APEX EXPO IPC
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MARCH 25-27, 2014
MANDALAY BAY RESORT AND CONVENTION CENTER
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Lead-Free Nanosolder Based Nanomaterials Assembly and Integration

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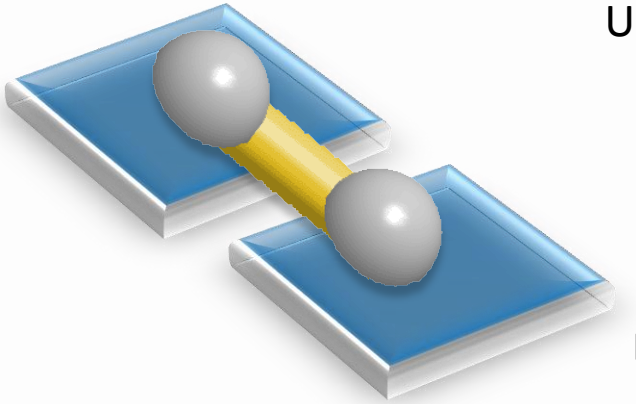

Mar 25th , 2014

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UMASS LOWELL

Outline

1. Introduction

- Nanosoldering in electronics integration

2. Nanowire-based Nanosolders

- Surface oxidation and flux effect
- One-dimensional diffusion for nanosolder joint formation

3. Nanoparticle-based Nanosolder Paste

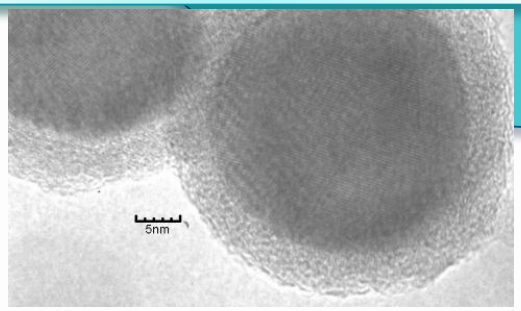
Conclusion & Future Work

Acknowledgement

Nanoelectronics era is already here!

Replace conventional solder paste

✓ nanoparticles in different materials such as Au, Ag, Cu, Sn, In and alloys in the form of **paste** or **inks**.

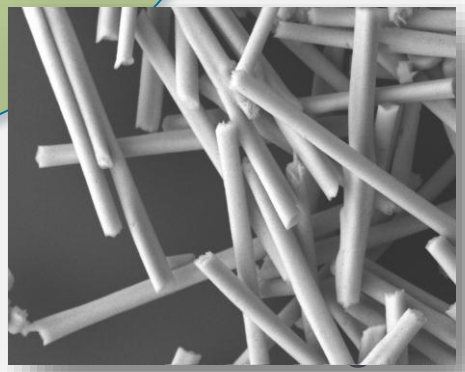


H. Jiang *et al.*, Chem. Mater. 2007, 19, 4482 4485

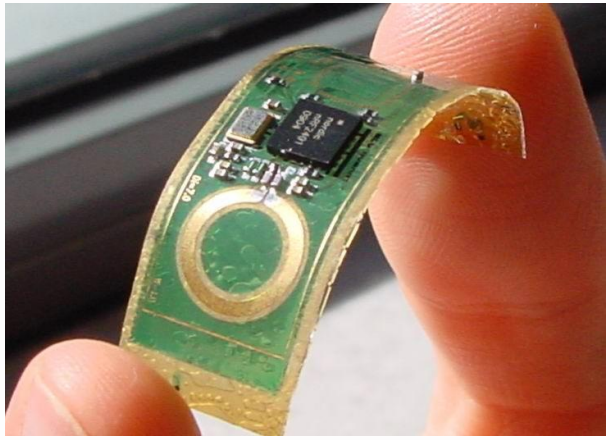
Nanoelectronics Integration

Nanojoint formation

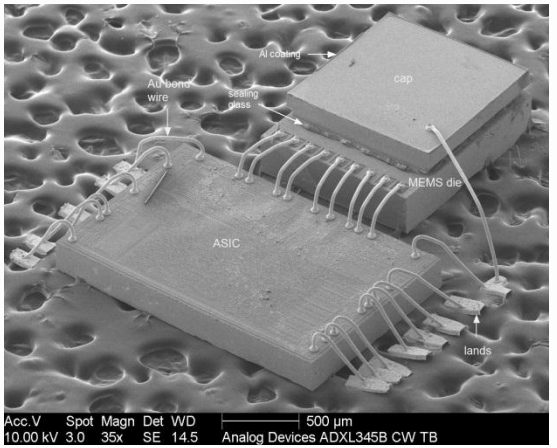
✓ Interconnections between nanocomponents such as nanotube, nanowire…



