



8th esa round table on micro and nano technologies
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European Space Agency

Nano-filled solder paste for highly dissipative power electronic assemblies

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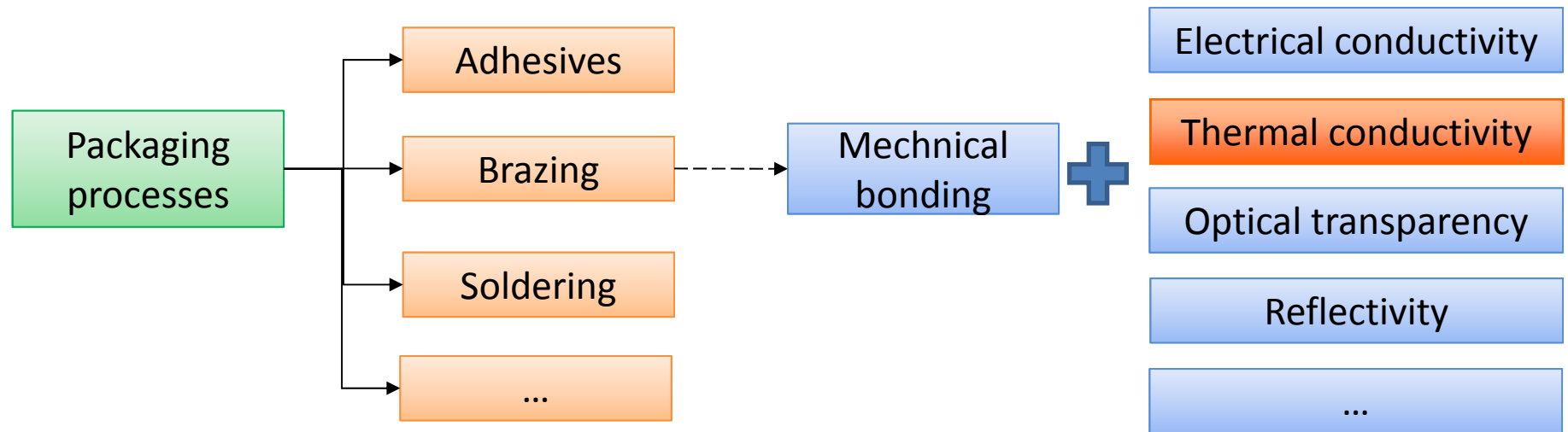
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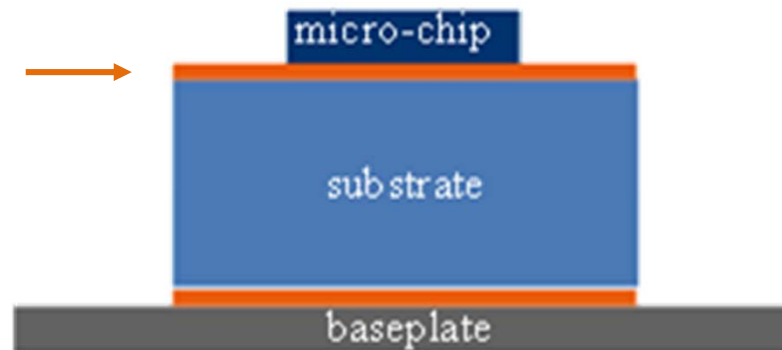
Context: need for new packaging solutions



- Recent development of high power devices: power X 10, up to 180W

AuSn: $k=58\text{W/m.K}$

Filled adhesives: $k\sim 1\text{W/m.K}$



Need:

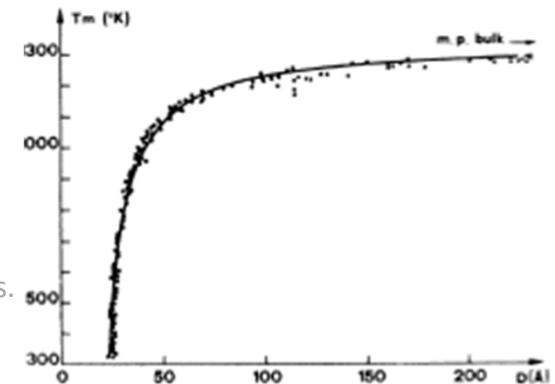
- * thermal conductivity $>$ AuSn
- * compatible with hybrid technologies (CTE: 7-10ppm/K, process, etc)

Interest of metals as new brazing materials

- Possible solutions: Cu, Ag, Au, alloys...
- Silver = best thermal conductor after carbon diamond (thermal conductivity: 429 W/m.K)
- Driving idea: take benefit of the strong decrease of the melting point with particle size
- Bulk silver (melting point: 961.93°C)
- Silver particles <10nm

Process:

- * short (few minutes)
- * low pressure (<10MPa)
- * moderate temperature (<300°C)



Ph. Buffat, J.P Borel, Phys. Rev. A 13, 6, (1976) 13.

