,
  - Deal with strong oxide layer on tiny indium bumps.



FLIP-CHIP ASSEMBLY

- **Several techniques:**
  - Thermo-compression or Room temperature compression,
  - Tacking + reflow in oven (under controlled atmosphere),
  - In-situ reflow with chemical flux,
  - In-situ reflow with mechanical scrubbing,
  - In-situ reflow with formic acid vapor.

FLIP-CHIP ASSEMBLY
Thermo-compression or Room temperature compression

REQUIRES:

- **High accuracy for alignment and parallelism,**
- **High pressure/force linked to size/number of bumps,**
- **Sensitive and accurate force control from touch-down, up to final force,**
- **High stiffness of bonder to maintain alignment and parallelism accuracy when applying force,**
- **Good management of the thermal expansion during bonding.**

Note: Oxide is broken when applying the force.

- **Pros: Low temperature process (even room temperature)**
- **Cons: Oxide residues stay in the indium bumps**

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FLIP-CHIP ASSEMBLY
Thermo-compression or Room temperature compression

- **Current state-of-the-art is 4kx4k pixel arrays.**
- **6kx6k pixel arrays are being attempted now.**
- **Larger arrays are coming.**

FLIP-CHIP ASSEMBLY
Tacking + Reflow in oven

REQUIRES:

- Chemical flux,
- High accuracy for alignment and parallelism,
- Sensitive and accurate force control from touch-down to final force,
- External oven (under controlled atmosphere).

- Pros: Low force tacking. Many assemblies are reflowed simultaneously (high throughput)
- Cons: Transfer from bonder to oven is very delicate → can affect the alignment; After reflow, flux must be cleaned → difficult process because small gap between the dies

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FLIP-CHIP ASSEMBLY
In-situ reflow with chemical flux

REQUIRES:

- **Chemical flux,**
- **High accuracy for alignment and parallelism,**
- **Sensitive and accurate force control from touch-down to final force,**
- **Good management of the thermal expansion during reflow.**

- **Pros: Components are secured during the entire process; oxide is easily removed; quality of indium joint is very good**
- **Cons: Dispense of chemical flux is not a clean process → not compatible with high accuracy bonder; After reflow, flux must be cleaned → difficult process because difficult access between the dies**

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FLIP-CHIP ASSEMBLY
In-situ reflow with mechanical scrubbing

REQUIRES:

- **High accuracy for alignment and parallelism,**
- **Sensitive and accurate force control from touch-down to final force,**
- **Good management of the thermal expansion during reflow,**
- **Mechanical scrubbing system which respects the high alignment accuracy.**

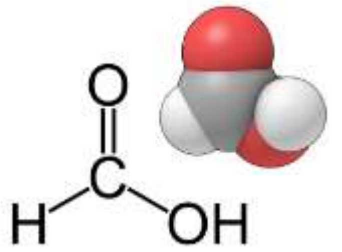
Note: Oxide is broken when applying the force.

- **Pros: No post bond cleaning because no flux**
- **Cons: Oxide residues stay in the indium bumps; difficult to keep the alignment accuracy after scrubbing**

FLIP-CHIP ASSEMBLY
In-situ reflow

- **Reflow of FPAs up to 1kx1k has been demonstrated using chemical flux or scrubbing to break through indium bump oxide skin,**
- **However, larger arrays would require more scrubbing force which is not compatible with the high alignment accuracy required by tiny bumps and small pitches,**
- **Large arrays have also their own thermal expansion (≠ CTE between detector and ROIC), then mismatch at high temperature.**

FLIP-CHIP ASSEMBLY
In-situ reflow with formic acid vapor



REQUIRES:

- High accuracy for alignment and parallelism,
- Sensitive and accurate force control from touch-down to final force,
- Good management of the thermal expansion,
- Gas control (formic acid vapor).

- Pros: Oxide is easily removed; quality of indium joint is very good; no post-reflow cleaning; formic acid cleaning offers a good surface preparation to flow the underfill material
- Cons: Long desoxidation process (2 to 4 minutes)

FLIP-CHIP ASSEMBLY
Microtubes

Technique patented by CEA-Leti

REQUIRES:

- **CEA-Leti Patent to develop the microtubes before assembly,**
- **High accuracy for alignment and parallelism,**
- **Sensitive and accurate force control from touch-down to final force.**

Note: Oxide is broken when applying the force.

