Fusion of robotic microassembly and self-assembly for microsystem integration and thin-chip microassembly for 3D integration

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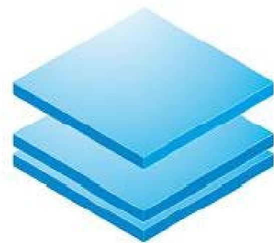
A European Project supported within the Seventh Framework Programme for Research and Technological Development

Part 2: Thin-chip hybrid-assembly and dielectrophoresis self-assembly



fab2asm
from fabrication to assembly

Thin-chip micro-assembly and dielectrophoresis self-assembly

- **Hybrid robotic and capillary self-assembly of ultra-thin dies**

- **Hybrid robotic and dielectrophoresis self-assembly**

- **Dielectrophoresis robotics**

Ultra thin dies assembly : interest and challenges

Applicative context:

Global reduction of electronic dies thickness in back-end electronic industries

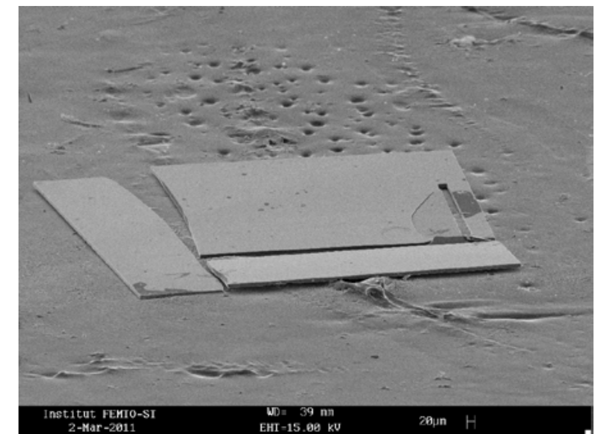
- 2013 : around 40µm thick components
- 2022 : thickness down to 10µm is expected

	2012	*2017*	*2022*
Wirebond (µm, minimum thickness)	**30**	**20**	**15**
Through Silicon Via (µm, minimum thickness)	**40**	**20**	**10**

General problematics:

Current methods deals with the positionning of die on adhesive tape for dicing before handling

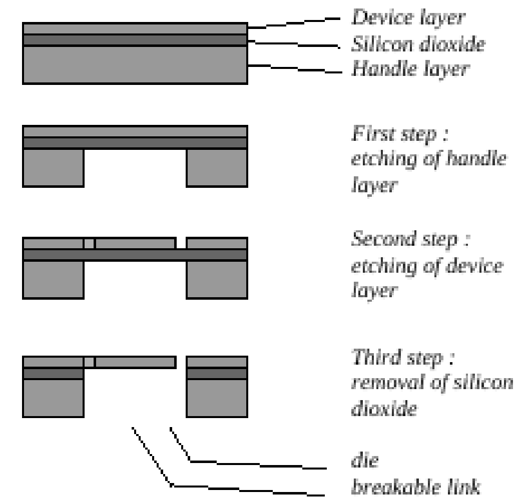
New method should be developed for ultra thin die

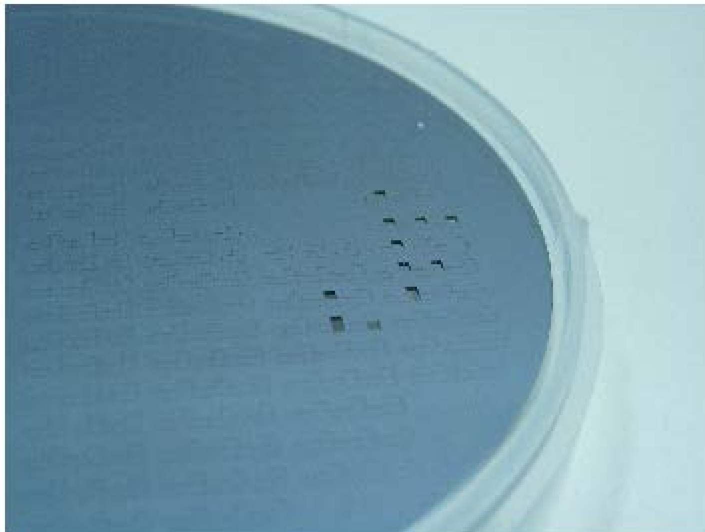


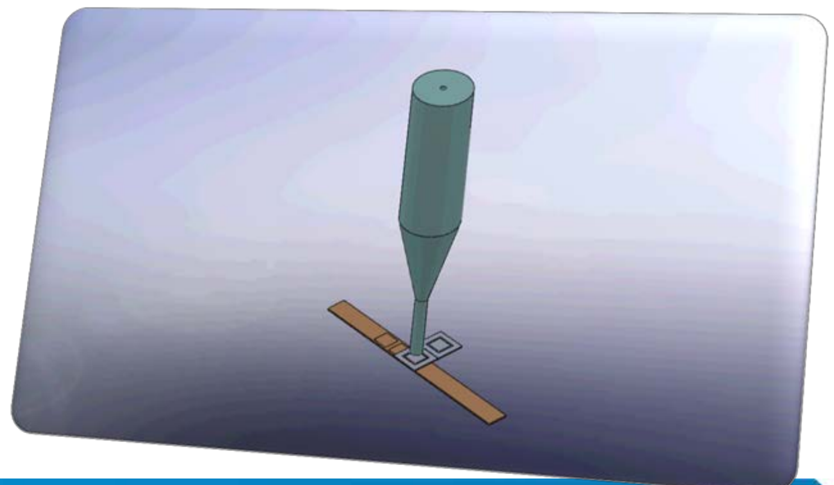
Design of breakable links

Fabrication of wide panel of breakable links in SOI wafer

Die size: 1mm x 1mm x 10µm (or 5µm)



