SET Corporation

SMART EQUIPMENT TECHNOLOGY

* FLIP-CHIP ASSEMBLY FOR FOCAL PLANE ARRAY

Pascal METZGER, PhD, CEO
OUTLINE

- Presentation of SET
- Wavelengths
- Applications
- Materials
- Flip-chip assembly
- SET experience and solutions
- Conclusion
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Paris
3h by train

Lyon
1h30 drive

Grenoble
(CEA-Leti)
1h45 drive

Annecy
45 min drive

Geneva
40 min drive

Chamonix
Mont-Blanc
50 min drive
SET Corporation AT A GLANCE

Since 1975: Equipment for semiconductor celebrating 40 years in 2015!

1981: 1<sup>st</sup> flip-chip bonder installed at CEA-Leti

SET former Device Bonder division of SÜSS MicroTec (1993-2007)

SET focuses on designing, assembling and selling high precision “flip-chip” bonders

Installed base > 280 Flip-Chip Bonders all around the world

Total surface of facilities 2 600 m²
Clean rooms surface (ISO 7, 6 and 5) 700 m²
PARTNERSHIPS & COLLABORATION

Member of SEMI

Member of the Pole of Expertise Minalogic

Member of the Pole of Expertise Mont-Blanc Industries

Die Bonding
Nanoimprinting
Main R&D World Consortia

IMEC
FhG -IZM
VTT
CERN UG
BSAC
Sematech
CNM
CEA-LETI
CNR

Flip-Chip Assembly for FPA

November 25th, 2017
Main CONFERENCES and EXHIBITIONS for 2017

European 3D Summit, Grenoble, January
Semicon Korea, Seoul, February
IMAPS, Scottsdale, March
Semicon China*, Shanghai, March
SSI, Cork, March
EXPO Electronica, Moscow, April
SMT*, Nuremberg, May
MiNaPAD, Grenoble, May
ECTC, Las Vegas, June
Nordic Conference, Gothenburg, June
Semicon West, San Francisco, July
Semicon Taiwan, September
CIOE, Shenzhen, September
EMPC, Warsaw, September
European Imaging & Sensors Summit, Grenoble, September
NEPCON, Hanoi, September
IWLP C, San Jose, October
Semicon Europa* (Productronica), München, November
IST:GST, Mumbai, November
Semicon Japan, Tokyo, December
IWPSD, New Delhi, December
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WAVELENGTH

- FPA can detect different wavelengths:
  - Infrared
  - UltraViolet
  - X-Ray
  - Gamma
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SOME APPLICATIONS

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

Visible image

Infrared image

Warmer

Cooler
INFRARED APPLICATIONS

Monolithic

Energy conservation

Industrial

Automotive Night Vision

DC + ROIC

Weather Satellites

Space / Astronomy

Medicine

Strategically important applications
Restricted technology
Available to few countries/companies

Security/Law Enforcement

Military Night Vision
X-RAY APPLICATIONS

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

Medical

Industry

Shorted vias in a 3D package

Voids on a glued BGA
GAMMA and UV APPLICATIONS

- **Research**
  - Research for scientific experiments

- **Aerospace**
  - Aerospace applications to give higher inspection capacities

*CERN (Switzerland): Higgs boson*

*Andromeda galaxy (visible light picture)*

*Andromeda galaxy (UV picture)*
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## DETECTOR MATERIALS and WAVELENGTH SENSITIVITIES

<table>
<thead>
<tr>
<th>Detector material</th>
<th>Short-Wave IR $\lambda$: 1.4-3 $\mu$m</th>
<th>Mid-Wave IR $\lambda$: 3-8 $\mu$m</th>
<th>Long-Wave IR $\lambda$: 8-15 $\mu$m</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>InGaAs (Indium-Gallium-Arsenide)</td>
<td>X</td>
<td></td>
<td></td>
<td>€</td>
</tr>
<tr>
<td>InSb (Indium-Antimonide)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>€€</td>
</tr>
<tr>
<td>Bolometer</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>€-€€</td>
</tr>
<tr>
<td>QWIP, SLS, Q-dot</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>€€€€</td>
</tr>
<tr>
<td>HgCdTe (Mercury-Cadmium-Telluride)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>€€€€</td>
</tr>
</tbody>
</table>
FPA DETECTORS and BUMPS

IR detectors

Reflow indium bumps (15 µm pitch)

Microtubes (10 µm pitch)