~~incompatible~~

compatible

Use of nanoparticles: health and security issues

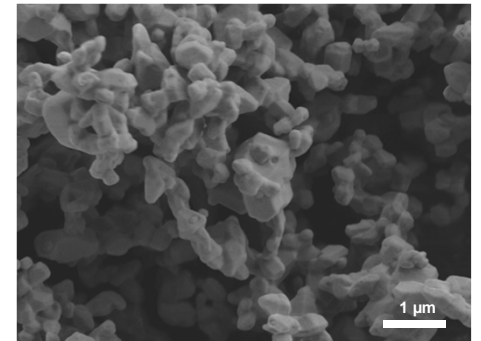
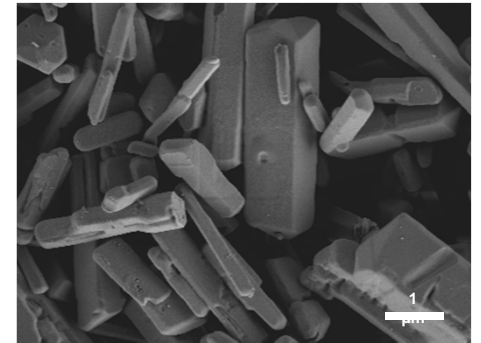
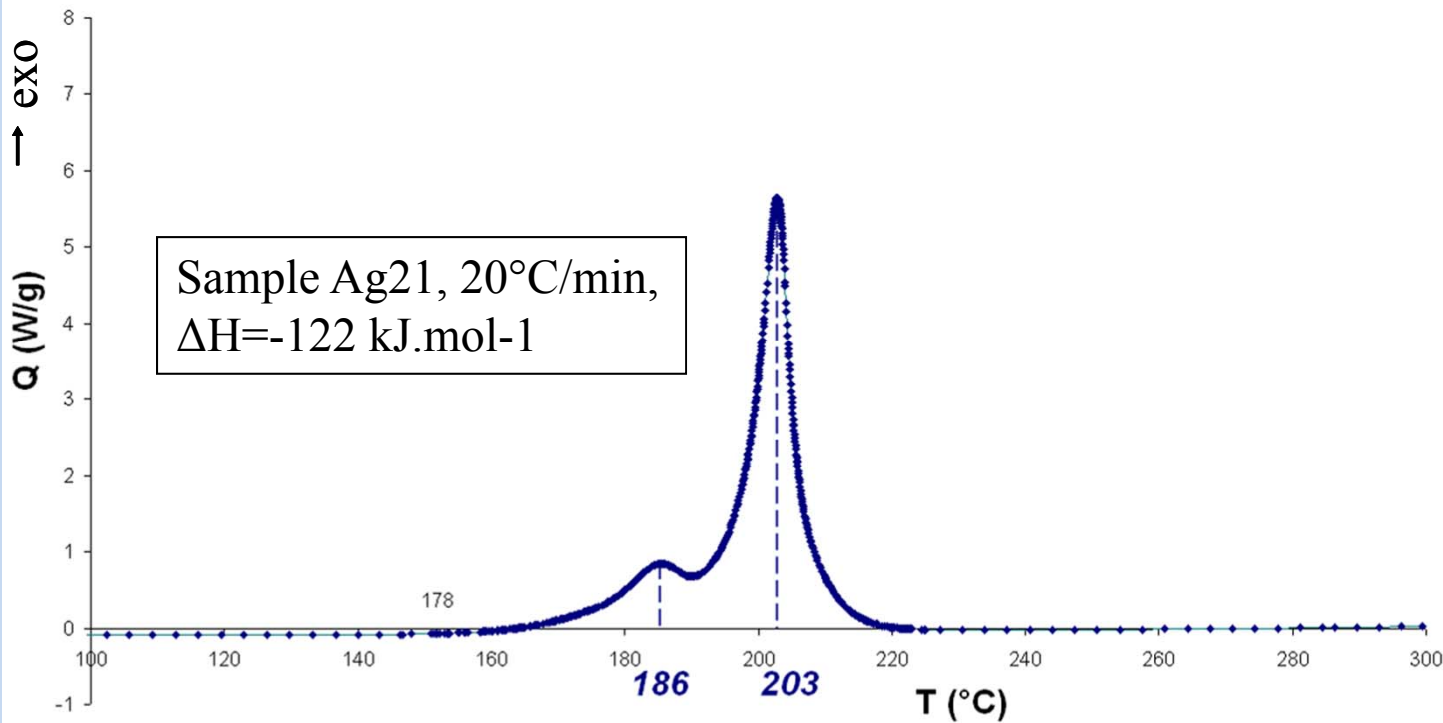
A scanning electron microscope (SEM) image showing the surface morphology of a nano-filled solder paste. The surface is covered with numerous small, spherical nanoparticles, which are distributed across a larger, textured substrate. The overall appearance is granular and porous.