Lead-free Nanosolder Applications



http://www.cmst.be/projects/intercon.html

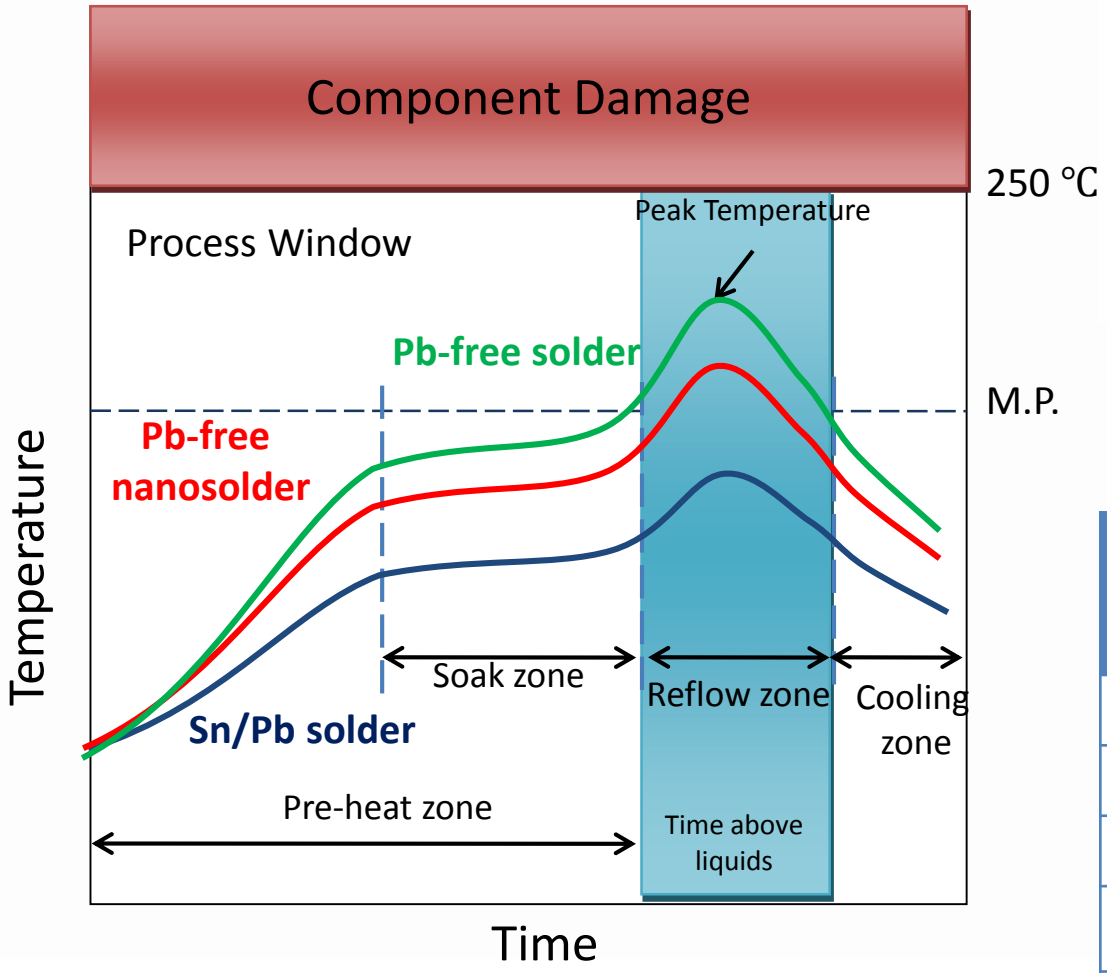


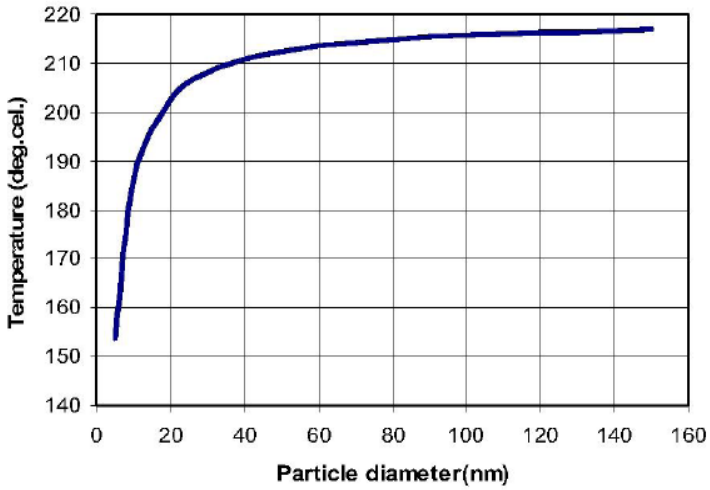
http://memsblog.wordpress.com/2009/09/28/chipworks/