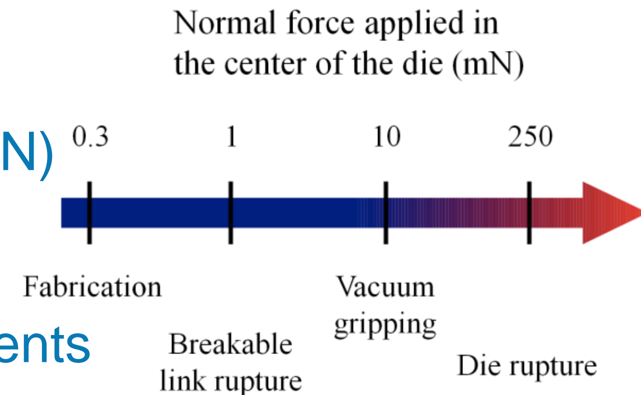


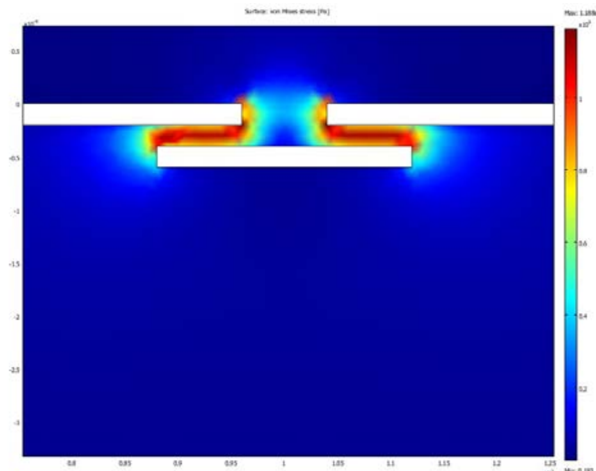


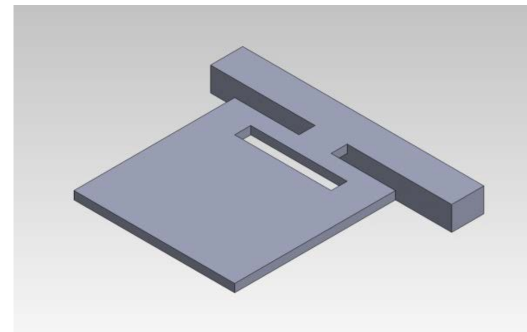
Design of the breakable link

Concept: exploit the weakness of silicon in torsion

Design: take into account four level of force:
- Force applied during fabrication process (0.3mN)
- Force required to break the link (1mN)
- Vaccum gripping force (10mN)
- Force induced the break of the silicon components (250 mN)

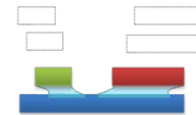






Hybrid assembly station

Component and interface design



Ultrafast robotic coarse placing

High precision self-alignment

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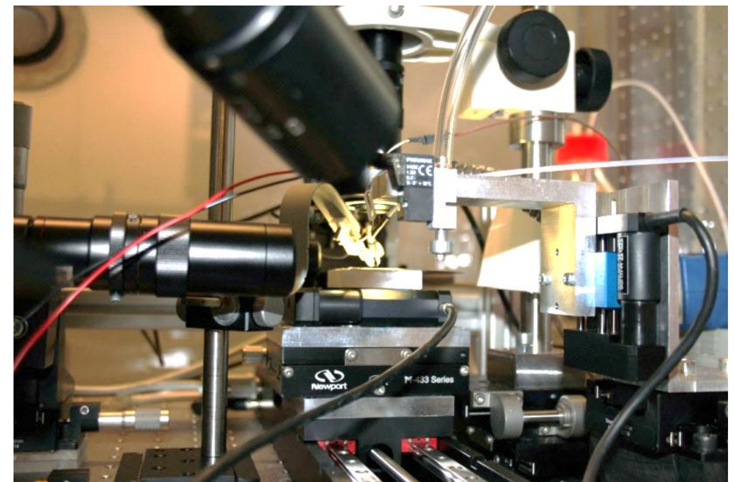