Use of a new precursor

Use of a new precursor

Patent
granted

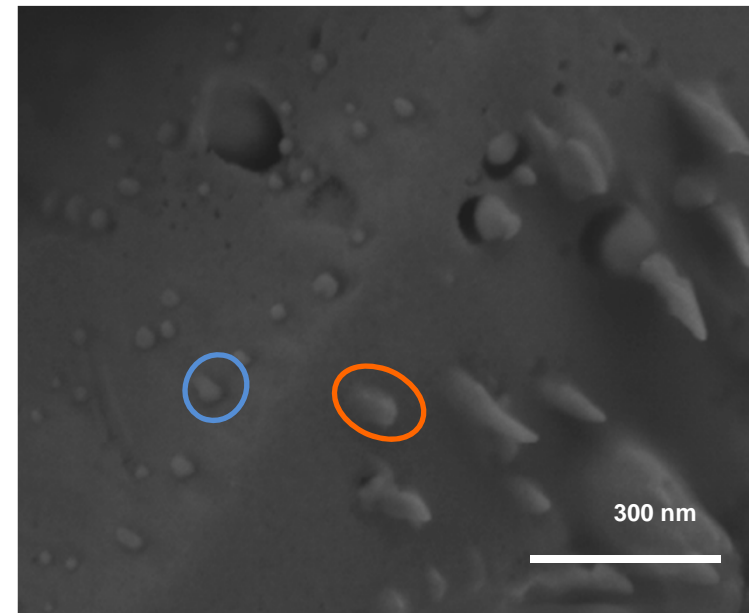
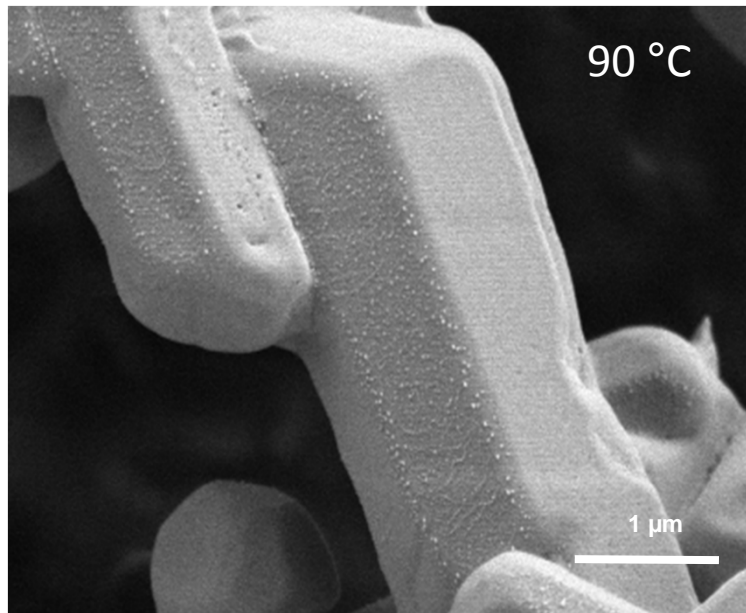
Nano-Ag <10 nm
+
Highly exothermal reaction



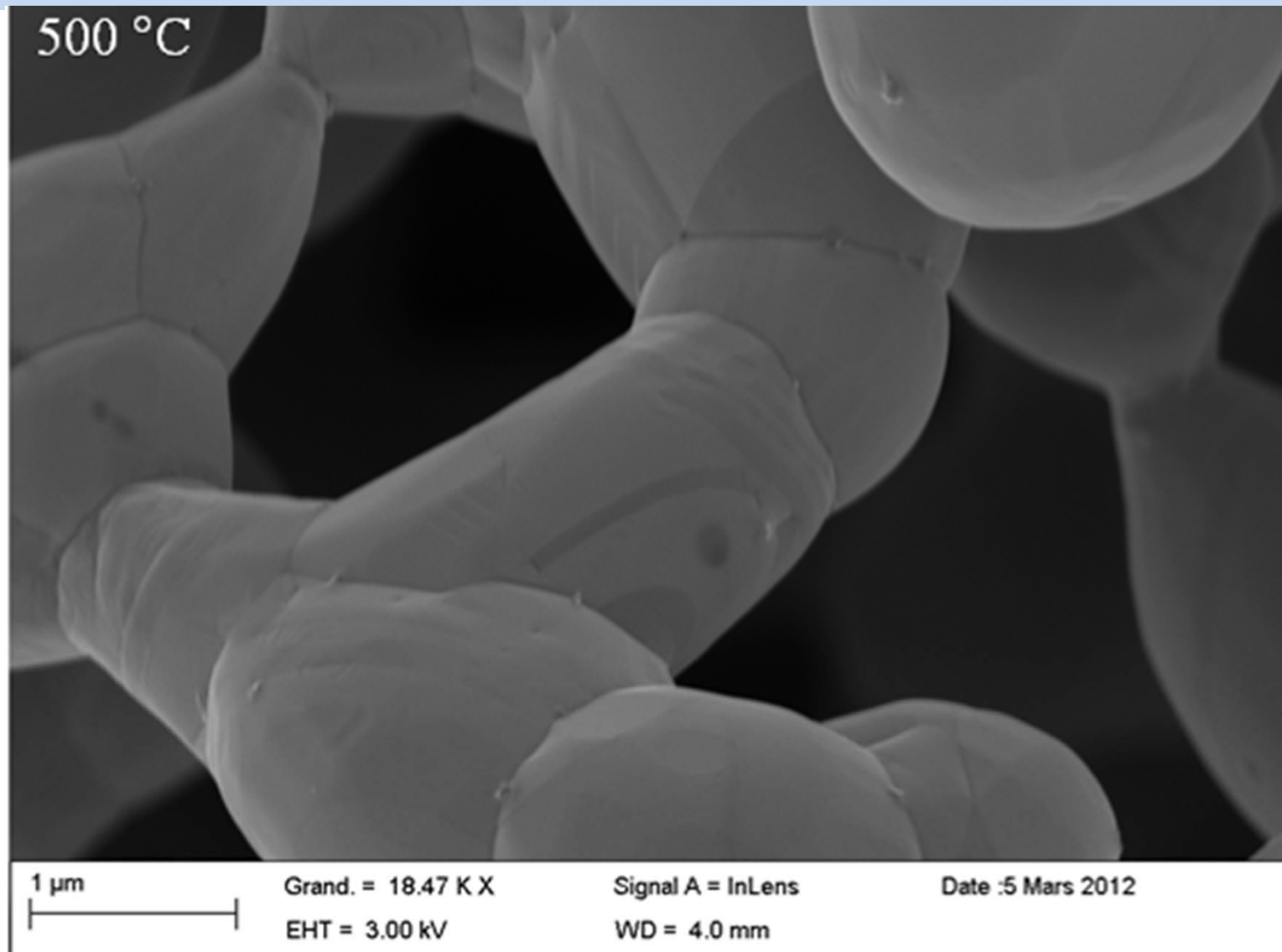
Particle surface transformations: isothermal study

