Open TSV technology for 3D sensor applications

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Chemnitz, 23 Jun 2015

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Introduction / Motivation

TSV concept at ams

Applications

Outlook / Conclusions

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World of Sensors

Providing a seamless human-machine interface for a richer and more intuitive user experience

Communications & Consumer

- Ambient light, color & proximity sensing
- Gesture recognition
- NFC based contactless payment solutions
- Active noise cancellation
- Power management solutions

Automotive

- Safety systems
- Battery management
- Position sensing
- Comfort & chassis sensors
- Advanced driver assistance

Industrial

- Industrial/building automation
- Motion control
- Heat, Ventilation & Air conditioning (HVAC))
- Position sensing

Medical

- Digital x-ray
- Computed Tomography
- Surgical Robots
- Diagnostic equipment

Environment

- Lightning sensors
- Chemical Sensors
- Seismic analysis
- Temperature sensors
- Day light harvesting

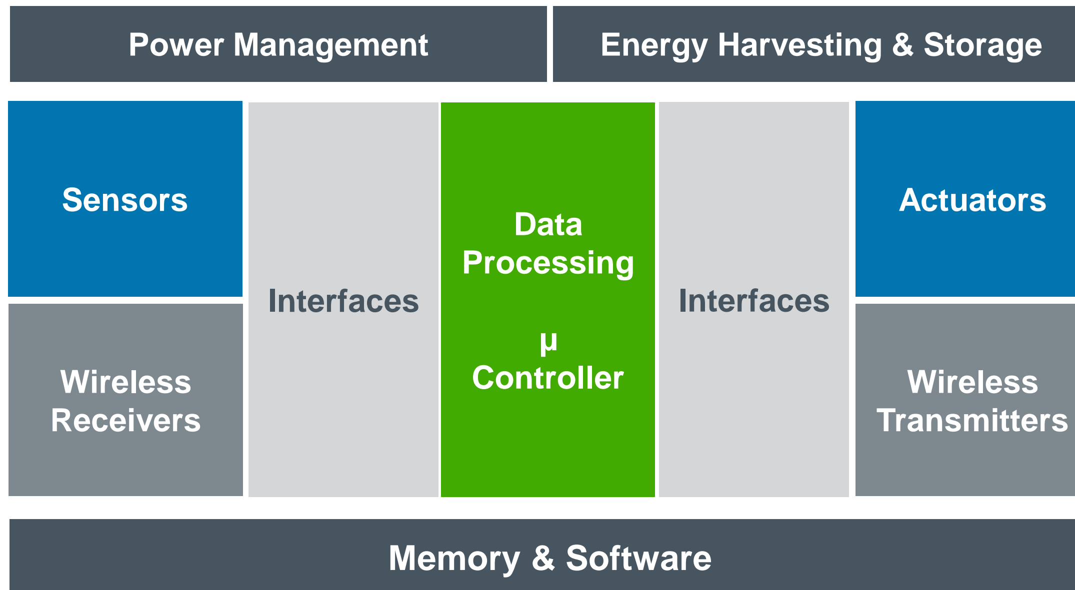
Health/Fitness

- Diabetes management
- Heart rate monitors
- Medication tracking
- Activity trackers

Sensors and Smart Systems

Sensors and ICs make systems smart

Smart system block diagram



Source: M.Schrems et al., 3D TSV Summit (2015)

Examples

Wearable/Fitness

Smart Watch

Smart Phone

Smart Home

…

Smart Everything!

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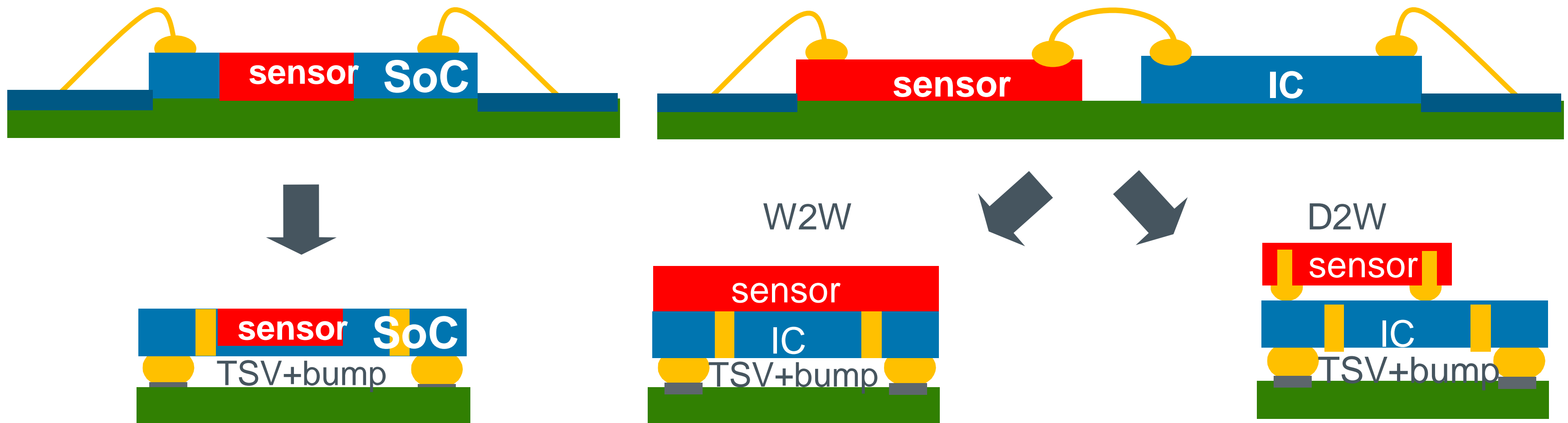
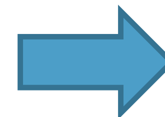
Sensor integration options



- SoC with TSV and RDL
- Integration by W2W bonding for matched sensor and IC die sizes and D2W stacking
- Integration by D2W bonding if the IC die size is larger than sensor die size