- Flexible Electronics
- Medical Devices
- MEMS Packaging
- Chipworks (µ-BGA → nano-BGA)
- Micro/Nano-electronics assembly and packaging (nanowire FET, sensor)
- …

Introduct

Solder reflow for lead-free solders ar



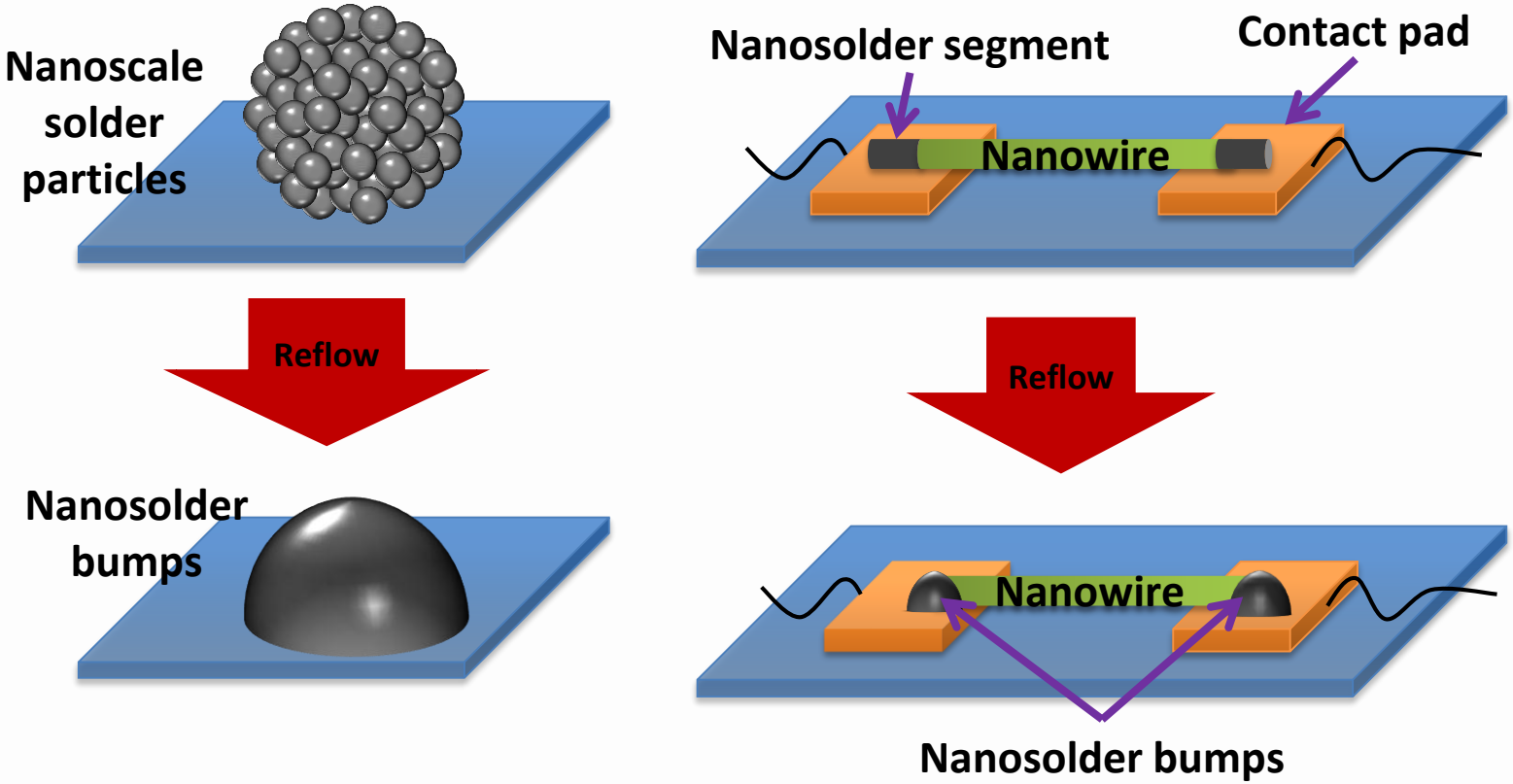


Theoretical plot of the melting point due to nanosize effect as function of particle size for Sn-4.0Ag-0.5Cu alloy.