Investigation of the phenomena occurring at the particle surface:

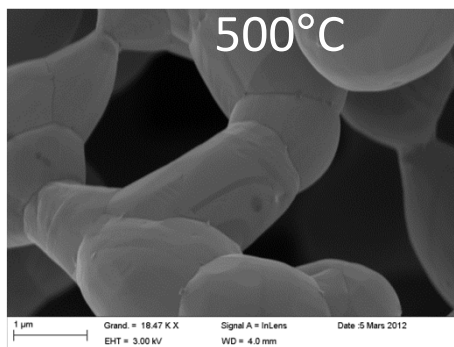
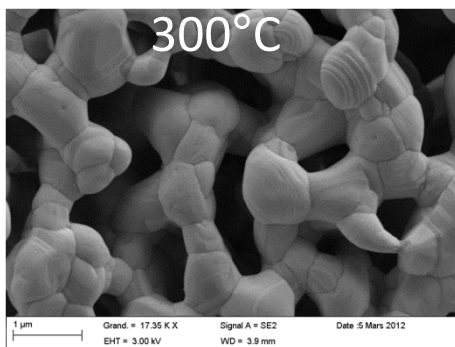
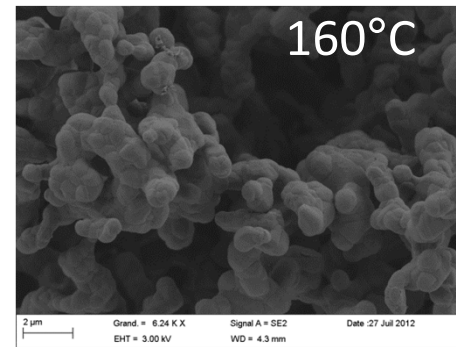
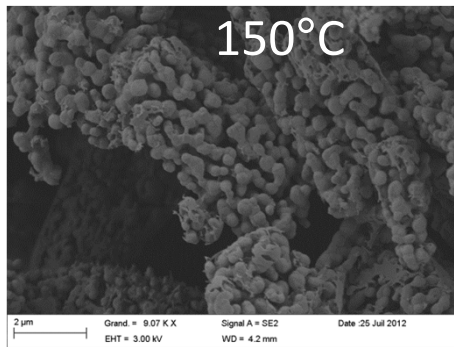
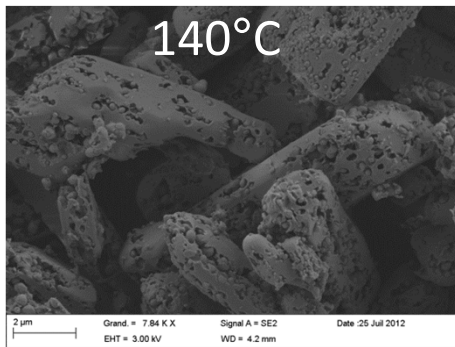
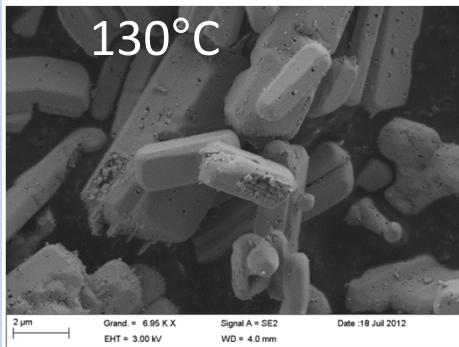
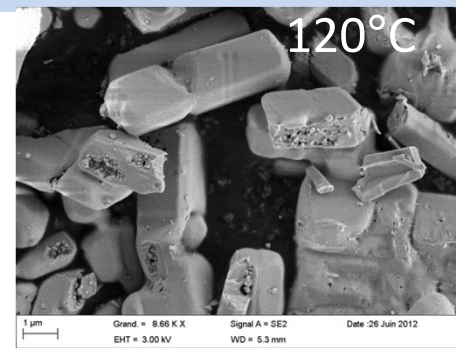
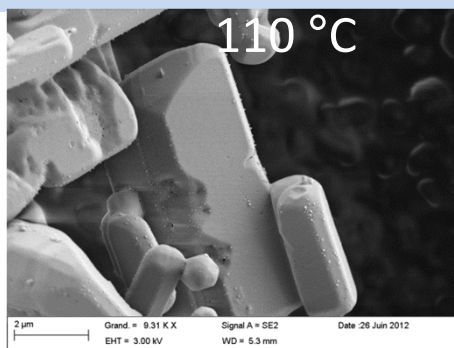
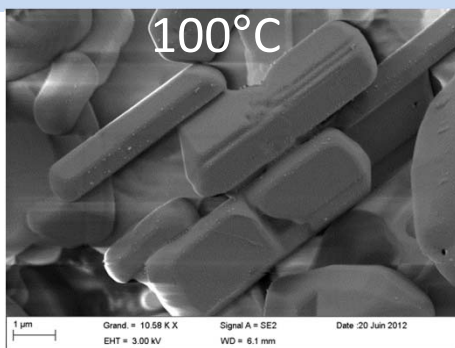
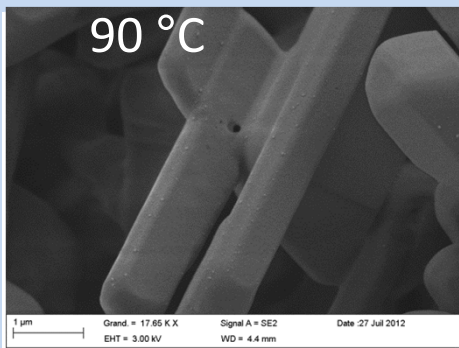
- Decomposition by isothermal holdings (10h) every 10 °C to better separate the exothermal phenomena
- Constant heating rate (5 °C/min)