- Form factor reduction
- Performance advantages
- System cost reduction

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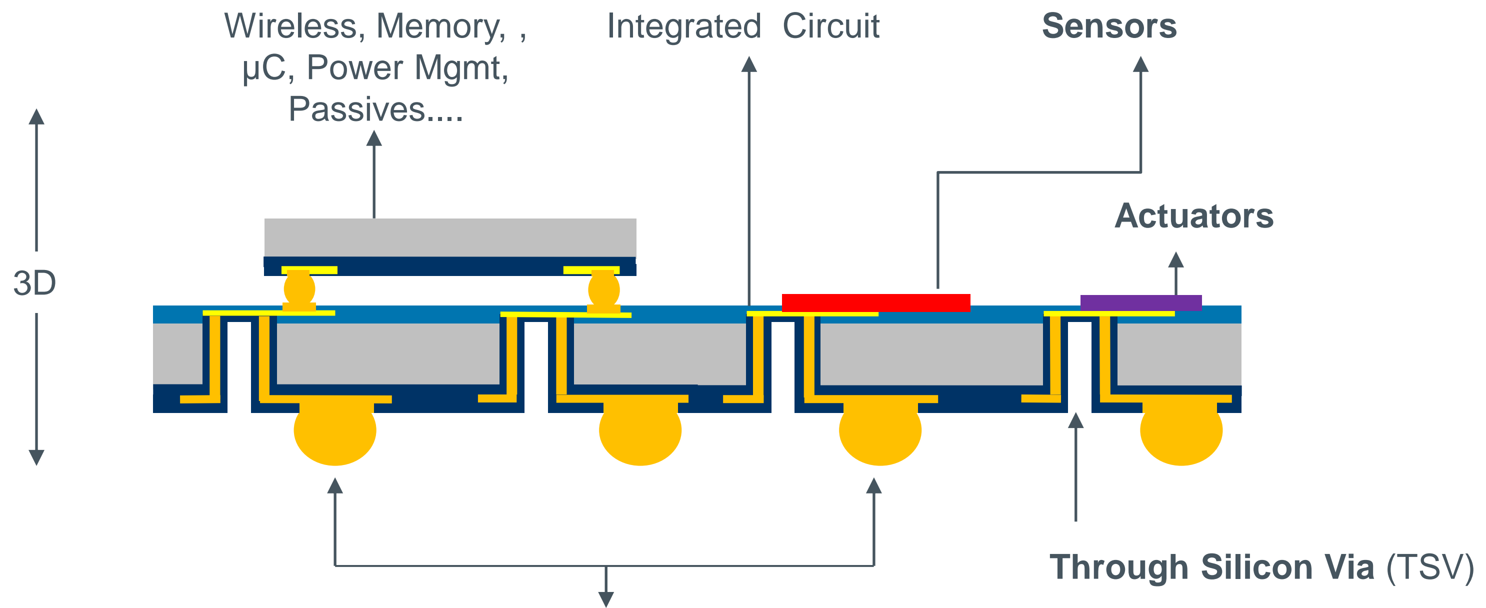
3D integrated miniaturized smart system



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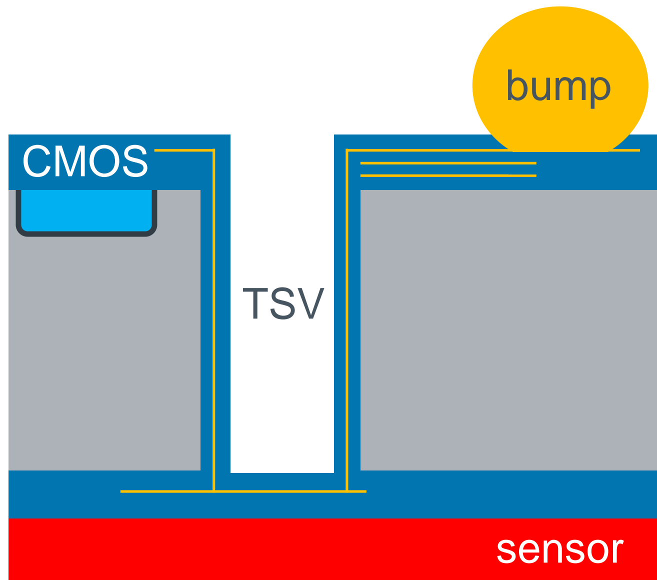
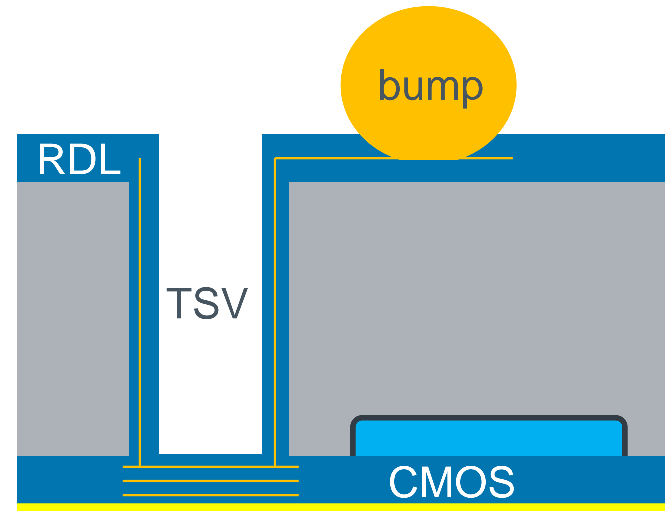
ams AG versatile open TSV integration concepts