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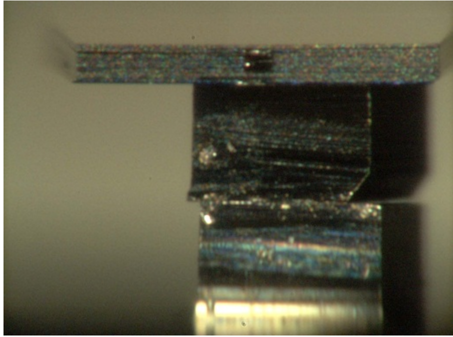
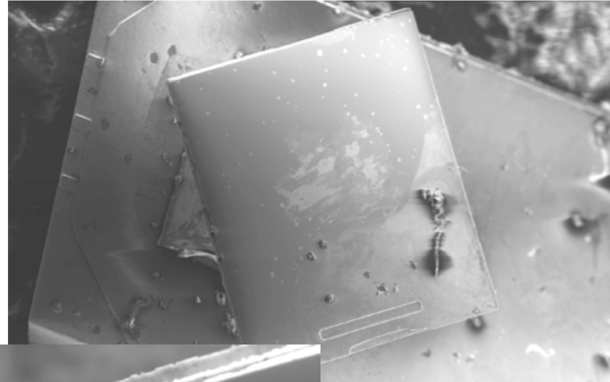
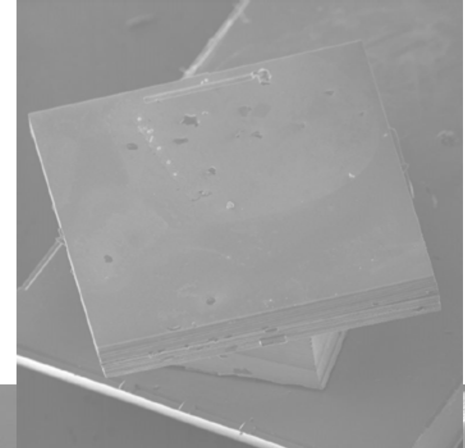
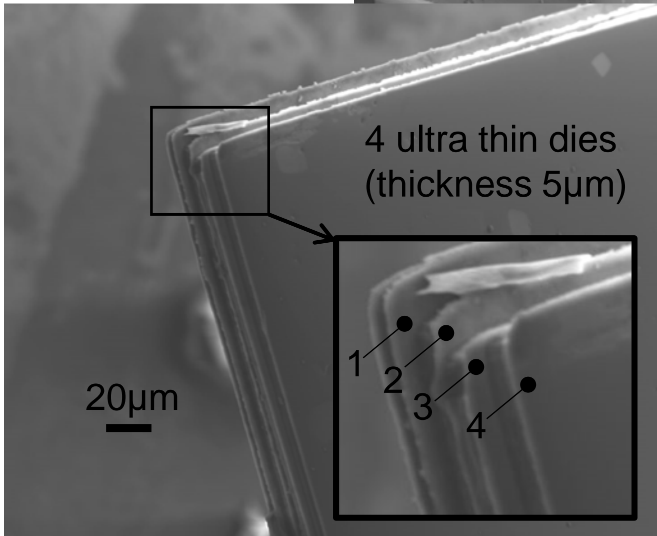
Hybrid assembly of ultra-thin dies

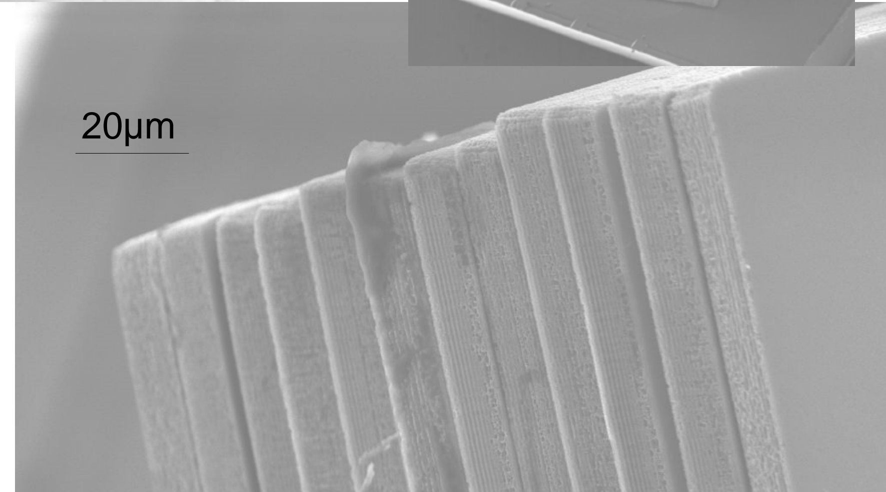
Assembly examples of 5µm and 10µm thick dies











Thin-chip micro-assembly and dielectrophoresis self-assembly

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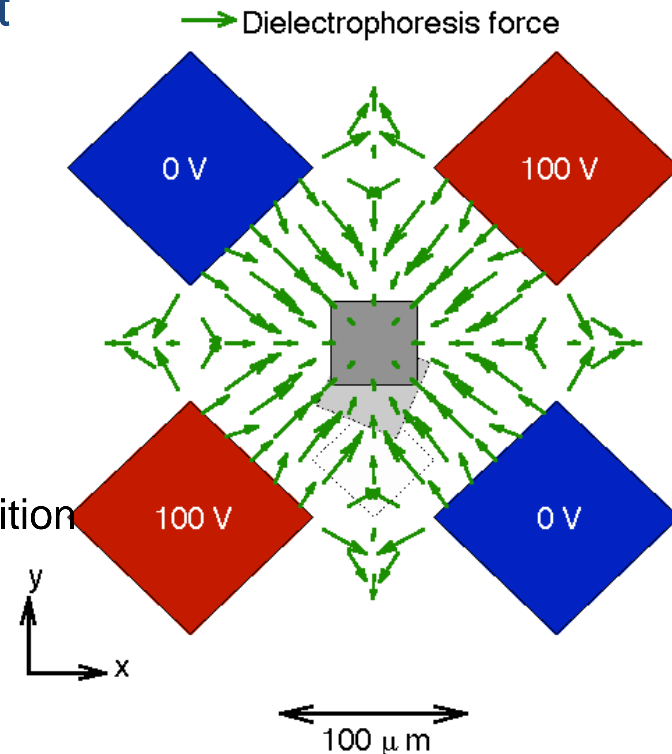
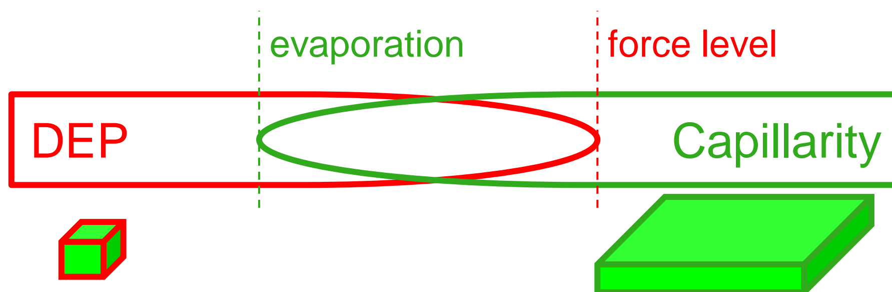
- **Hybrid robotic and dielectrophoresis self-assembly**