W.Guan el al. 2006 IEEE

Alloy system	Melting Point (°C) Bulk size
63Sn/37Pb	183
Sn	231
Sn/3.5Ag	221
Sn/3.8Ag/0.7Cu	217

Nanosolders Assembly and Packaging



2-dimensional interconnect /nanoparticle solder --close to the conventional soldering technique

1-dimensional interconnect /nanowire bridge

F. Gao *et al*, *Proceedings of the 2011 Nanotechnology Conference, 2011, 2, 422-425*

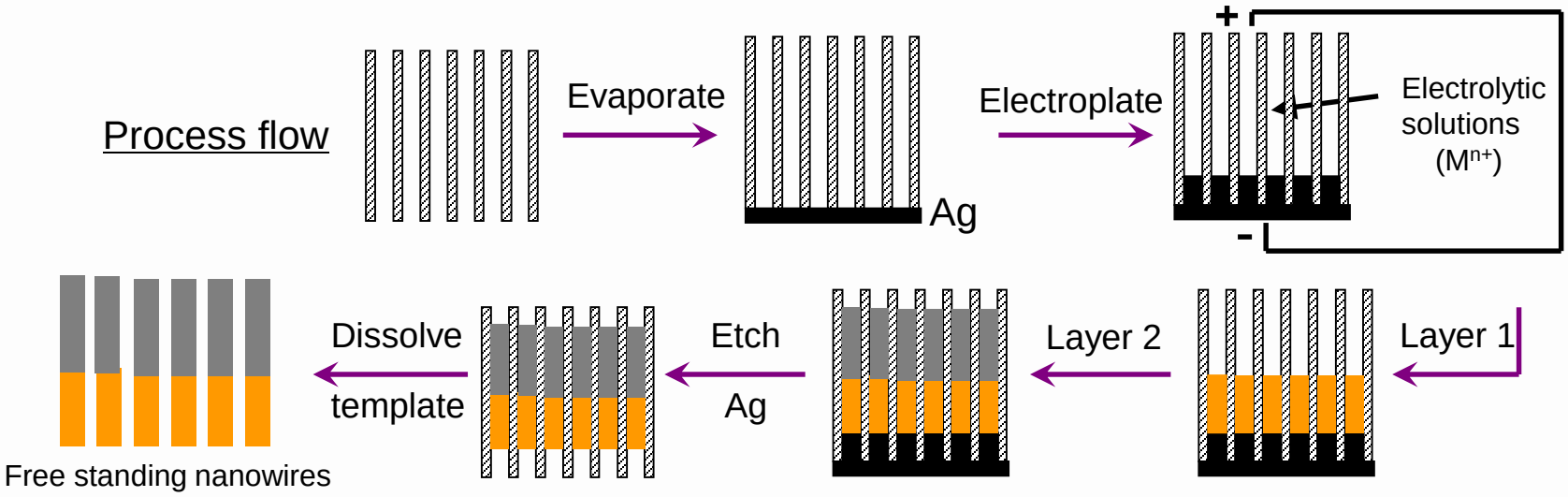
1. Introduction

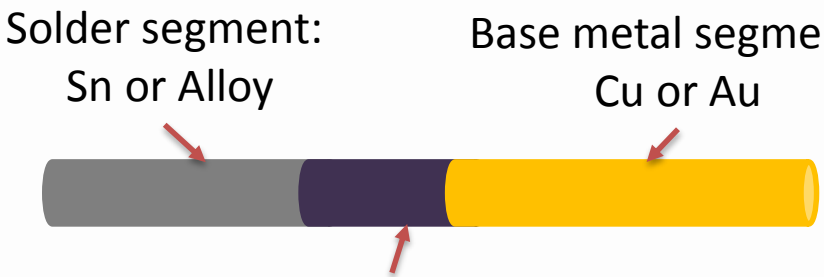
✓ **2. Nanowire-based Nanosolder**

- Surface oxidation and flux effect
- One-dimensional diffusion for nanosolder joint formation