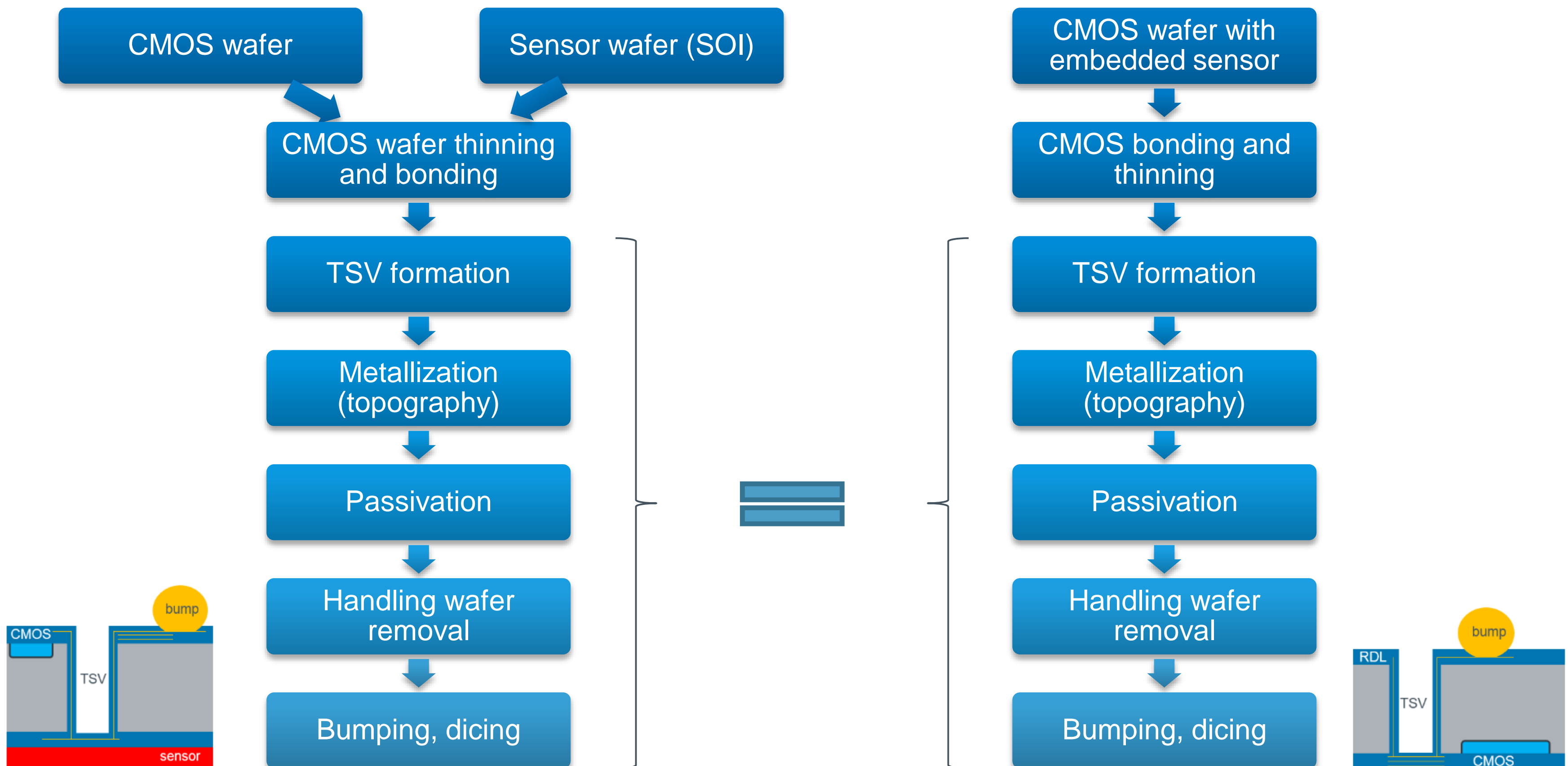


W2W based concept
(3D)



SoC and D2W compatible concept
(2.5D, passive/active interposer)

Process flows outlines



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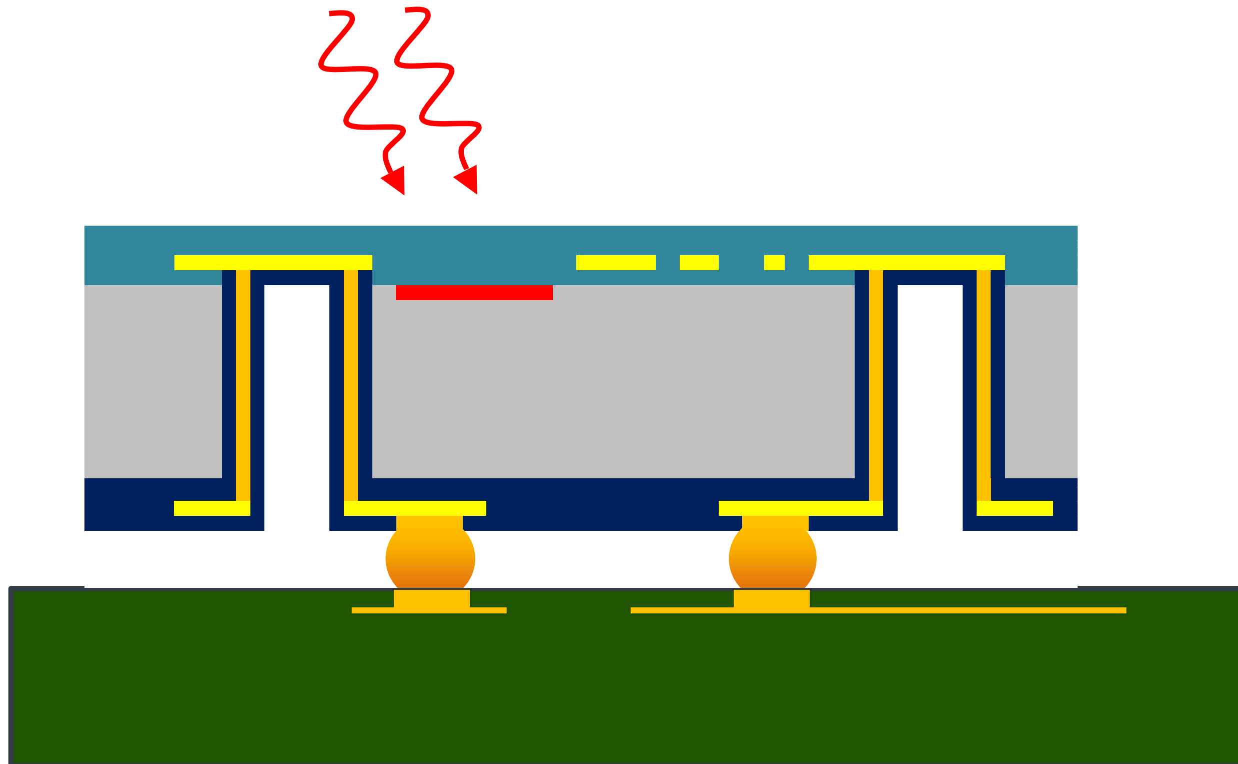
2.5D optical sensor

Active interposer



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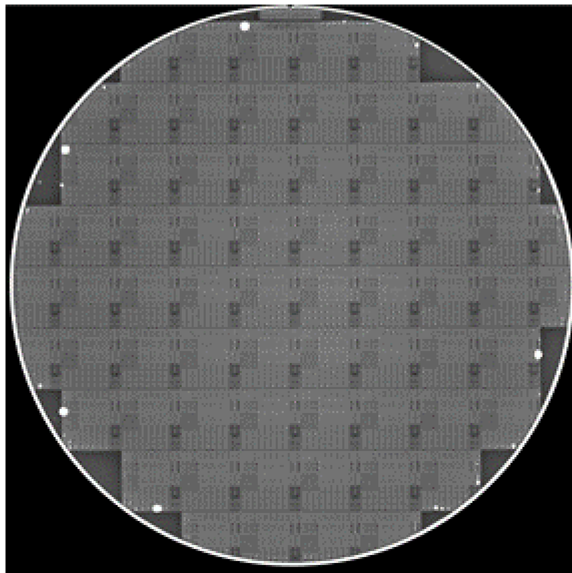
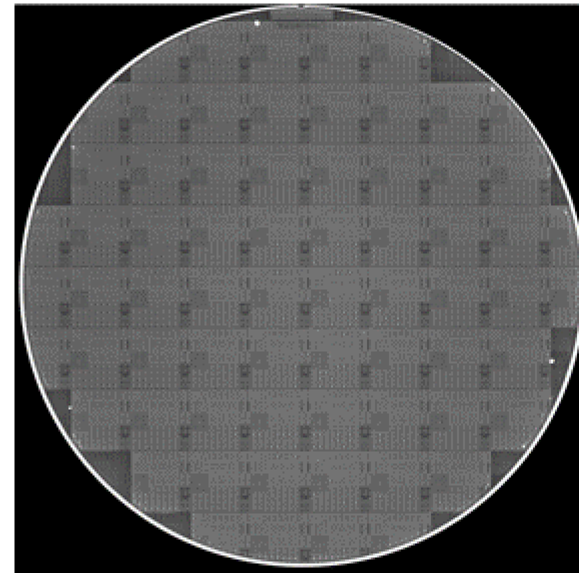
Permanent handling wafer bonding