Particle surface transformations: isothermal study



Particle surface transformations: isothermal study

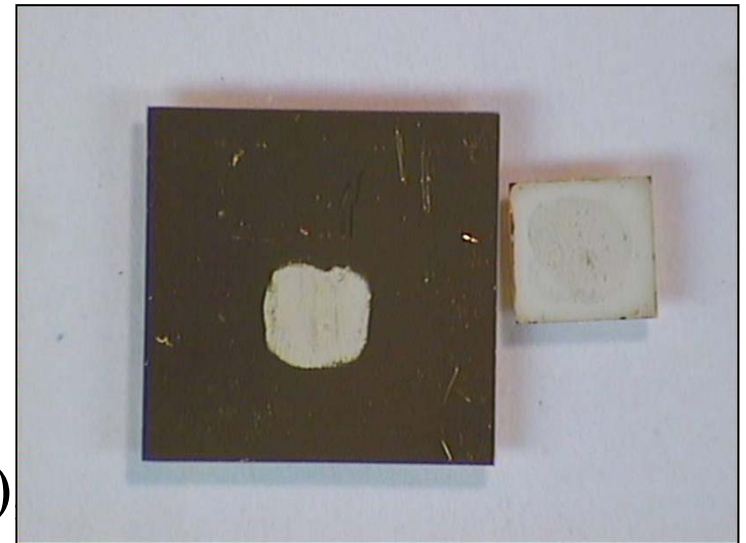
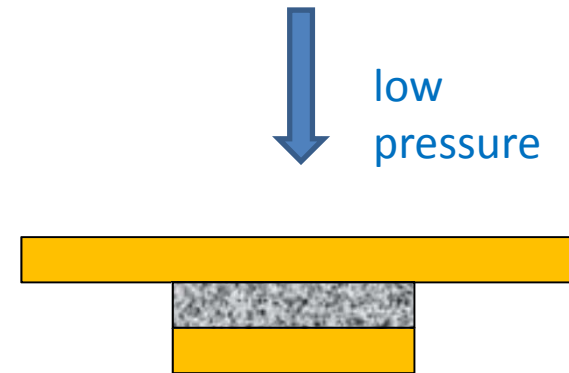


A scanning electron microscope (SEM) image showing a highly porous, interconnected network of nano-sized particles, likely a nano-filled solder paste. The structure consists of numerous small, irregularly shaped particles that have aggregated into a complex, web-like structure. The particles are distributed throughout the field of view, with some larger, more distinct clusters visible. The overall appearance is that of a highly textured, porous material.