Joint shaping on indium bumps (15 µm pitch)
FLIP-CHIP BUMPS

Conventional flip-chip solder ball

Indium-bumped FPA today

Indium-bumped FPA tomorrow
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FPA CHALLENGES: SMALLER PIXEL & BUMP SIZE

2 different approaches: Bump-to bump and bump-to-pad

Very important for FPA:
- Sub-micron alignment in $\text{XY}\Theta$,
- Guaranty parallelism,
- Deal with strong oxide layer on tiny indium bumps.
FPA CHALLENGES: SMALLER PIXEL & BUMP SIZE

Parallelism constraints

- // - Flatness

- // - Waviness
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 temperature** to control 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
FLIP-CHIP ASSEMBLY
Thermo-Compression or Room Temperature Compression

STATUS

- 4kx4k pixel arrays = Current state-of-the-art
- 6kx6k pixel arrays = Being attempted now
- Larger arrays = Coming

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FLIP-CHIP ASSEMBLY
Tacking + Reflow in Oven

REQUIRES:

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

**Pros:**
- Low force tacking
- Many assemblies reflowed simultaneously $\rightarrow$ Higher throughput

**Cons:**
- Delicate transfer from bonder to oven $\rightarrow$ Can affect alignment
- After reflow, flux must be cleaned $\rightarrow$ Difficult process because small gap between the dies

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FLIP-CHIP ASSEMBLY
In-situ Reflow with Chemical Flux

REQUIRES:

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

Pros:
- Components secured during the entire process
- Oxide easily removed
- Quality of indium joint 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 small gap 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, up to final force
- **Good management of temperature** to control 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
- Difficulty to keep the alignment accuracy after scrubbing
FLIP-CHIP ASSEMBLY
In-situ Reflow with Mechanical Scrubbing

STATUS

- Reflow of FPAs up to 1kx1k has been demonstrated using chemical flux or mechanical 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) → 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, up to final force
- **Good management of temperature** to control 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 typical)

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Flip-Chip Assembly for FPA
FLIP-CHIP ASSEMBLY

Microtubes

REQUIRES:

- **High accuracy** for alignment and parallelism
- **Sensitive and accurate force control** from touch-down, up to final force
- CEA-Leti’s patent on technique to develop the microtubes before assembly

Note: Oxide is broken when applying the force.

 Sources illustrations: CEA-LETI

Pros:
- **Low temperature process** (even room temperature)

Cons:
- **Oxide residues stay in the interconnection**
- **Requires a patent (royalties)**
FLIP-CHIP ASSEMBLY

Some references

REFERENCES
[1] F. Marion et al., “Electrical characterization of high count, 10 µm pitch, room temperature vertical interconnections”, IMAPS International Conference on Device Packaging, March 9-12, 2009


Technical papers

Technical papers: Focus on bonding!
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SET EXPERIENCE AND SOLUTIONS

1975: Creation of the company (42 years ago)

1982: Beginning of flip-chip with Reflow + Flux techniques with CEA-Leti (35 years experience in flip-chip)

1990’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
SET SOLUTIONS
PRINCIPLES

Flip-Chip technology

General architecture of SET bonders

Chip

Microscope

Substrate
Bumps pitch down to 15 µm

± 1 µm post-bond accuracy

Force from 25 to 200 kgf

Temperature up to 450°C

High Process Flexibility:
- Thermo-compression
- Room temperature compression
- Reflow
- Formic acid vapor

Automatic mode for production
Bumps pitch down to 5 µm

± 0,5 µm post-bond accuracy

Force from 100 to 400 kgf

Temperature up to 450°C

High Process Flexibility:
- Thermo-compression
- Room temperature compression
- Reflow
- Formic acid vapor
- Force control / Z control
- Higher stiffness

Automatic mode for production
Oxide removal with formic acid vapor

Unique concept based of semi-open chamber with injection of formic acid vapor

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
Actually, 3 (optical) possibilities to measure parallelism

- Autocollimator:
  - Laser leveling:
  - Optical sensors:
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 100 kN (10,000 kgf)
- Room temperature
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CONCLUSION

- Strategic FPAs market growing

- Challenges very well identified:
  - Array size increasing → Higher bonding force required
  - Pixel size shrinking → Higher bonding accuracy required

- Flip-chip method to be chosen:
  - According to constraints of final products/applications
  - Size and Pitch of the bumps are key parameters

- To get a good FPA:
  - Flip-chip assembly must be accurate
  - Bonder must flexible to run all these different techniques on the same platform, from R&D to production purposes.
Thank you for your attention

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