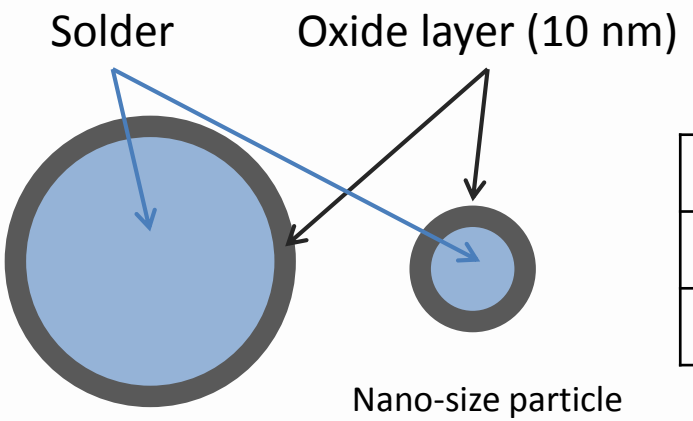
3. Nanoparticle-based Nanosolder Paste

Nanosolder Fabrication

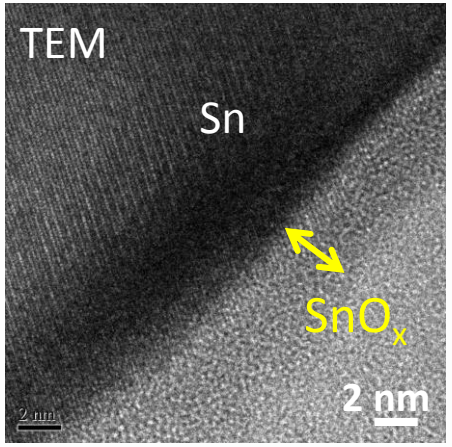




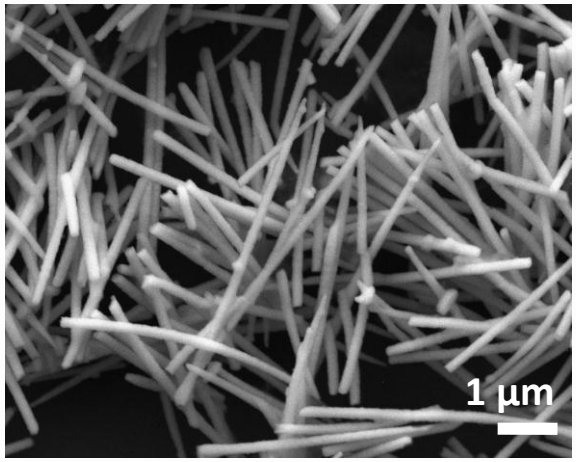
Nanosolder Oxidation

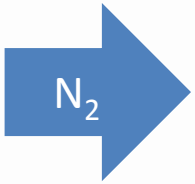


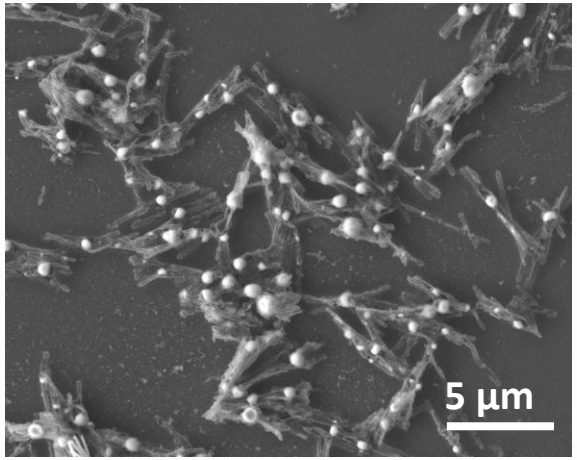
	D	Oxide
Micro	1 µm	0.01%
Nano	30 nm	11.11%



3-4 nm Oxide layer







F. Gao, K. Rajathurai, Q. Cui, G. Zhou, I. NkengforAcha, Z. Gu. *Applied Surface Science* 2012, 258, 7507-7514.

Flux Effect of Nanosolder

- Remove oxidation layer
- Enhance wettability

Rosin based flux mainly formula:

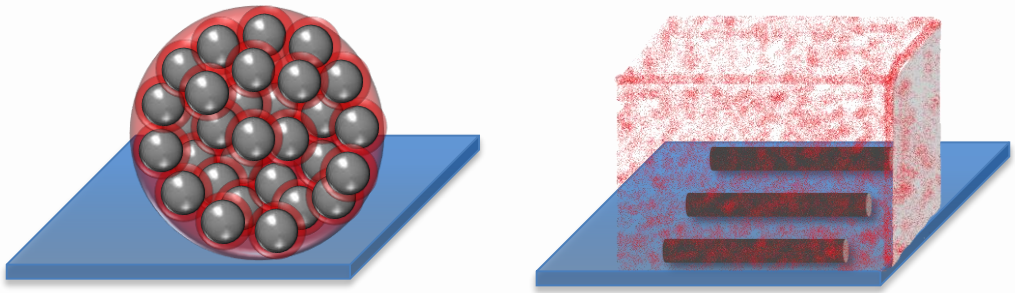
$C_{19}H_{29}COOH$

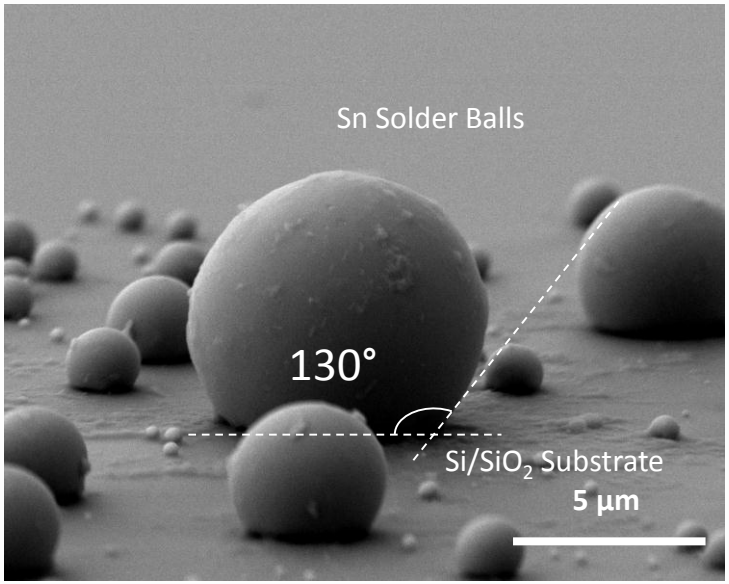
RCOOH + MX = RCOOM +HX

M= Sn, etc
X = oxide, hydroxide or carbonate

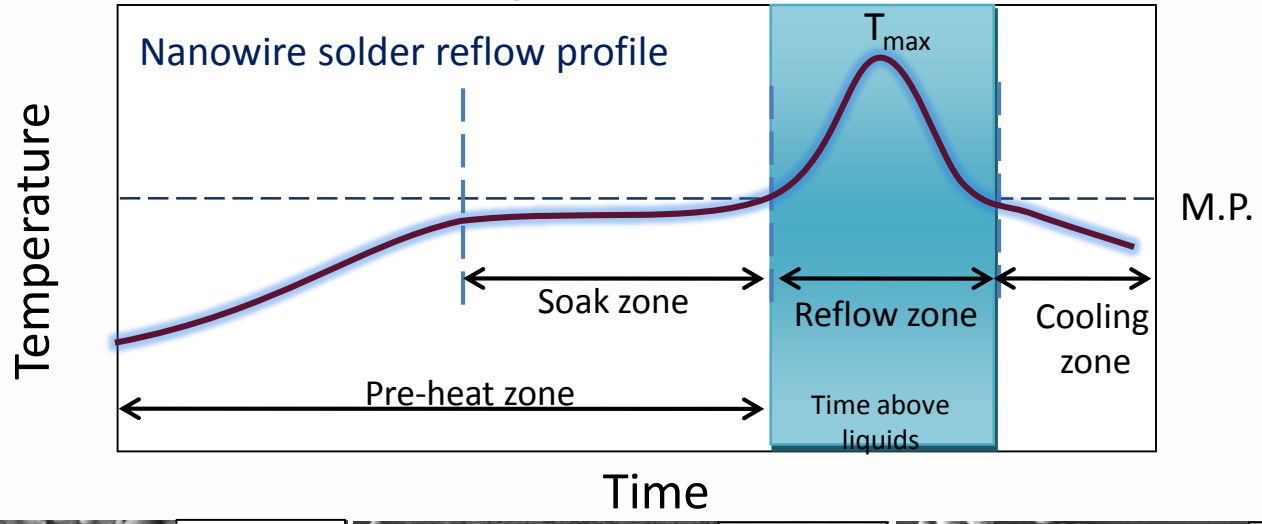
Flux Vapor Vs. Liquid Flux
- Quantity
- Cleaning residue

