# The MADEin4 project

# Advanced Photoluminescent Metrology Equipment As Part Of A European Semiconductor and Automotive Industry 4.0 Cycle Time and Yield Improvements Scheme


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# Brief History of Semilab

## 1990: Founding

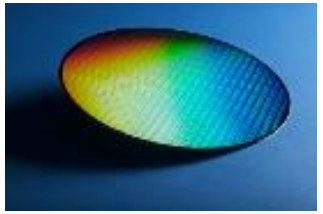
**By researchers as a spin-off from the Research Institute for Technical Physics of the Hungarian Academy of Sciences**

## 2004-2010: Photovoltaic area

- **90% annual growth (industry growth ~ 40%)**
- **Dominant player in front-end electrical metrology**

## 2004-2021: Semiconductor area

- **Growth by company and technology acquisitions**
- **5th biggest pure-play metrology company**

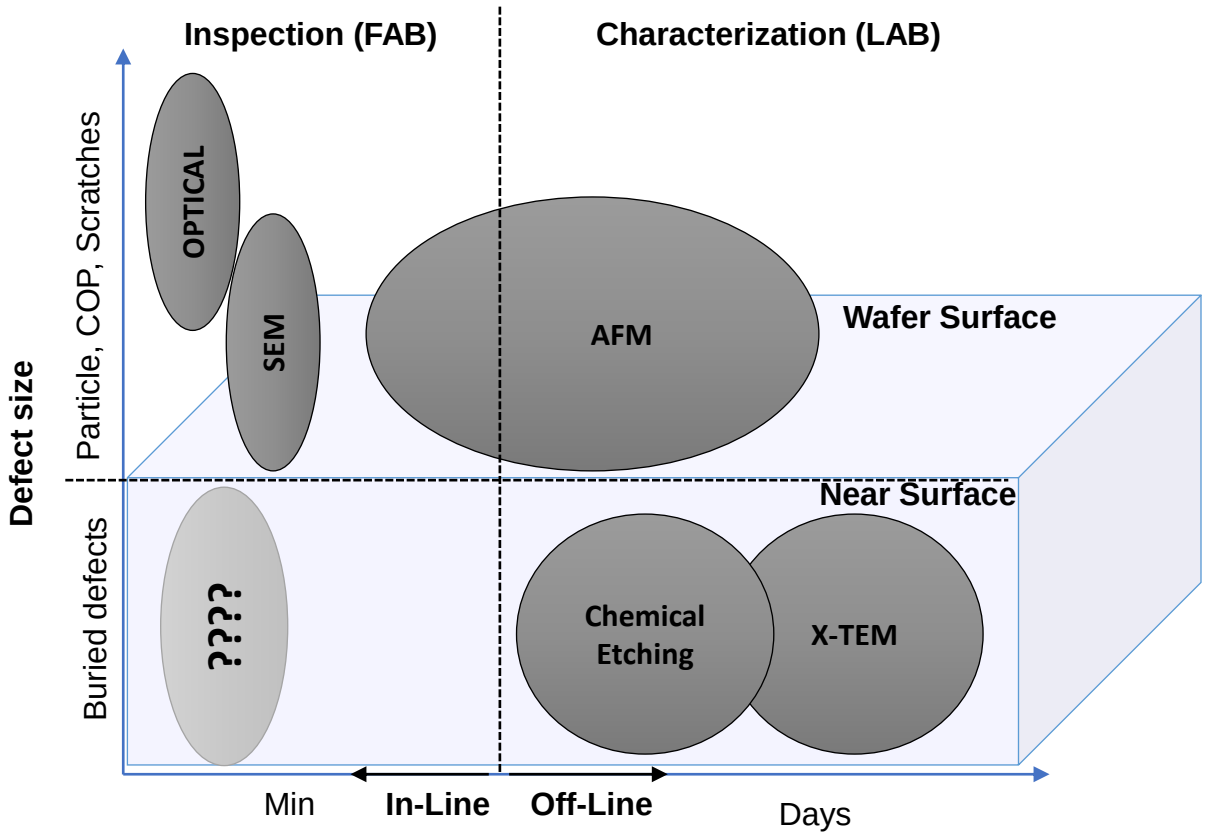


## 2008-2021: Flat panel area

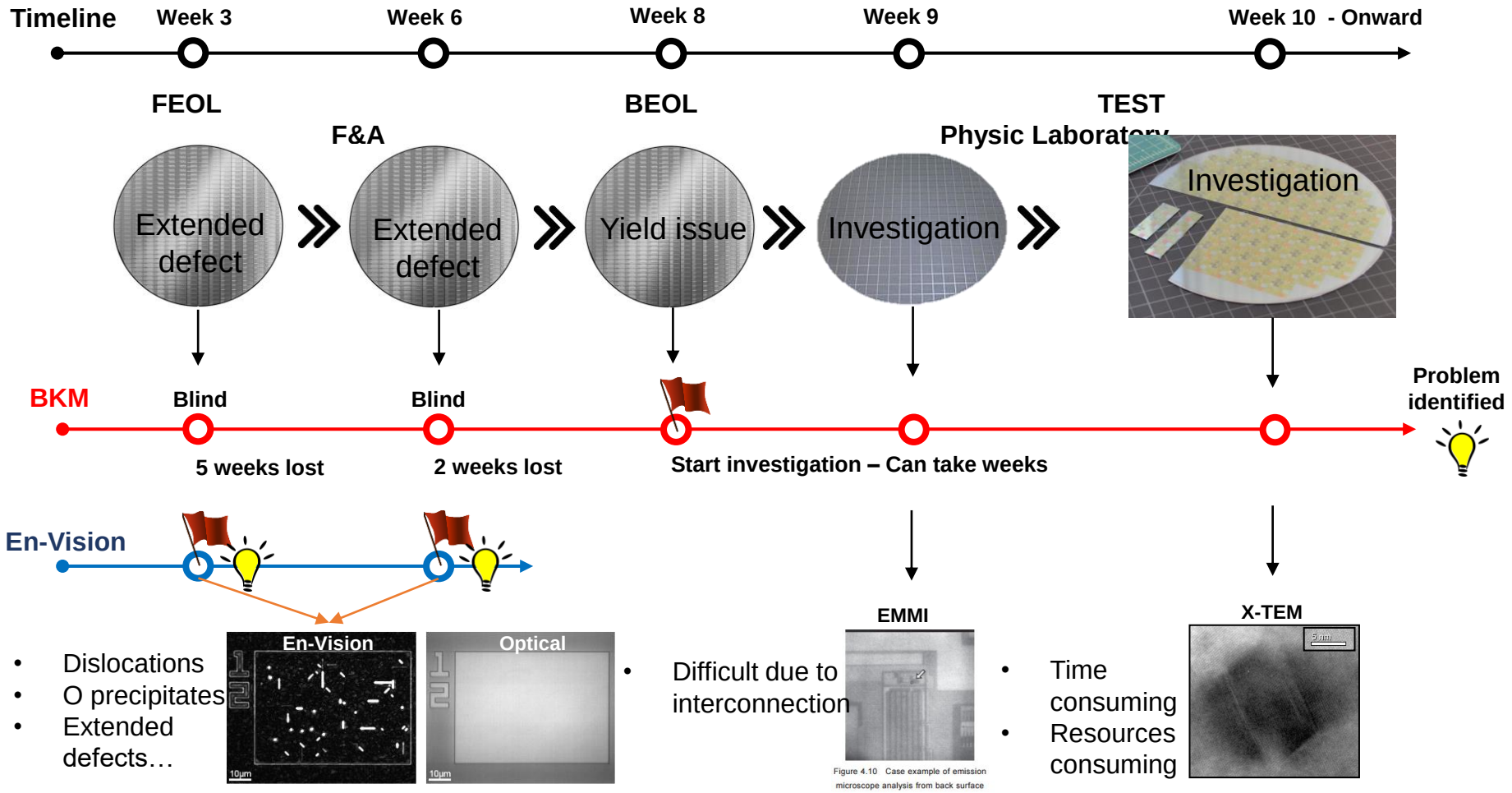
- **Building significant customer base in FPD industry**