- **Dielectrophoresis robotics**

Dielectrophoresis principle

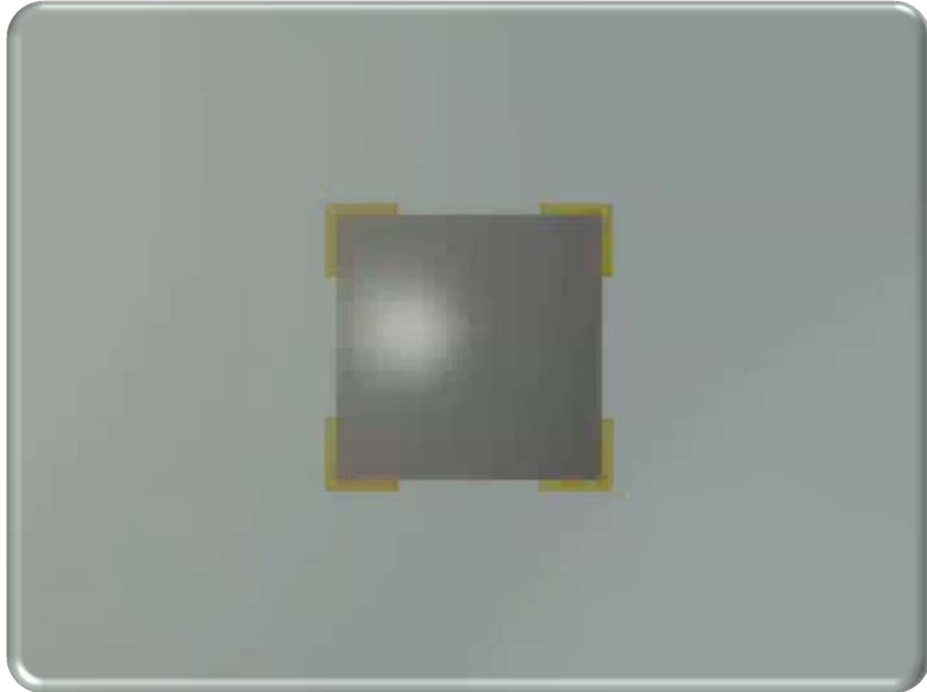
- DEP = non-uniform E+ dielectric object
- DEP system requirements
  - Electrodes immerged in an liquid medium
  - Electric voltages application
- Motion characteristics in DEP
  - High nonlinearity
  - High speed motion (~10ms)
  - High precise final stable and controllable position