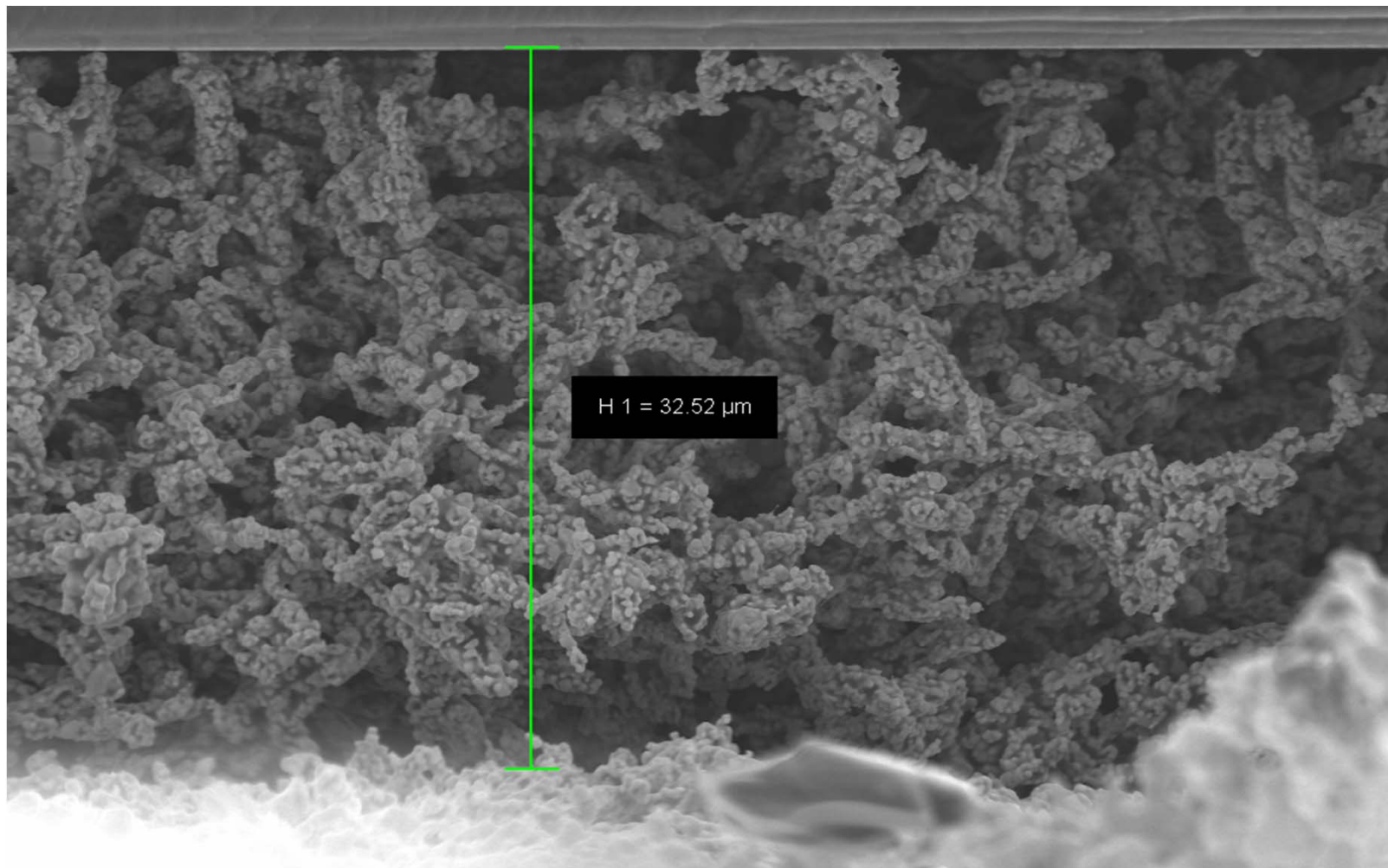
Brazing and characterisation


Suspension preparation and brazing process

- Dispersion of the powder in pure ethylene glycol
- Dispense on a 4 x 4 mm² alumina substrate
- Drying under primary vacuum to remove the solvent
- Covering with a 10 x 10 mm² alumina substrate
- Heating to 300 °C, then cooling at room temperature
- Control by Scanning Acoustic Microscopy (SAM), Scanning Electron Microscopy (SEM) shear tests (MIL Std 883)



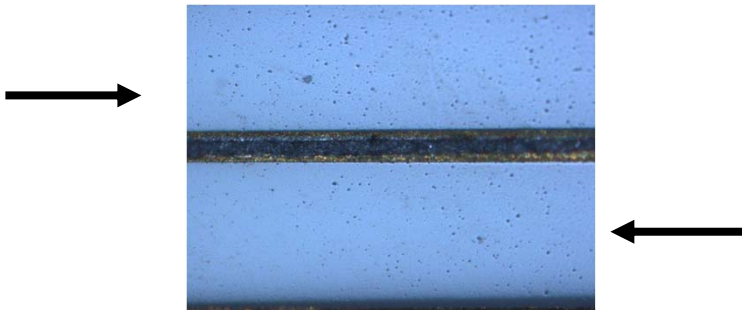
Suspension preparation and brazing process



10 μm	Grand. = 1.98 K X	Signal A = SE2	Date :24 Juin 2011
	EHT = 10.00 kV	WD = 7.8 mm	