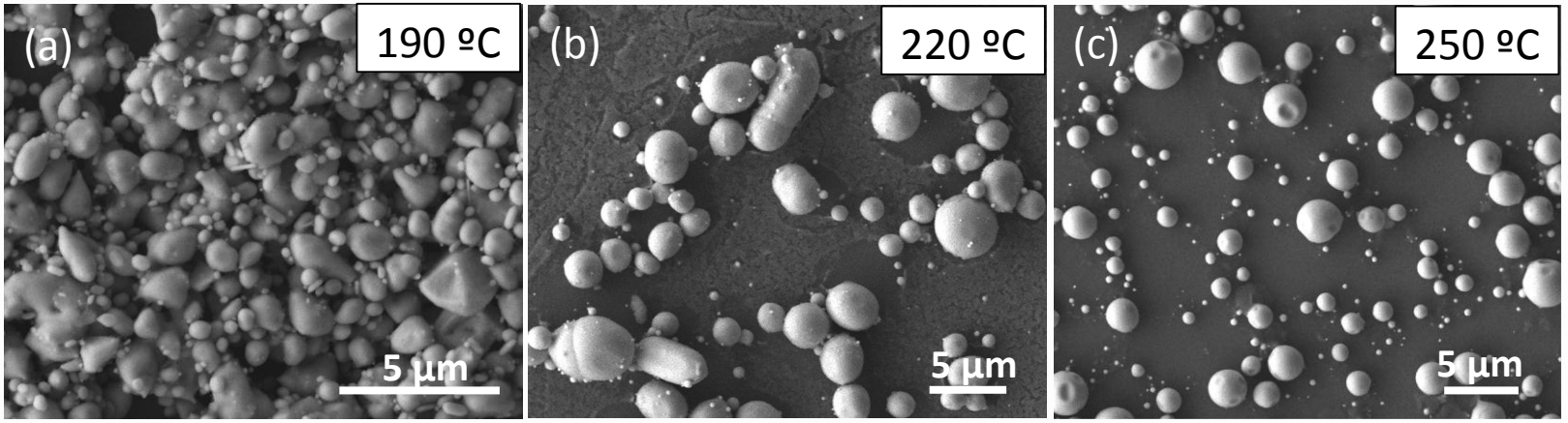
Micron-solder + semi-liquid flux Nano-solder + flux vapor





Flux + Temperature Effect

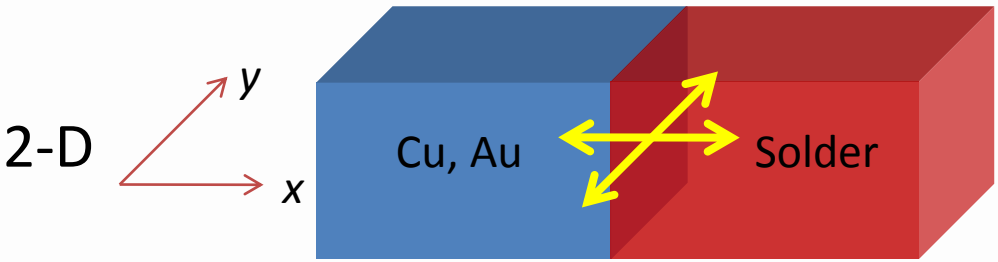




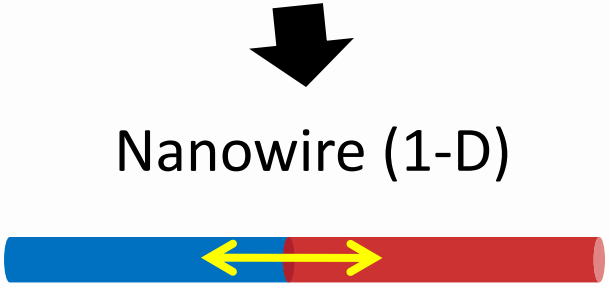
$T_{max} < T_{M.P.}$ $T_{max} \sim T_{M.P.}$ $T_{max} > T_{M.P.}$