Objectives

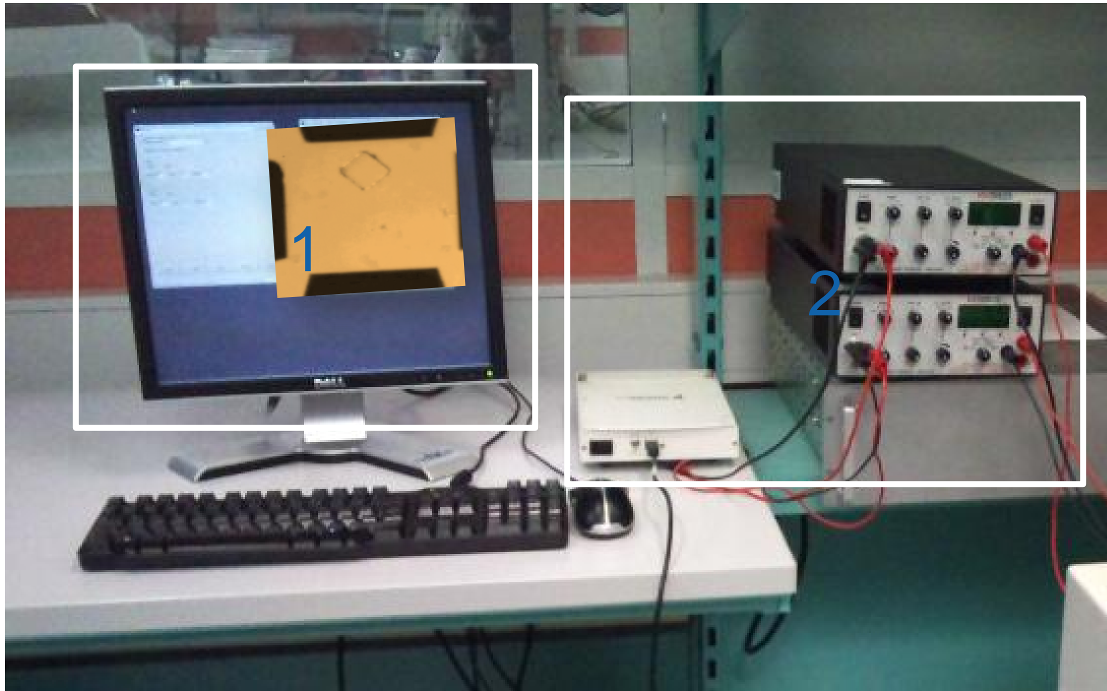
High speed and precision self-alignment

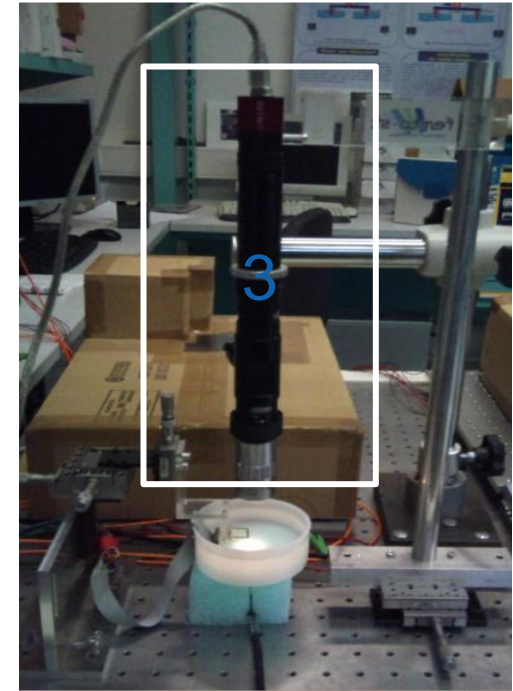


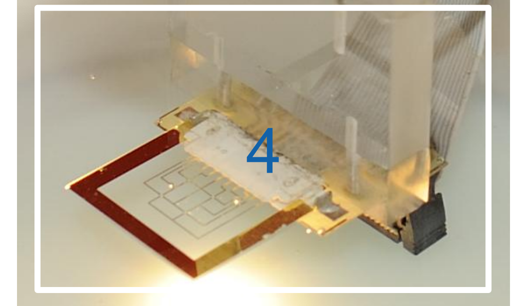
High speed and precision self-assembly

- Original way: long range force field → Dielectrophoresis.

Experimental setup





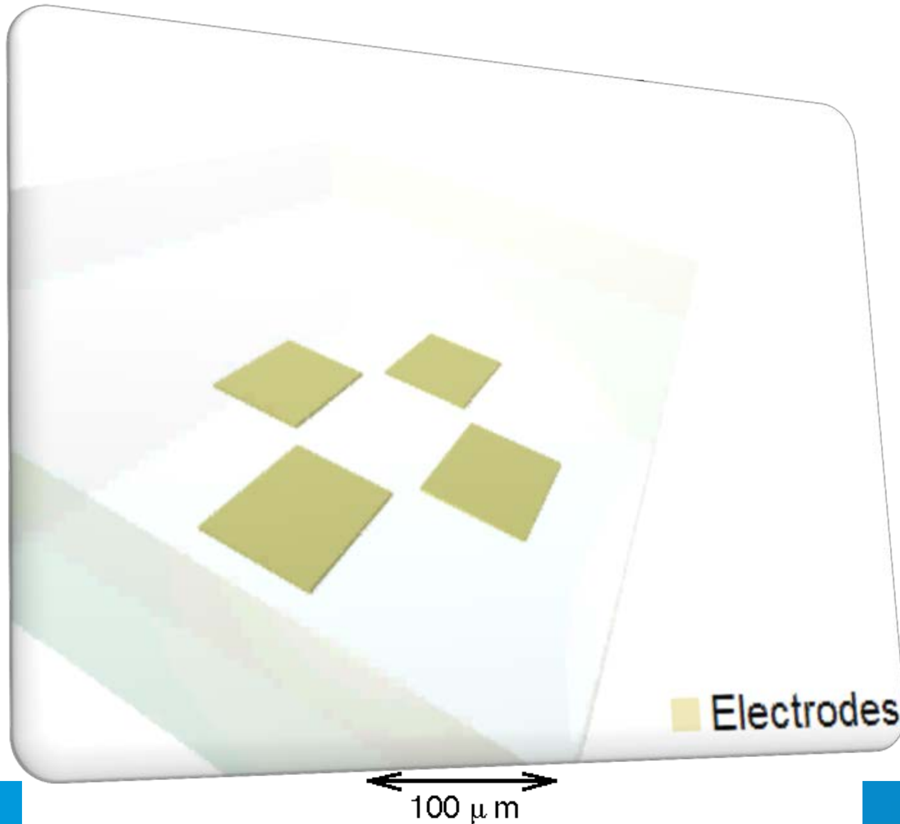


1- Computer
2- Acquisition card and voltage amplifier
3- Camera and optics
4- Electrodes and connectors

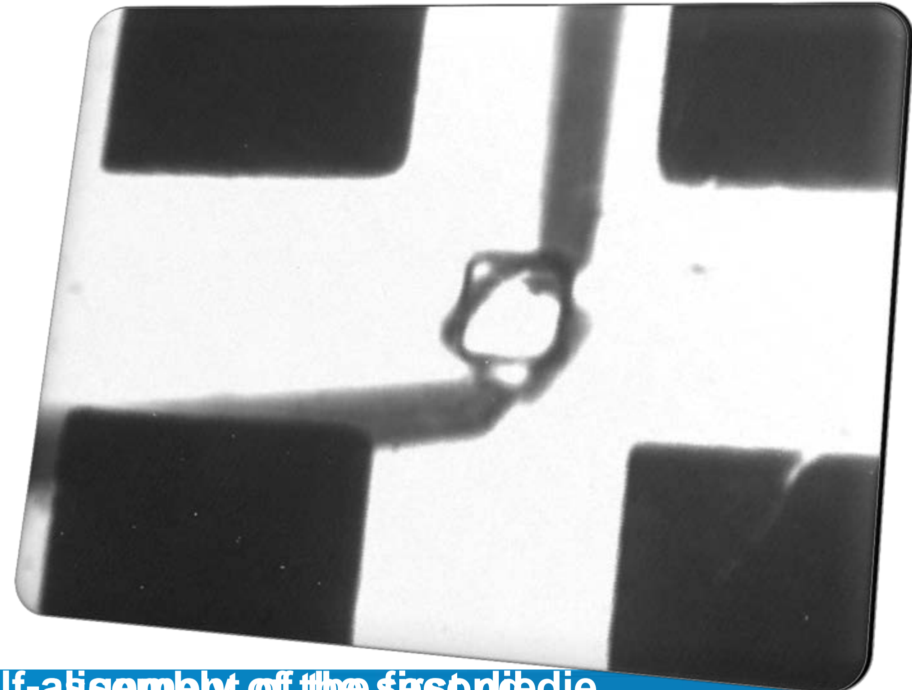
Self-assembly using electric field (DEP)