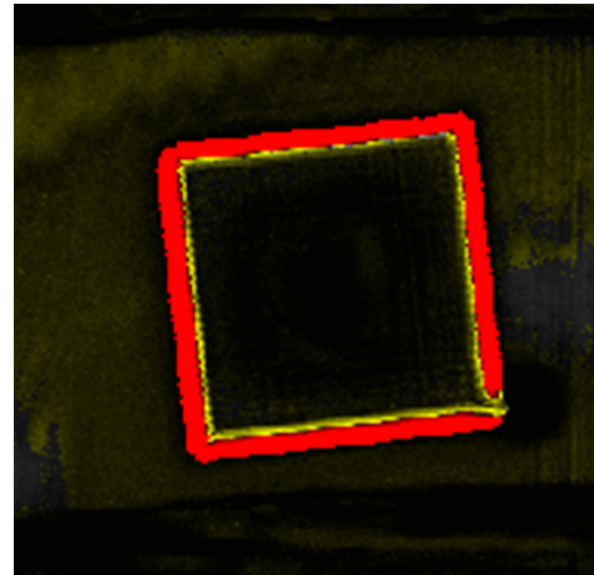
Mechanical joining characterization

- Shear tests:
all the samples meet the minimal requirement of 5 kg shear force

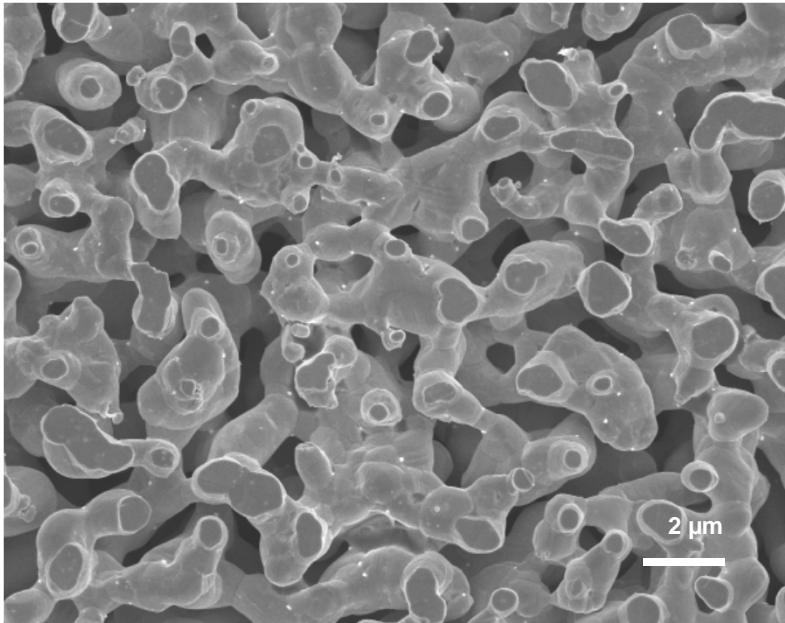


S1	7,5 kg
S2	15,2 kg
S3	5,6 kg
S4	10,9 kg

- SAM characterisation:
homogeneous interface



Porosity estimation

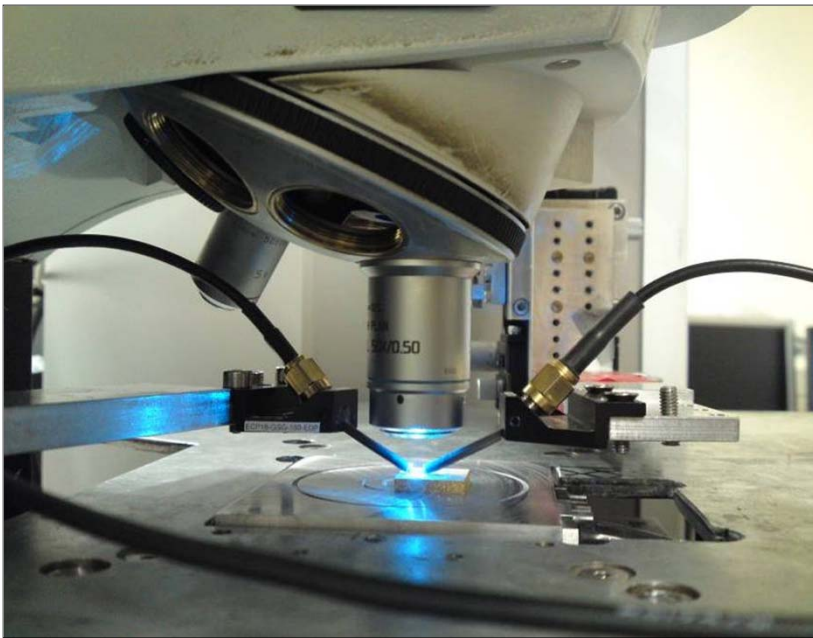


Interface aspect after brazing a glass plate with an alumina substrate. After the sintering the glass was easily removed.

- CO₂ release during the reaction: the sintering can't be complete
- Image analysis → 80 % porosity
- Estimated thermal conductivity: 85 W/m.K

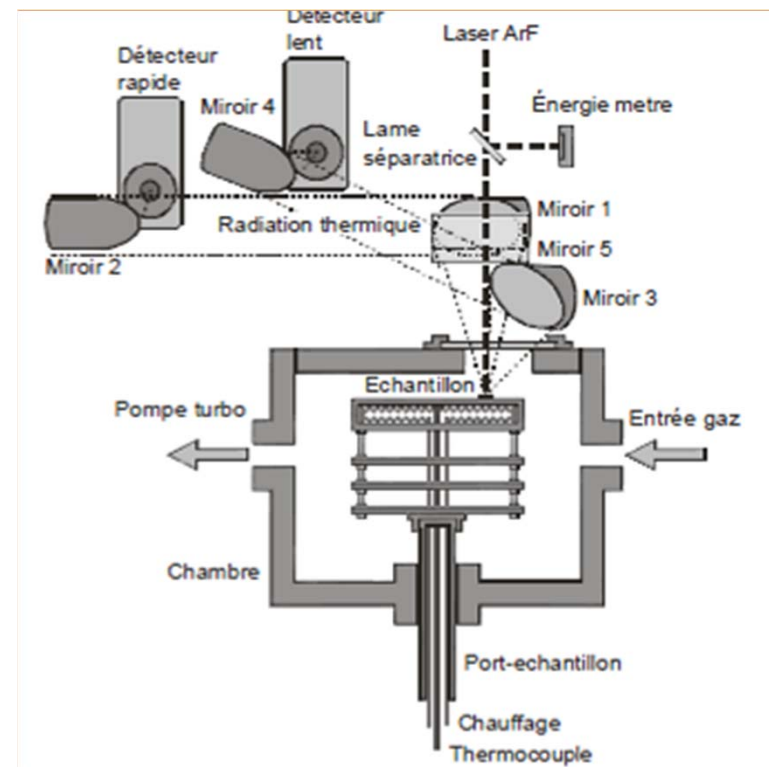
Thermal conductivity measurements

Micro-Raman IR thermography (active assemblies)