# The Challenge

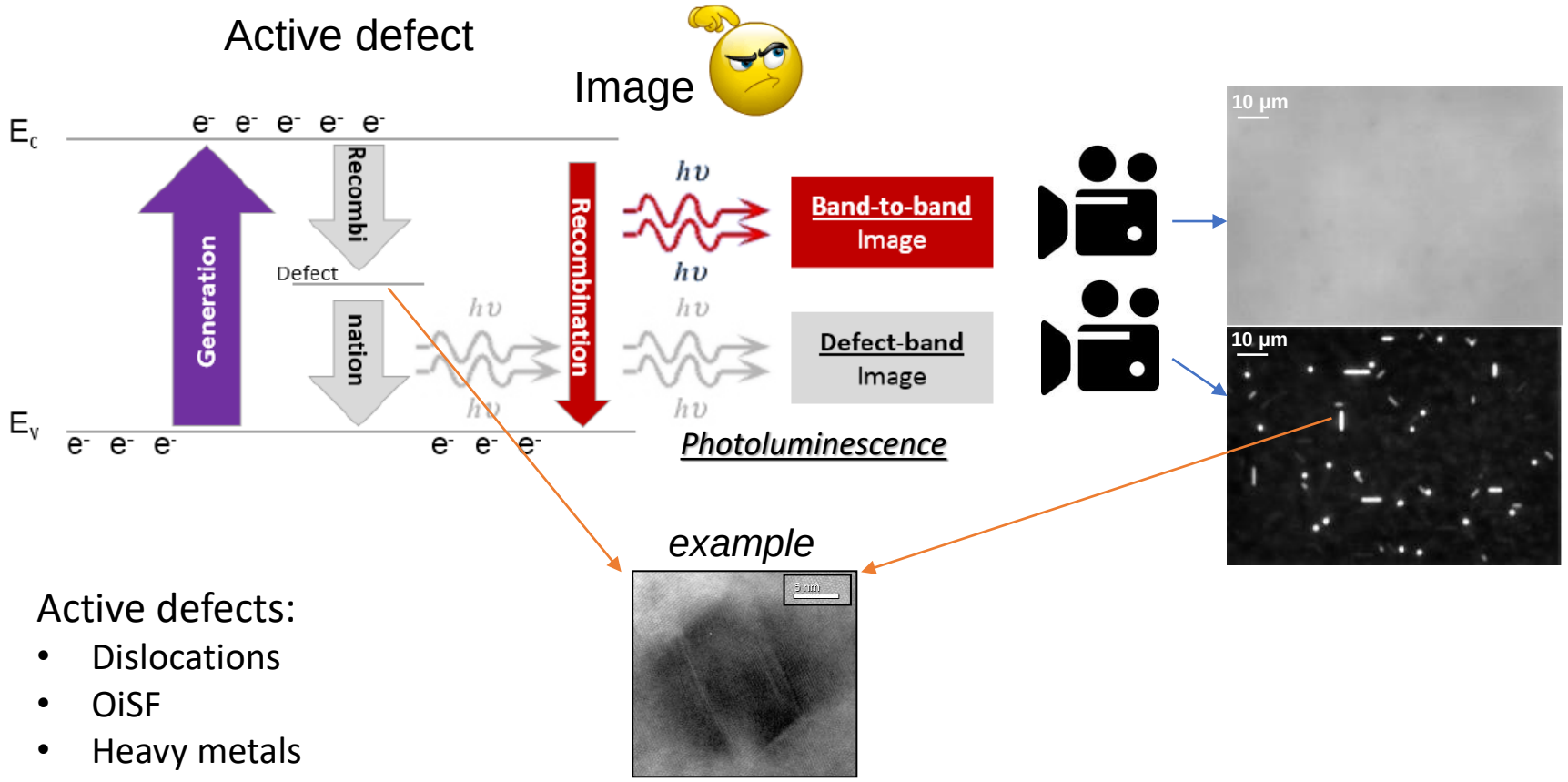
- Inspection tools: give mostly surface data (critical dimensions, pattern defects, etc.)
- Metrology tools: give process and material data, surface defects or maybe near-surface defects
- Failure Analysis tools and lab equipment: give detailed data but take a very long time and can only work after testing and fault isolation
- What about buried, non-visible, electrically active defects which kill the device but can only be discovered