Topics of direct bonding development

- **Bond oxide CMP optimization**
- **Optimization of stepper shot map**



CSAM of conventional HW bond



CSAM with optimized stepper shot map

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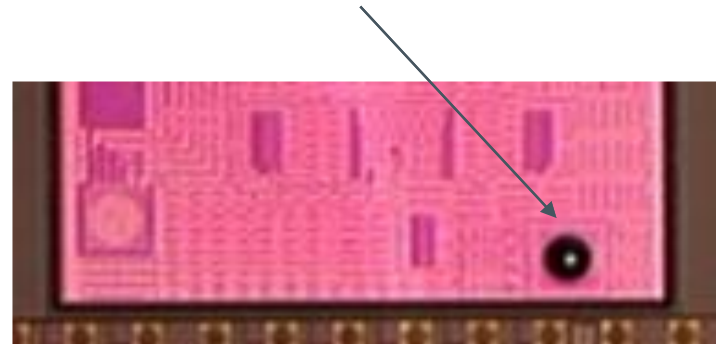
Impact of bond voids on TSV

Even small voids <0.25 mm^2 can cause TSV damages

CSAM with micro voids



Microscope image of CMOS front side after HW removal

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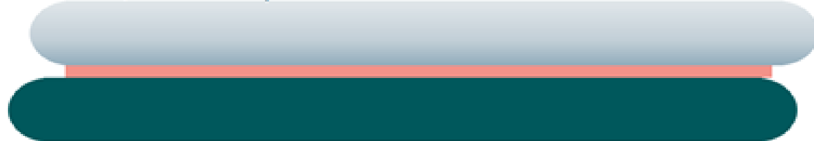
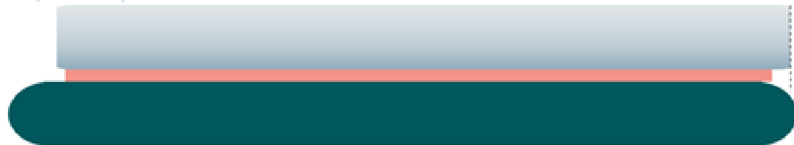
Wafer thinning and edge trimming

- **Thin wafer has a sharp edge→ protection during handling required**
- **Thin wafer must be smaller than handling wafer → edge trimming**

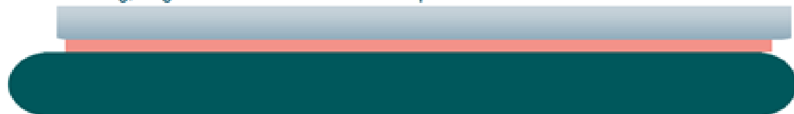
Bonded stack, thickness 1450 µm

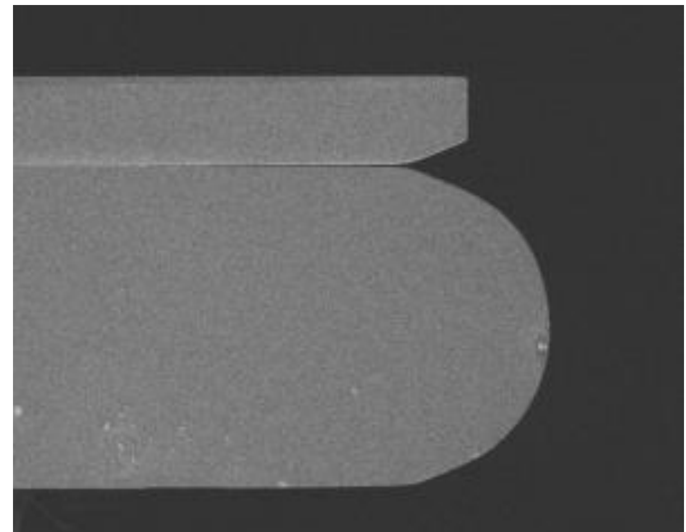


Edge trimming



Wafer thinning, target thickness CMOS wafer 200µm





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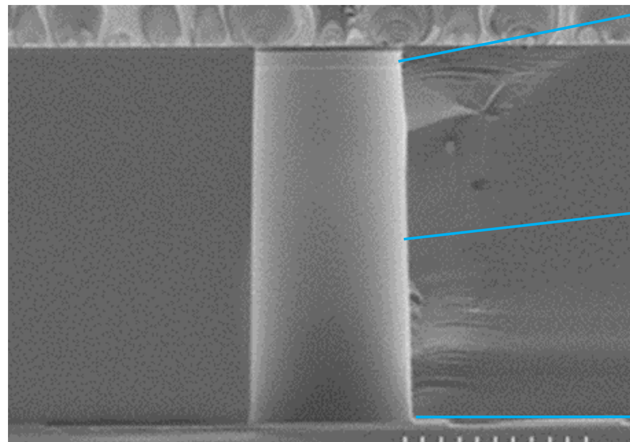
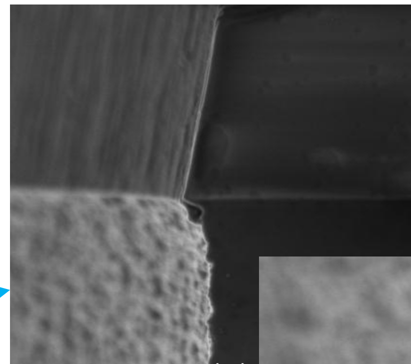
TSV DRIE development

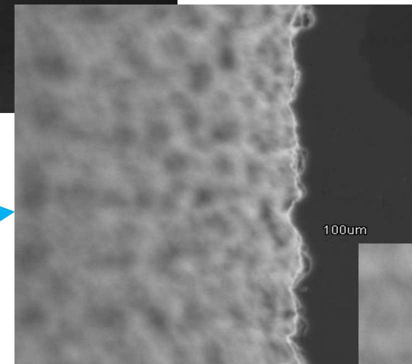
- **AR 2.5:1**
- **Stop on oxide**
- **Sidewall**