Objective: using electric field for self-assembly

Principle:



Result: 100µm large dies self-assembly



Self-alignment of the first die
Self-assembly of the second die

Thin-chip micro-assembly and dielectrophoresis self-assembly

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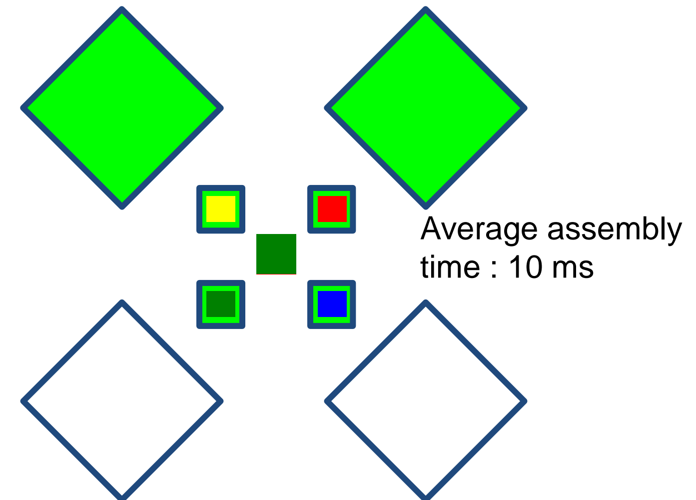
Position control using DEP

Programmable self-assembly principle

- Enhance the precision of the final position
- Using several assembly location
- Requirements:
  - Non linear control law
  - High speed real time control system
- Average assembly time : about **10's ms**

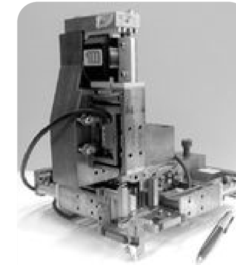


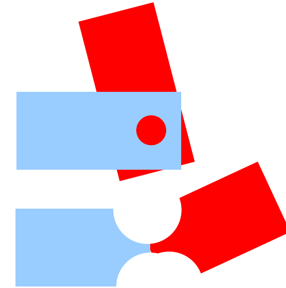
Micro-actuation principle usable for 6DOF positionning

Non contact actuation: new generation of robots?

Evolution of the movement transmission in production robots

- 1961 : first robot 'UNIMATE' is used in General Motors
- 80's : first use of compliant joint in robots

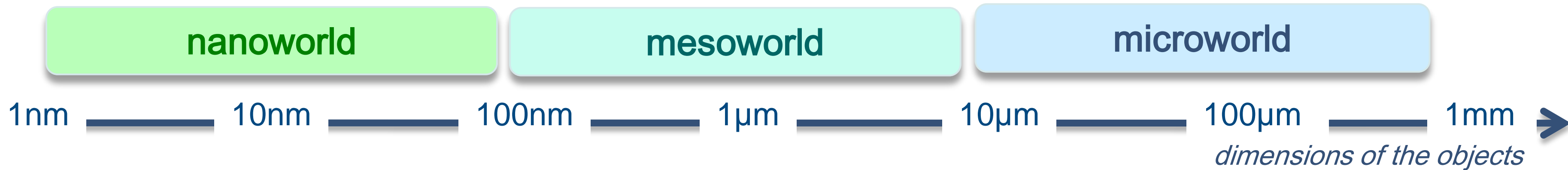




Robot throughput

the smaller the object is, the bigger the impact of the inertia of the robot is:

type	Robot weight	Objet weight	ratio
Car industry	600kg	30kg	20
Microelectronic	10kg	5 g	2000



Non-contact mesorobotics

Proposed approach

- robots based on new movement transmission without inertia

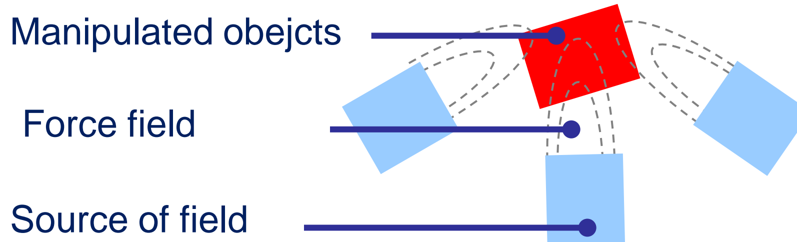
Objectives

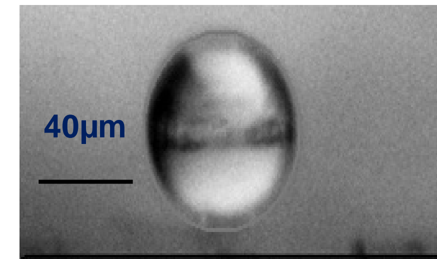
- to perform controled pick-and-place operation @ up to 100Hz
- develop a new objective of miniaturisation:

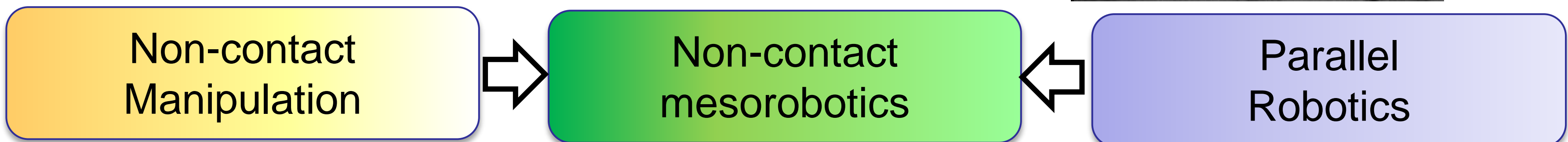
« assemble smaller components in order to assemble them faster »

Scientific positionning

- Closed-loop control of non contact manipulations
- Parallel robotics on new actuators'







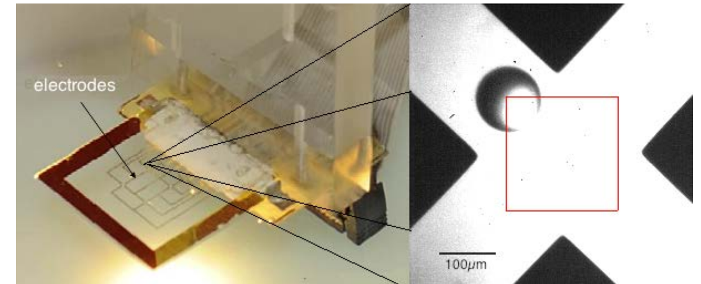
Open loop control using dielectrophoresis

Open loop control

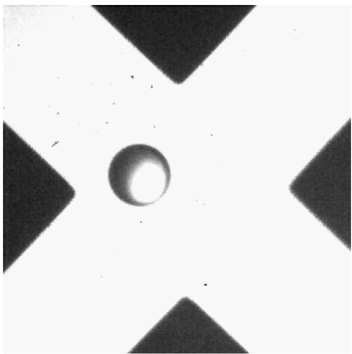
only based on the model

Test bench :

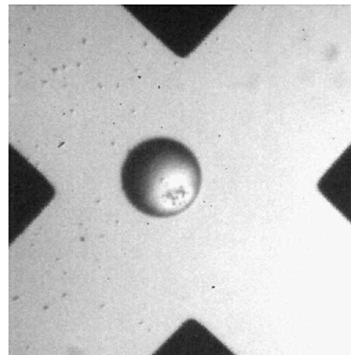
controlling a 50µm bead trajectory
square reference trajectory

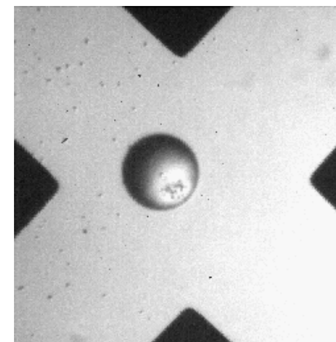


Results :

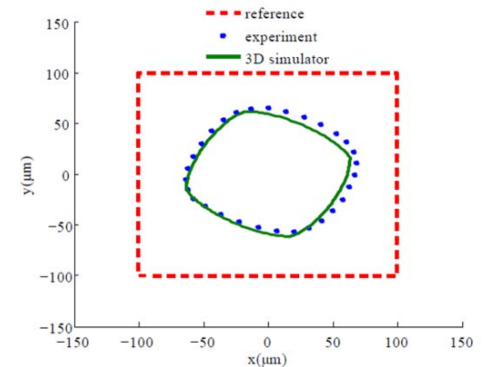


Low speed (1s)





High speed (0,1s) *replay*

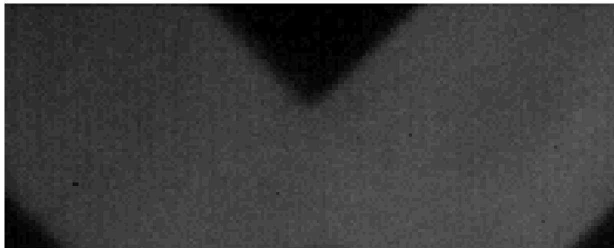


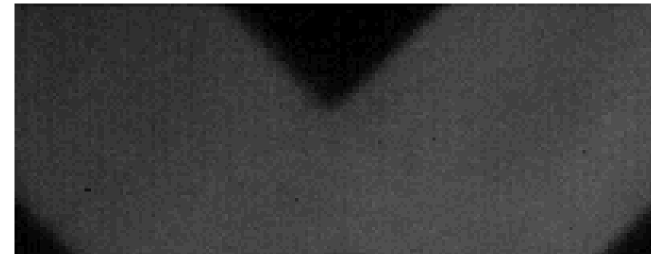
closed loop control using dielectrophoresis