# The Challenge



# The Idea: Defect Luminescence




Active defects:

- Dislocations
- OiSF
- Heavy metals
- ……

**Electrically active defects: kill devices and emit light if charge carriers recombine through them. → Capture the light, catch the defect.**

# Boost Productivity by Collaboration

- Semilab developed the EnVision system based on the idea shown
- MADEin4 project to boost productivity using the system
  - Booster 1: Improve productivity by enhanced metrology system productivity (at the same time enhancing sensitivity)
  - Booster 2: Use big data and smart algorithms to reduce cycle time – connect early defect detection to yield impact or device performance, thus enable high-reliability performance prediction

# Application Development Roadmap

| Market | Device | Parameter | Process step |
|---|---|---|---|
| • Automotive<br>• Power | BCD, Power IC, Analog, BiCMOS, MEMS | • Stress induced dislocations (DTI)<br>• EPI quality control | • After DTI filling & densification (anneal)<br>• After EPI, after stress inducing steps |
| • Consumer<br>• Industrial<br>• Automotive | CMOS Image Sensors | • Dark current (Pixel passivation)<br>• White Pixels (Crystal defects) | • After pixel passivation steps (dielectric deposition and DTI anneal). FEOL / BEOL.<br>• After DTI anneal, after stress induced steps |
| | 3D IC | • Back grinding defects | • After back grinding |
| | Logic & Memory | • Implant defects<br>• Bulk Micro Defects | • After implant<br>• After hot processing<br>• Exploratory work on advanced nodes |

# Application Development Example

- Even within the detected light, additional wavelength filtering is possible
- Based on that and literature, defects may be identified, such as this rod-like defect of unknown origin on an imager device
- Classification of defects is possible with wavelength filtering