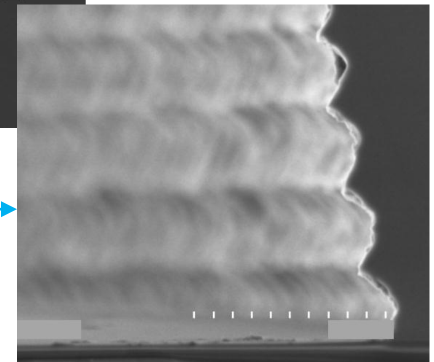
SEM cross section



low undercut



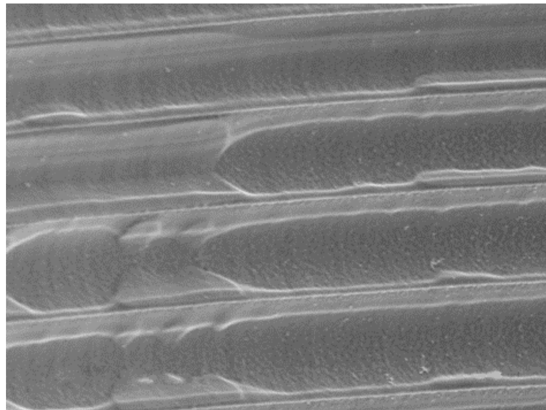
low roughness



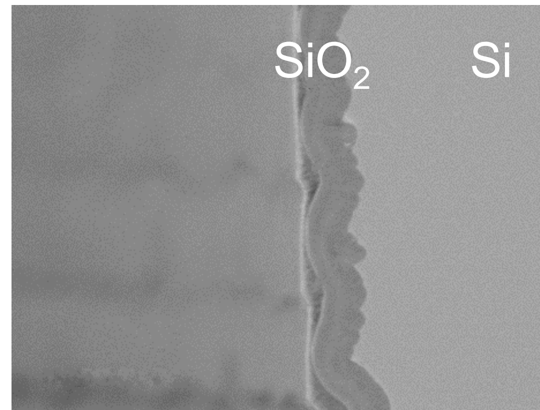
no notching

TSV clean

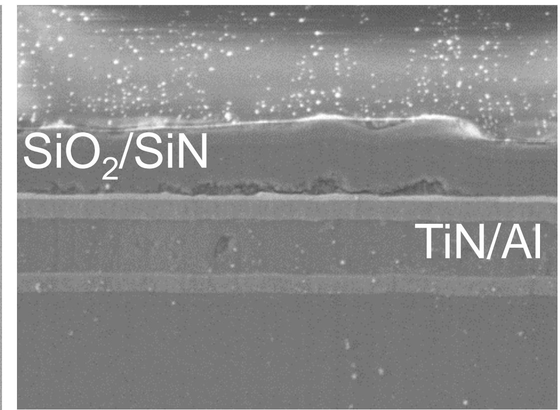
- **Clean TSV sidewalls/bottom critical for layer adhesion**
- **High topography structures: Conventional methods inefficient**



Bosch process



Isolation etch



Metal etch

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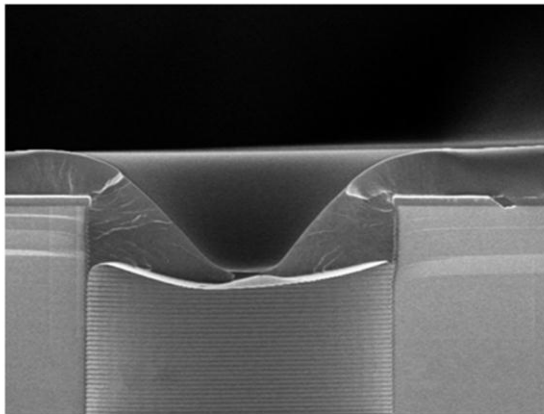
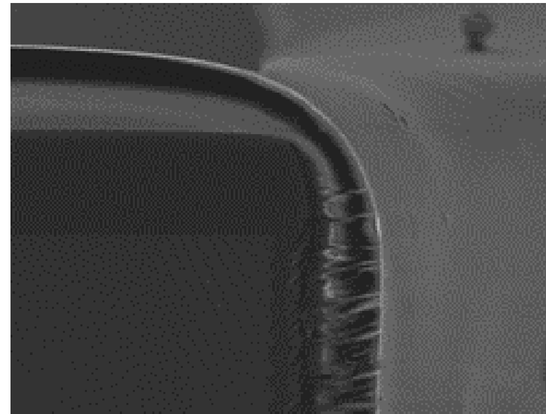
Lithography

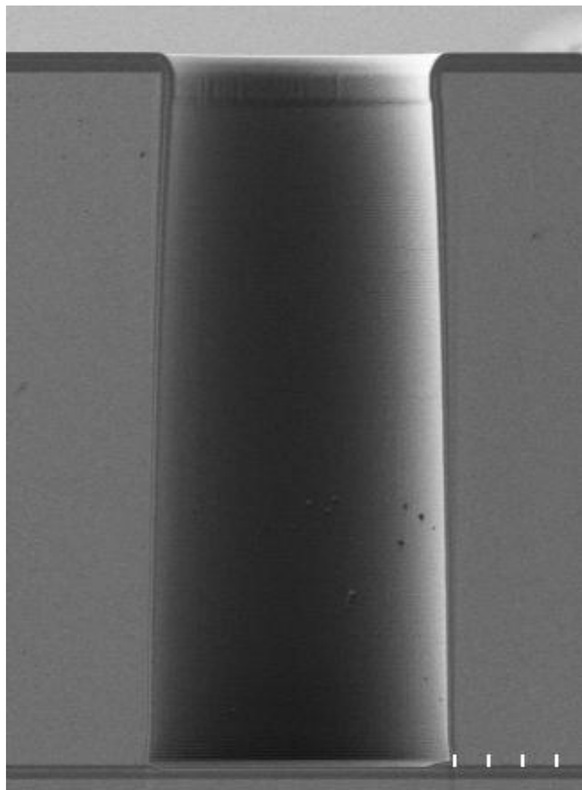
Options for lithography (resist coating) on high topography wafers include

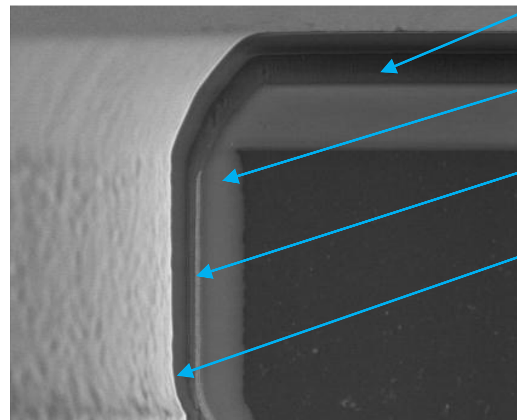
- **Dry film lamination**
- **Nanospray/Spray coating**