Source: CEA-LETI

Microtubes (10 µm pitch)

- **Pros: Low temperature process (even room temperature)**
- **Cons: Oxide residues stay in the interconnexion; Requires a patent**

Focal Plane Array,

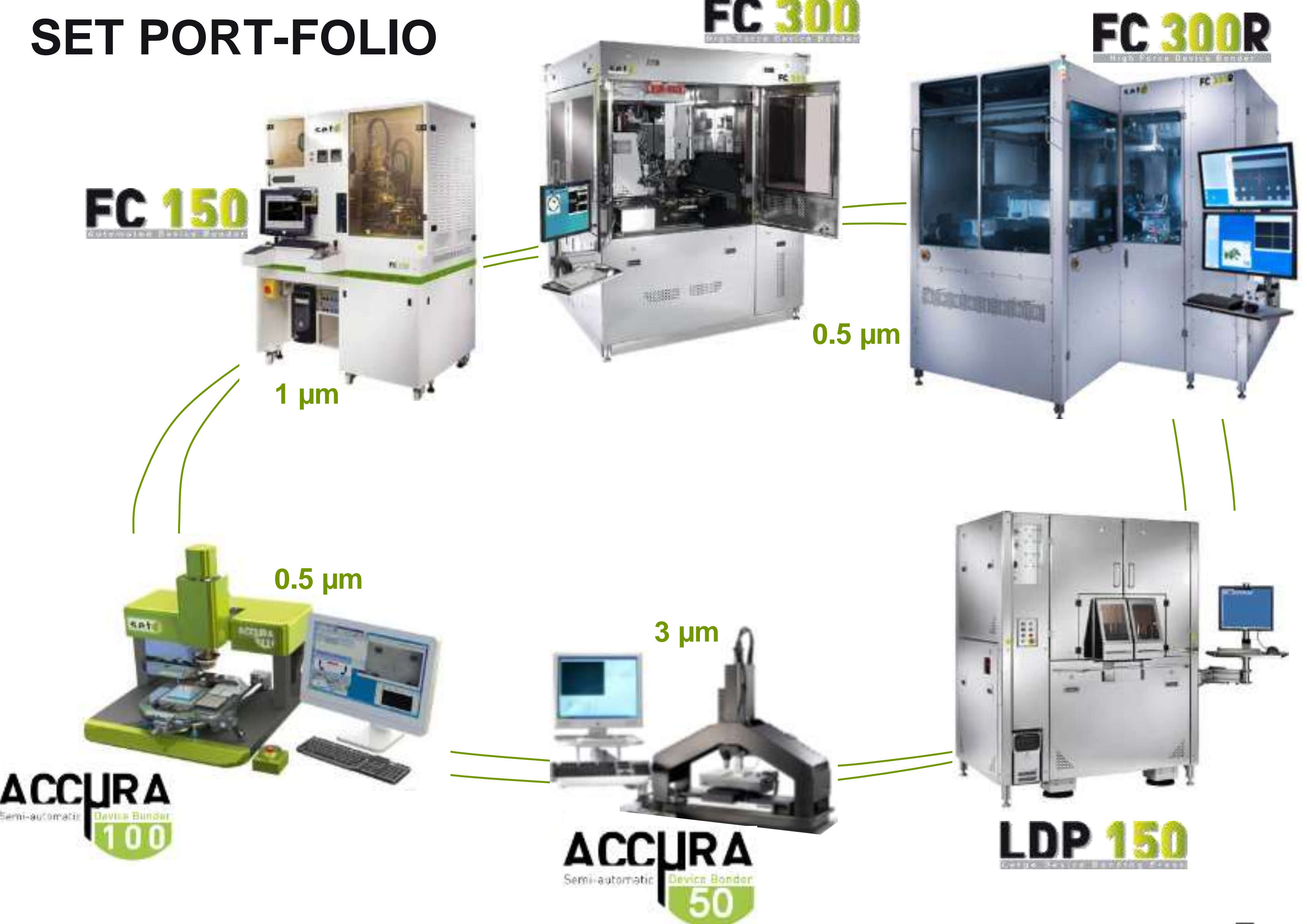
the SET

experience & solutions

SET EXPERIENCE AND SOLUTIONS

SET builds equipment since over 30 years for FPA applications. All techniques can be done on the same platforms.

- Company created in 1975 (39 years ago)
- 1982: Beginning of flip-chip with Reflow + flux techniques with CEA-Leti,
- Since the 90's: Development of high force / room temperature solutions in collaboration with American private companies,
- 2008: Introduction of formic acid vapor solution, qualified by several important names of FPA manufacturers in the world,
- 2010: CEA-Leti technique with microtubes developed on SET Bonder.



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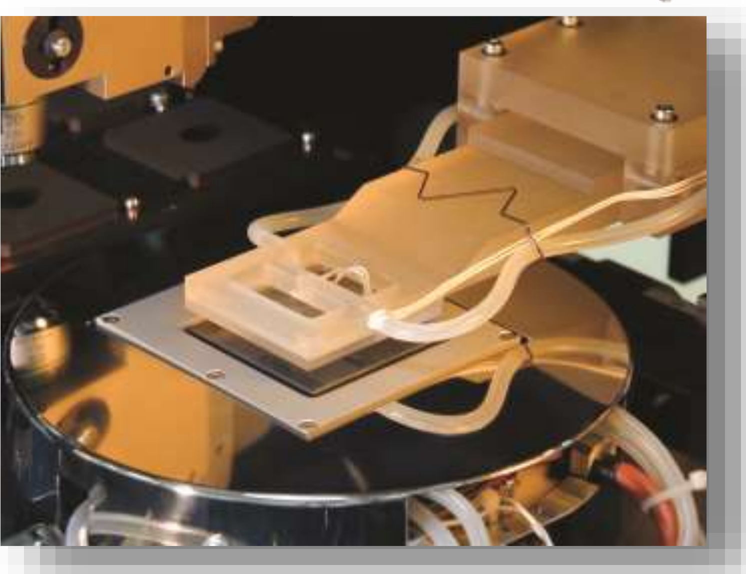
SET SOLUTIONS
FC150 – R&D BONDER