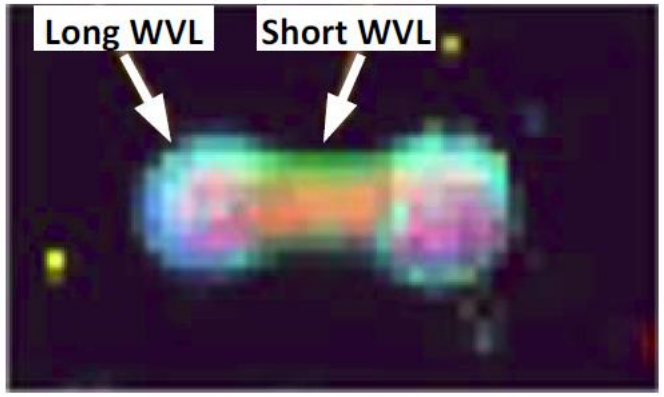
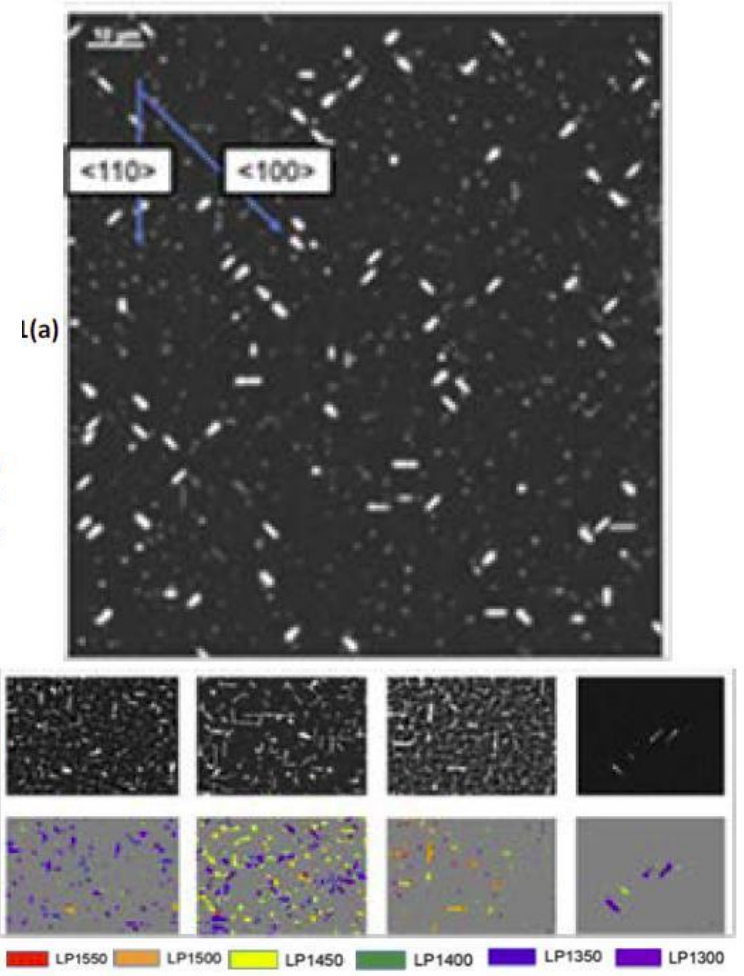



Fig. 2. A possible color representation of DPL emission from a large (about 6μm) rod-like defect. Colors correspond to emission peak position; longer emission wavelength at the ends, shorter in center.



# Application Development Example

- Experiment to correlate defect and device performance on CMOS Imager used in a variety of markets
- Here, defect source and impact mechanism is known
  - High-energy implant causes dislocation which acts as recombination center causing device failure
- Goal: collect more data and possibly use machine learning to identify more correlations or impact mechanisms

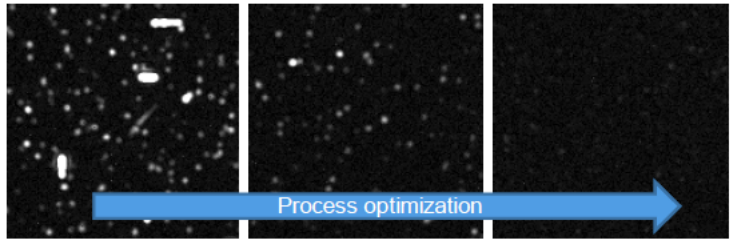



Fig.8. Reduction of defect count achieved during optimization of process used for P-N junctions in CMOS devices [1, 5]. Notice reduction of defect count, defect intensity and defect size during process optimization.