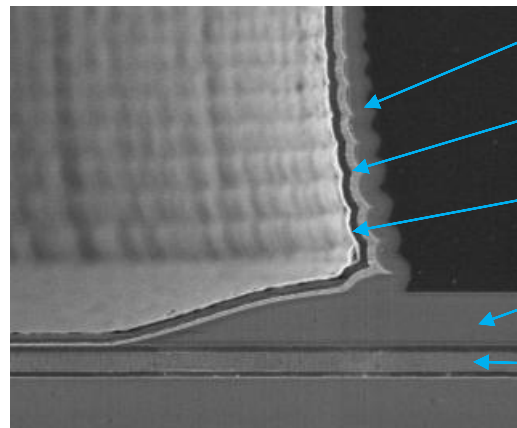




Open TSV layer stack







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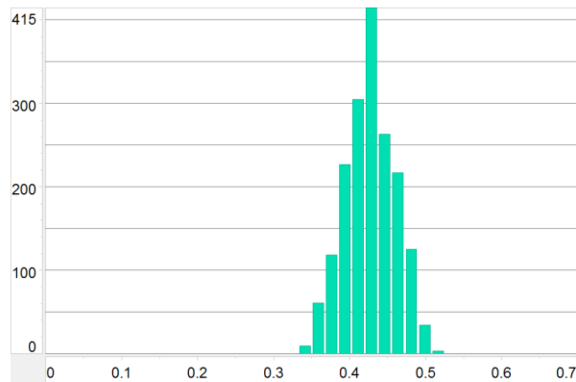
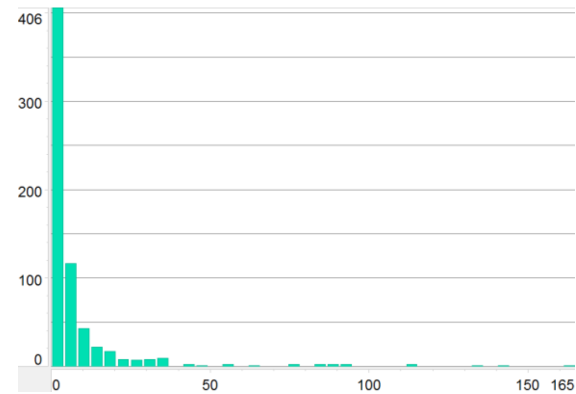
Electrical characterization



TSV resistance
avg = 0.43 Ohm



TSV leakage < 1 nA

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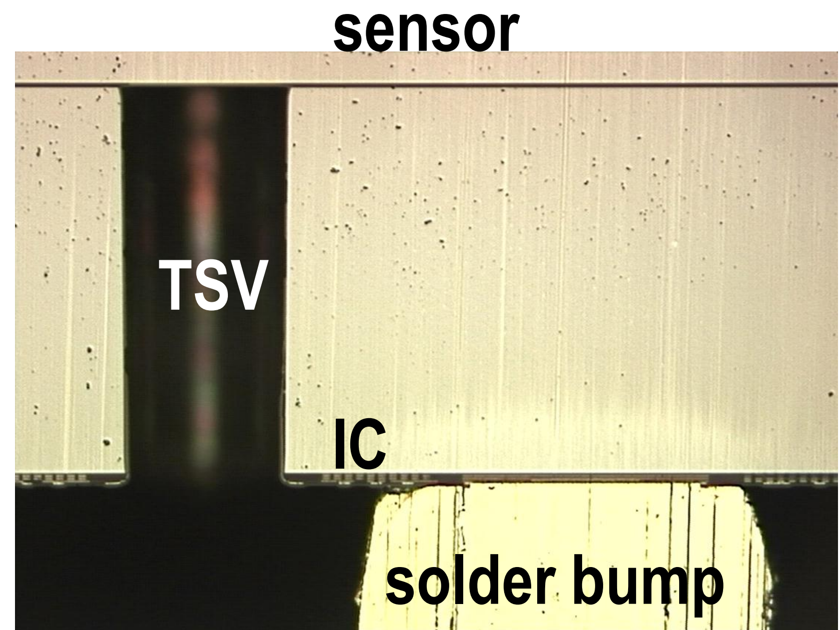
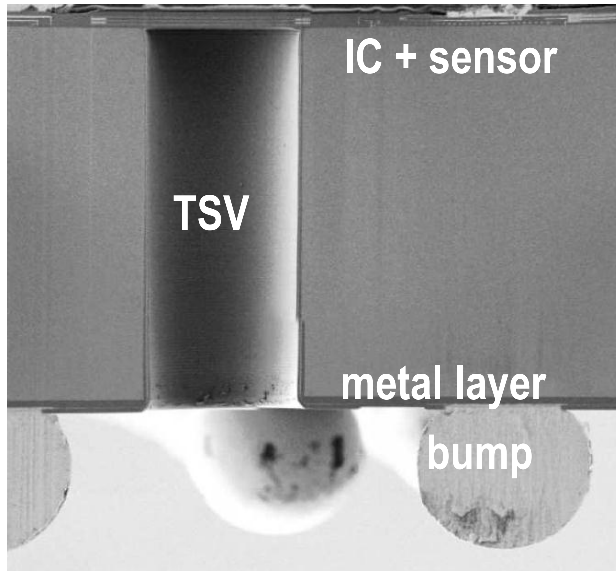
3D integrated photo sensor IC product example