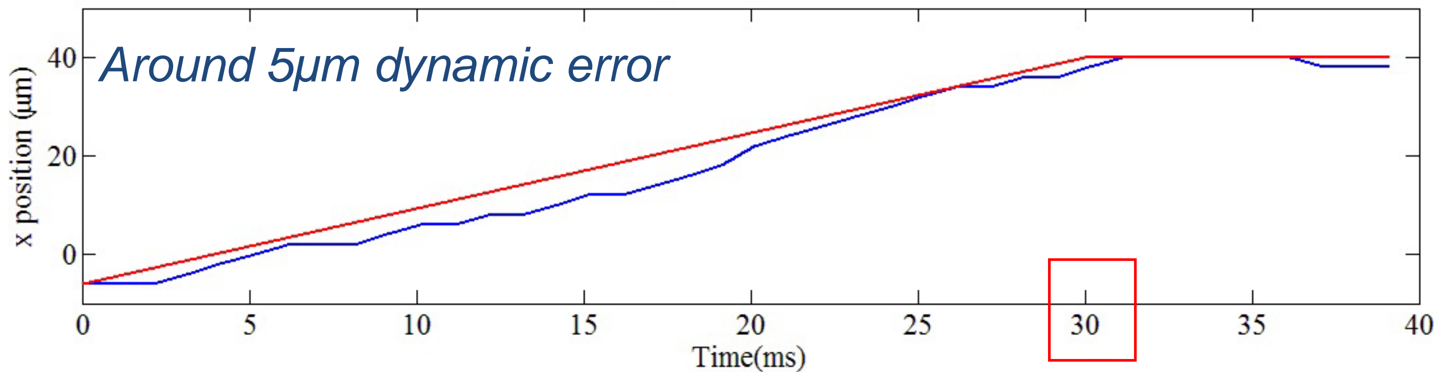
Closed loop control

based on the visual feedback : improvement of the robustness

Results :







Conclusion

Push the state of the art of stacked ultra thin dies from 40µm to 5µm

Proof of concept of dielectrophoresis hybrid-assembly

Proof of concept of closed loop non-contact mesorobotics

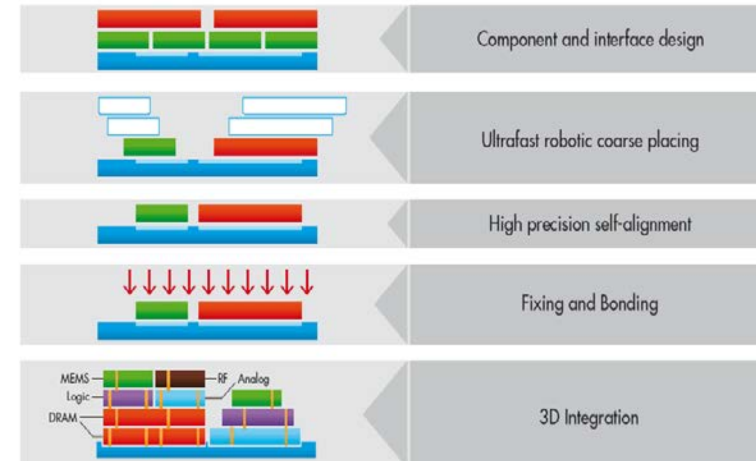
Acknowledgment FAB2ASM project

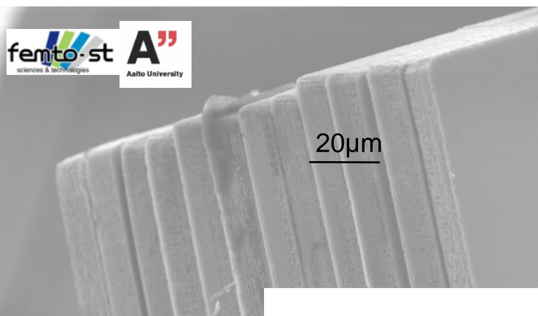
Hybrid self-assembly and robotic assembly
- High speed assembly
- High precision

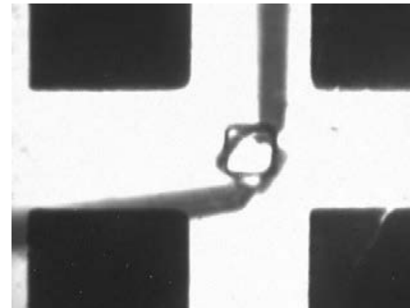
Examples of results

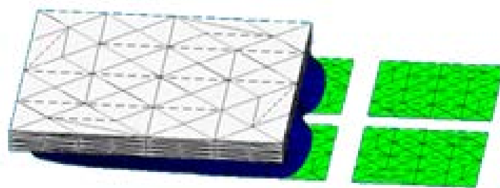
Assembly of 10µm thick dies *(state of the art : 40µm)*

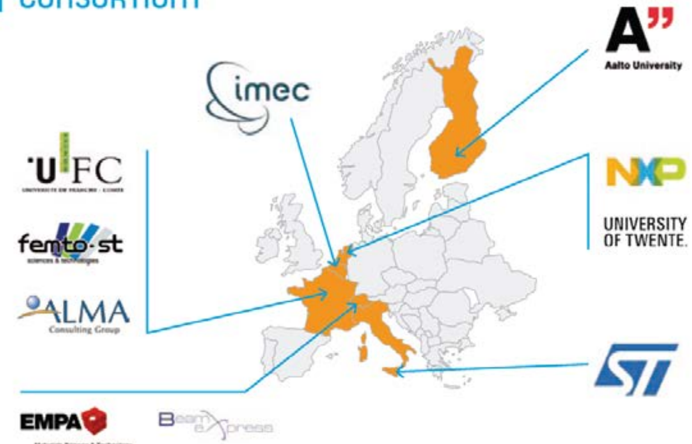
Assembly of 120x120 µm dies at 24kUPH *(10 kUPH)*











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