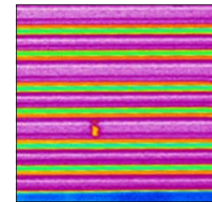
(Center for Device Thermography and Reliability
H. H. Wills Physics Laboratory, University of Bristol)

Impulsional photothermal radiometry (passive assemblies)



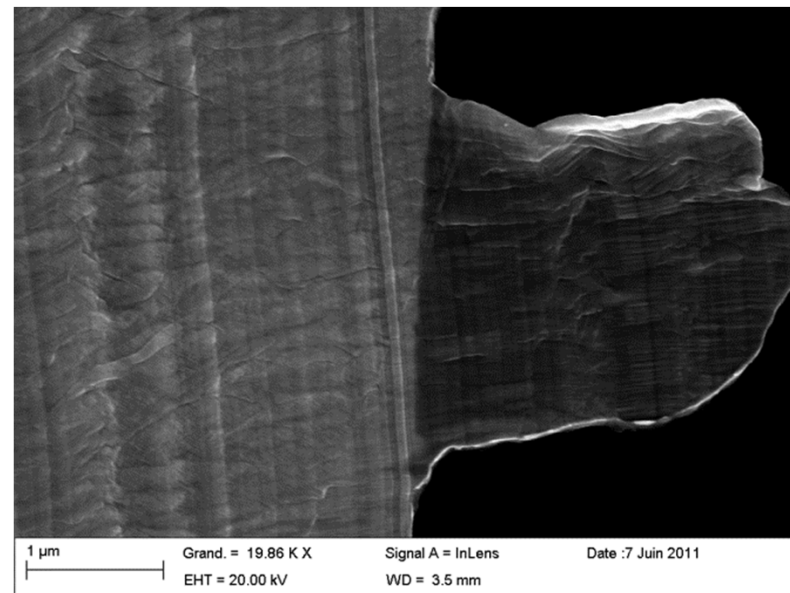
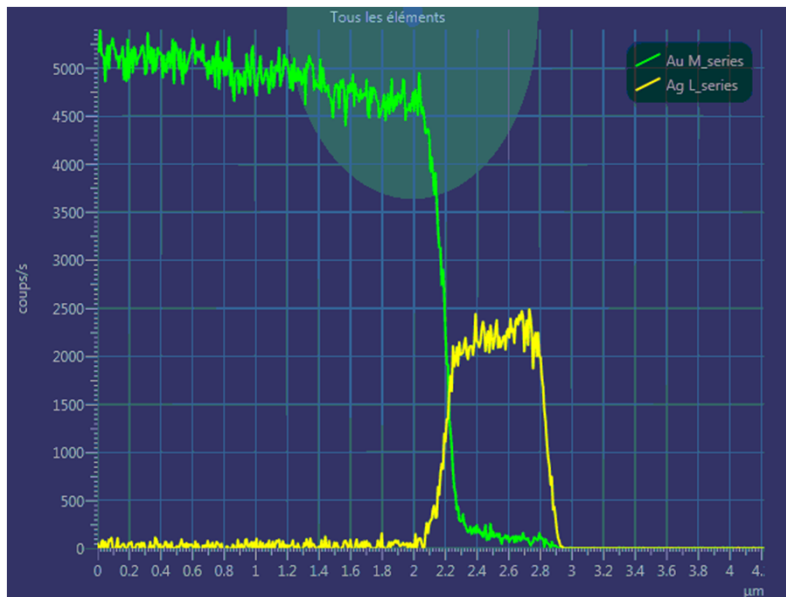
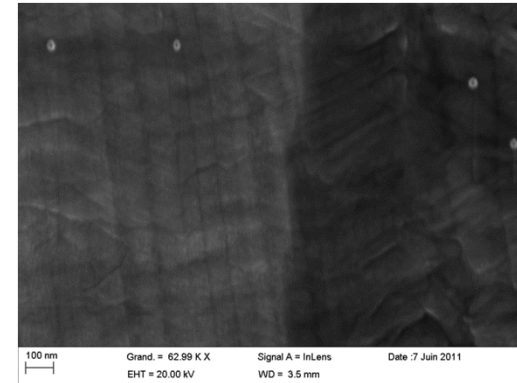
Thermal conductivity measurements

Micro-Raman IR thermography	90 W/m.K
Impulsional photothermal radiometry	Up to 120 W/m.K



Interface compatibility

- Good metallurgical compatibility with gold-plated surfaces: interdiffusion on 1 μm



Conclusion

- Interest of a new silver precursor as new brazing material for high thermal conductivity electronic interfaces (low pressure, moderate temperature)
- Creation of very reactive small nanoparticles: intermediate step
- Perspective:
compatibility with space requirements, long term performance?
 - mechanical tests
 - temperature storage (125°C)
 - thermal chocks (-55/+125°C)
 - Ag electromigration (under electrical bias)

A scanning electron microscope (SEM) image showing a dense, interconnected network of nano-sized particles, likely silver or copper, used in solder paste. The particles are irregular in shape and form a complex, porous structure. A semi-transparent rectangular box with a fine grid pattern is overlaid on the center of the image, containing the text "Thank you for your attention".

Thank you for your
attention