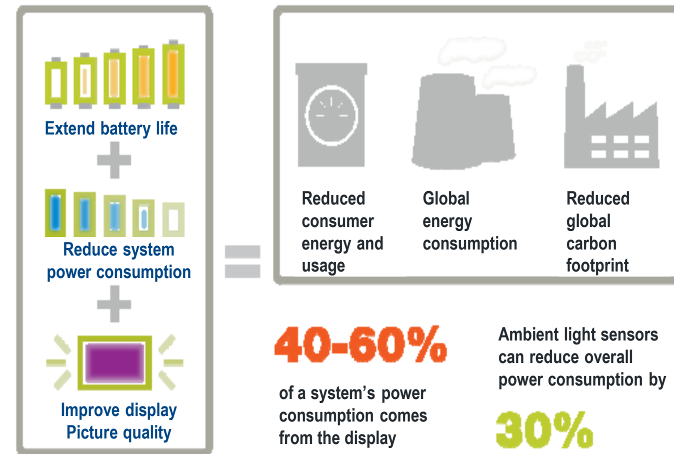


Ultra low-noise circuitry
➔80% less energy consumption

2.5D integrated optical sensor IC product example



Source: M. Schrems et al., ESSDERC 2014



Source: F. Schrank et al., Minapad 2015

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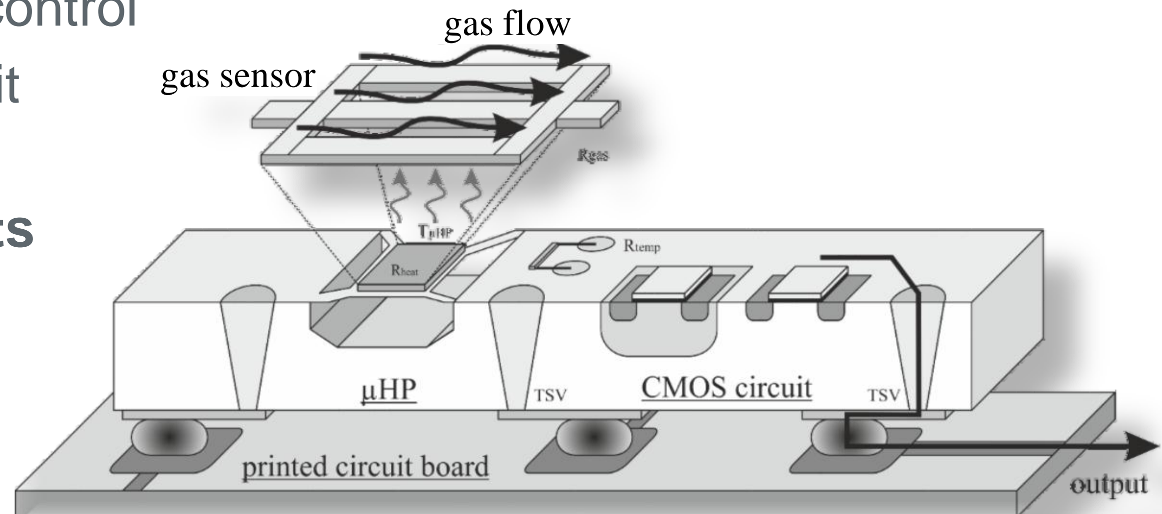
3D chemical sensor ICs with TSV

- **Sensor architecture**
  - Gas-sensing metal oxide layer
  - Micro-hotplate (µHP)
  - Temperature control
  - Readout circuit
- **TSV interconnects**
- **System-On Chip**
- **CMOS process**



Source: A.Nemecek et al., Semicon Europe 2014, FHWN, ams AG, AIT, MCL

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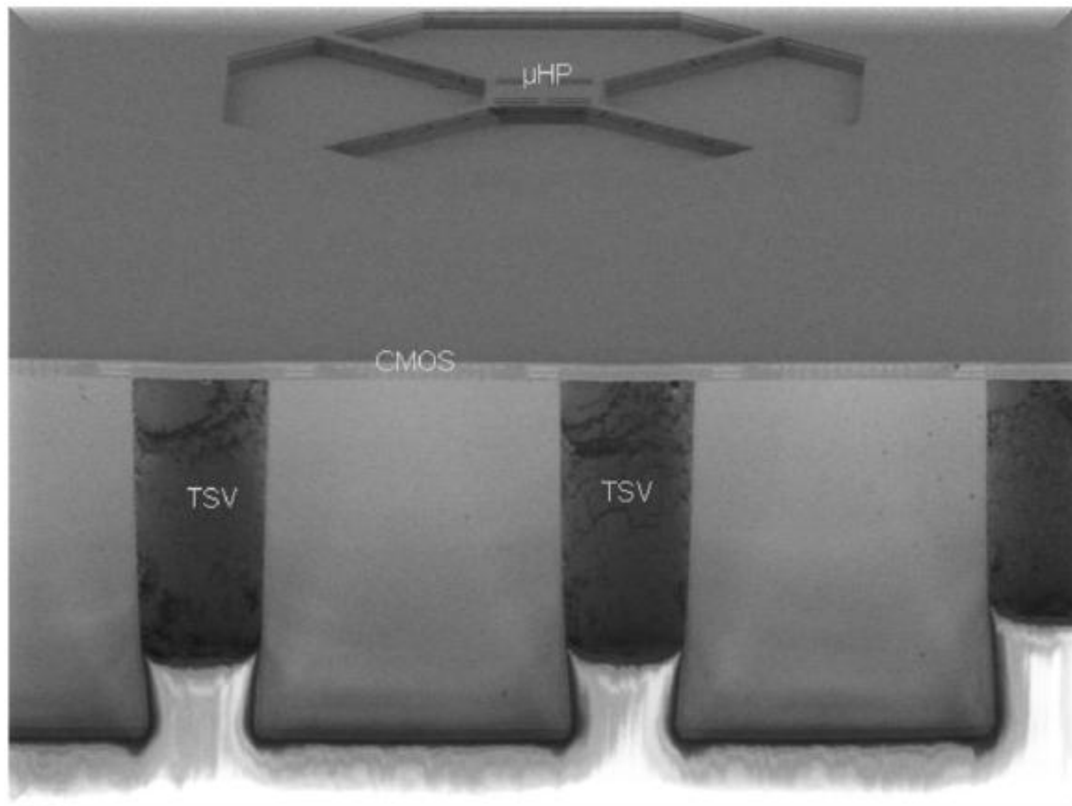
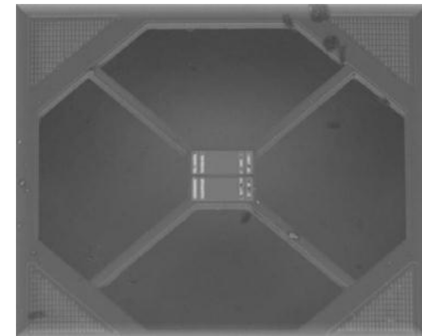
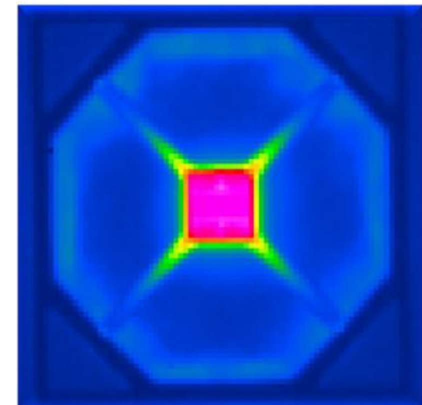
3D chemical sensor ICs with TSV contd.