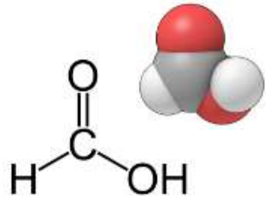
- **Bumps pitch down to 15 µm**
- **± 1 µm post-bond accuracy**
- **Force from 25 g to 200 kg**
- **Temperature up to 450°C**
- **High Process Flexibility:**
  - Thermo-compression
  - Room temperature compression
  - Reflow
  - Formic acid vapor
- **Automatic mode for production**



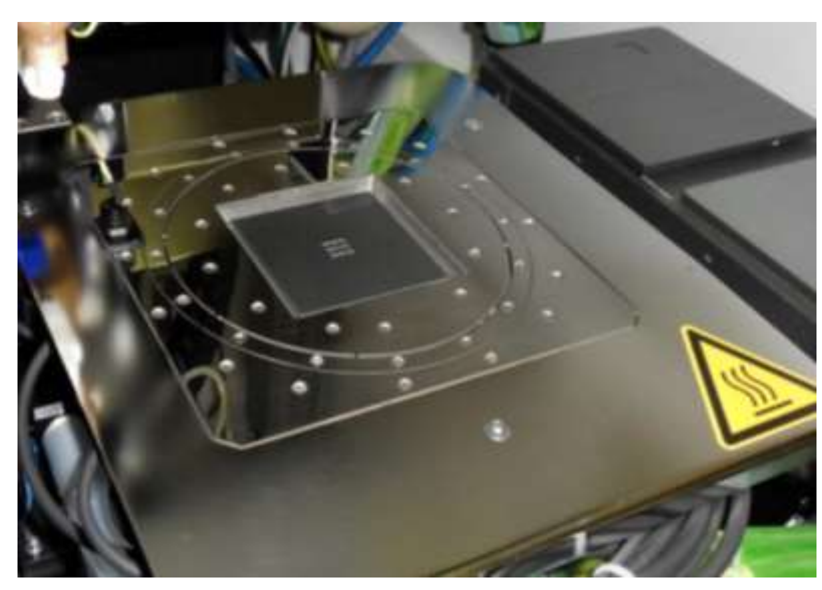
SET SOLUTIONS
FC300 – R&D BONDER

- **Bumps pitch down to 5 μm**
- **± 0,5 μm post-bond accuracy**
- **Force from 100 g to 400 kg**
- **Temperature up to 450°C**
- **High Process Flexibility:**
  - Thermo-compression
  - Room temperature compression
  - Reflow
  - Formic acid vapor
- **Automatic mode for production**

SET SOLUTIONS
Oxide removal with formic acid vapor



- **Unique concept based of semi-open chamber with injection of formic acid vapor (patented)**
- **All vapors are exhausted for safe use**
- **Formic acid vapor is built-in thanks to an evaporator**
- **Allows to:**
  - Remove oxide on bumps,
  - Shape the bumps,
  - Generate a good adhesion indium-to-indium bumps,
  - Get a good diffusion of indium bumps on gold pads
- **Additional benefit: Get better flow of underfill**



SET SOLUTIONS
LDP150 – LARGE DEVICE PRESS

When arrays become very large (i.e. 4kx4k), very high force is required at room temperature.

Detector and ROIC are aligned and pre-bonded on FC150 or FC300, then LDP150 applies the remaining pressure.

- XY accuracy is maintained within 3 µm
- Parallelism is maintained
- Self levelling system
- Force up to 10,000 kg
- Room temperature

CONCLUSION

- **FPAs market is growing.**
- **The challenges are very well identified:**
  - Array size is increasing → higher bonding force is required,
  - Pixel size is shrinking → higher bonding accuracy is required.
- **The flip-chip method must be chosen according to the constraints of the final products/applications. The size and pitch of the bumps are key parameters.**
- **To get a good FPA, the flip-chip assembly must be accurate and the bonder must flexible to run all these different techniques on the same platform, from R&D to production purposes.**

Thank you for your attention.

Flip-Chip Assembly for Focal Plane Array

Jean-Stéphane MOTTET
✉ jmottet@set-sas.fr
☎ +33 450 358 392

SET CORPORATION S.A.
131 impasse Barteudet - 74490 Saint-Jeoire - FRANCE
www.set-sas.fr

set Smart Equipment Technology