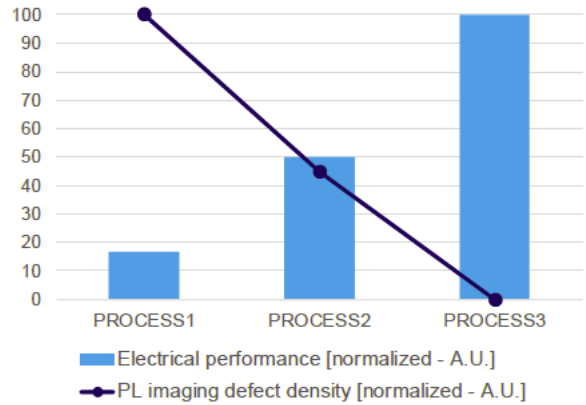
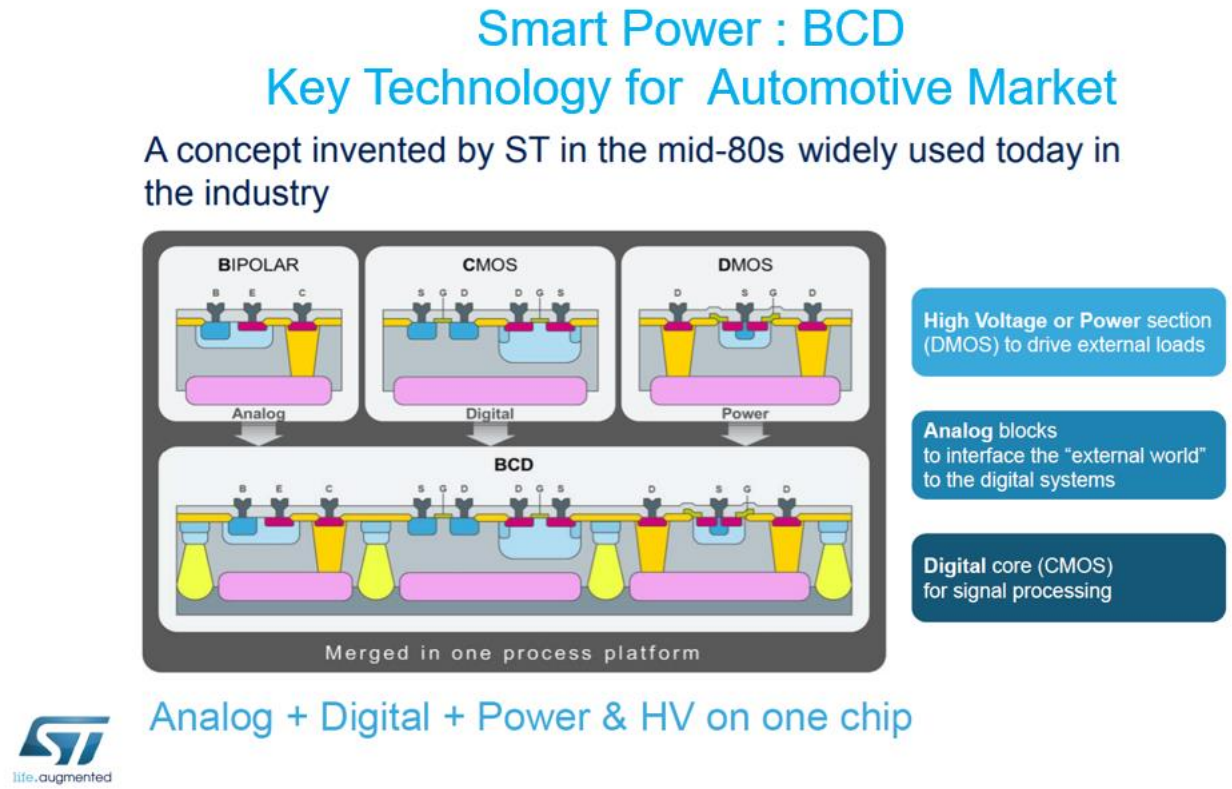



Fig. 9. Process optimization; reduction of defect count as measured by DPLI and corresponding yield improvement [1,5].

# Collaboration with ST-I

- Semilab deployed the technology in ST Italy
- Applications are being developed and tested on devices for automotive and power applications




Courtesy of ST-I

# Summary

- Semilab developed a new technology to detect non-visible, electrically active defects in the semiconductor manufacturing process to increase reliability of products intended, among others, to the automotive market
- The implementation in MADEin4 project included:
  - Improving sensitivity and developing new applications
  - Implement big data analysis by smart algorithm for improving cycle time of microelectronic device fabrication
  - Connecting to customers in key European industries such as automotive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