Source: A.Nemecek et al., Semicon Europe 2014, FHWN, ams AG, AIT, MCL

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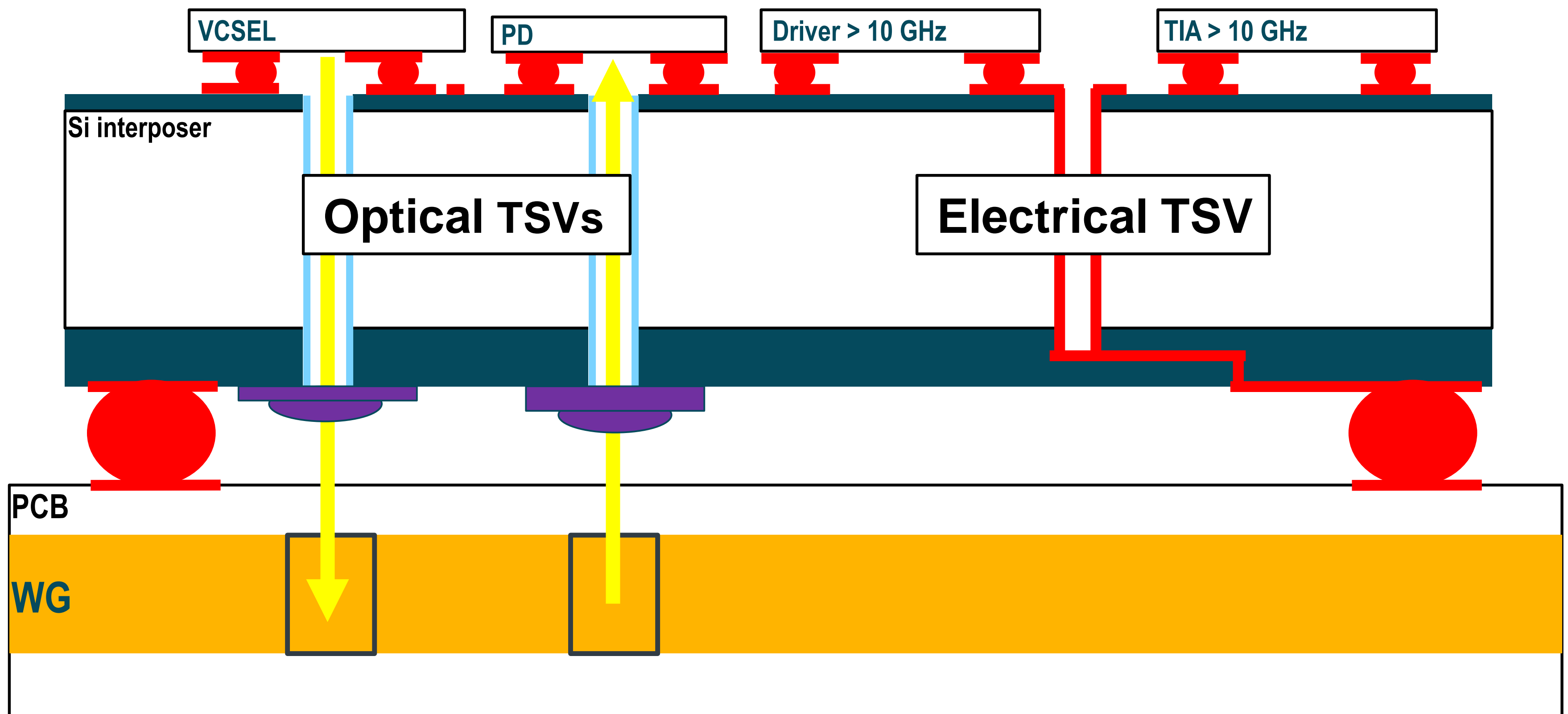
Si Interposer with optical and electrical TSVs



Source: T.Tekin, EU FP7 PhoxTroT – Semicon West 2014 (FhG, ams AG)

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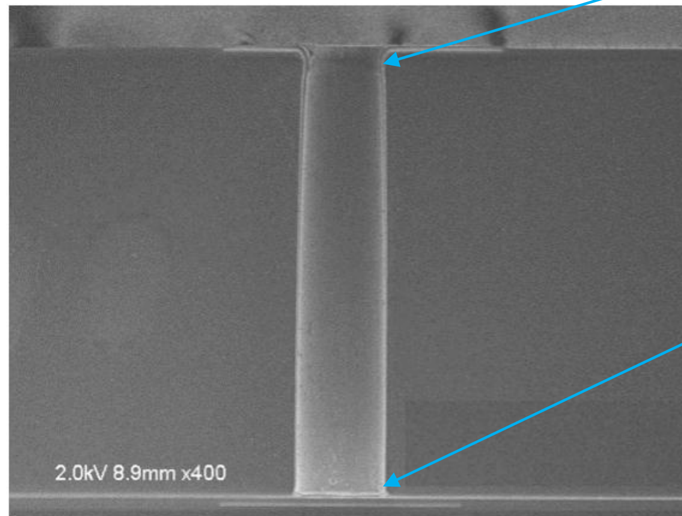
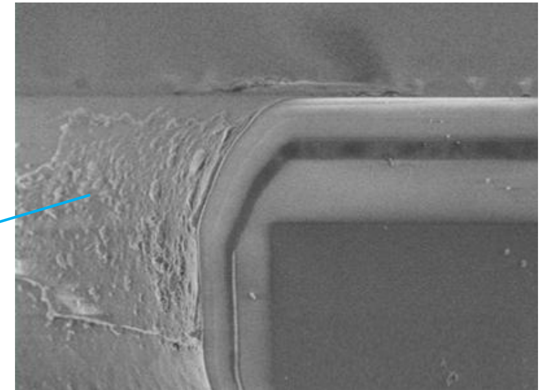
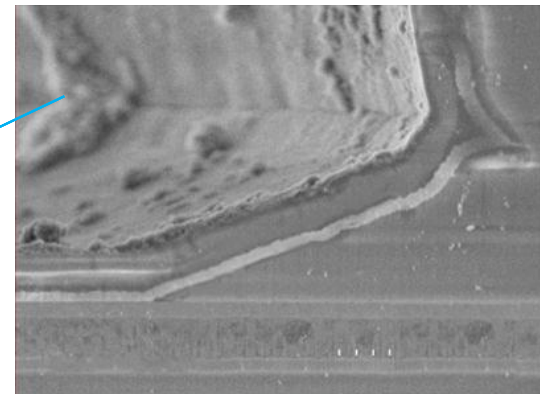
Outlook – TSV shrink

- **TSV last with increased AR to 5:1**
- **Challenges:**
  - DRIE
  - Deposition
  - Cleaning



SEM of cross section





Conclusion

- **Open TSV AR 2.5:1 (100 µm and 80 µm diameter)**
- **Versatile process flow for TSV and RDL established**
- **Maturity of technology proven with electrical data**
- **First results of TSV shrink to AR 5:1**

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Acknowledgement

- **Entire ams AG project team**

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