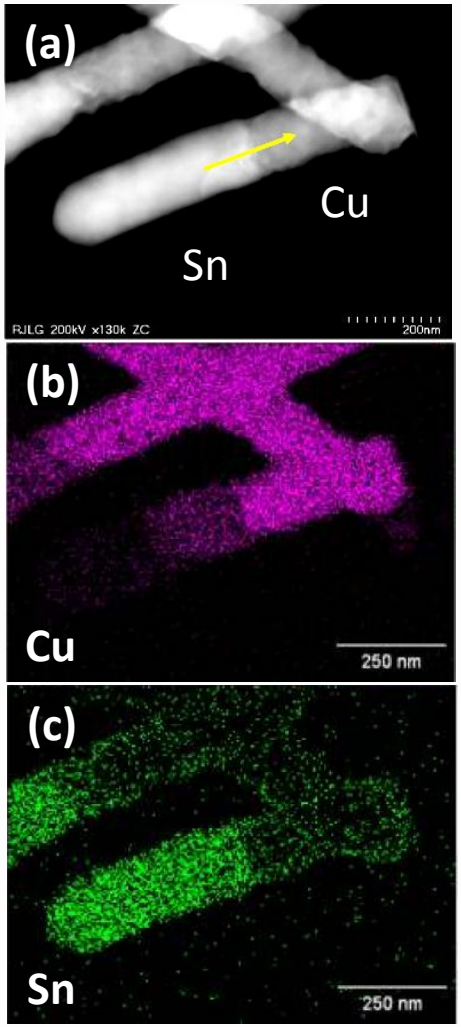
F. Gao, K. Rajathurai, Q. Cui, G. Zhou, I. NkengforAcha, Z. Gu. *Applied Surface Science* 2012, 258, 7507-7514.

Interface Diffusion in Nanowire



How much IMC in nanosolders?



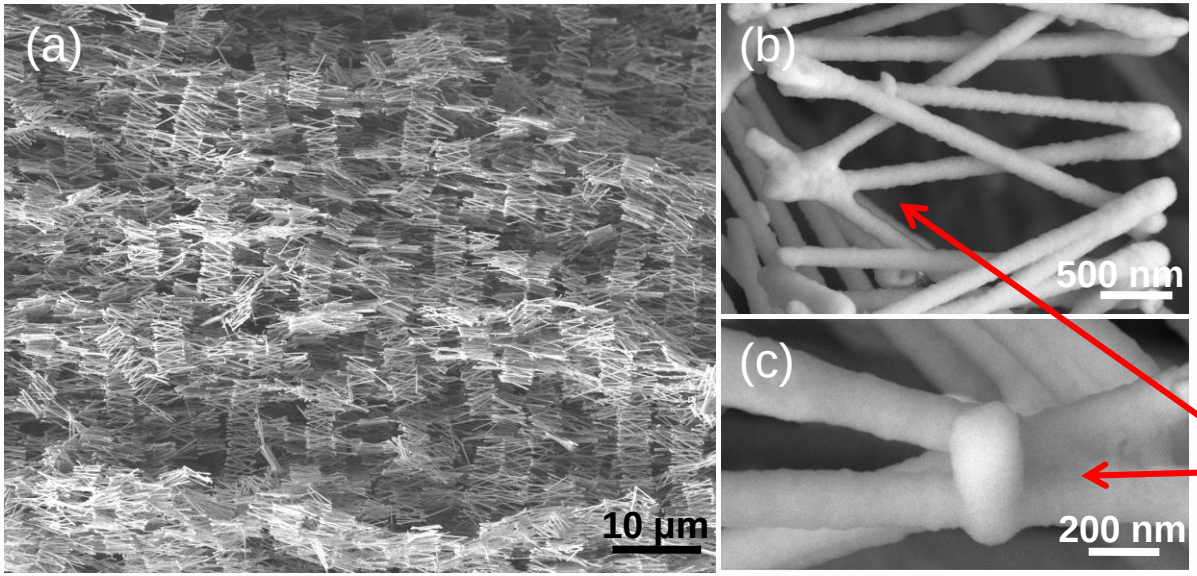


F. Gao, *et al*, *Science of Advanced Materials* 2012, 4, 881-887

Solder Joint Formation

--Nanowire assembly and Nanosolder joint formation in liquid phase

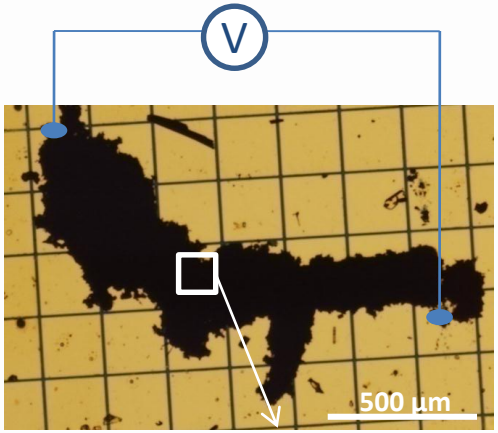
Magnetic nanowire segment + External magnetic field

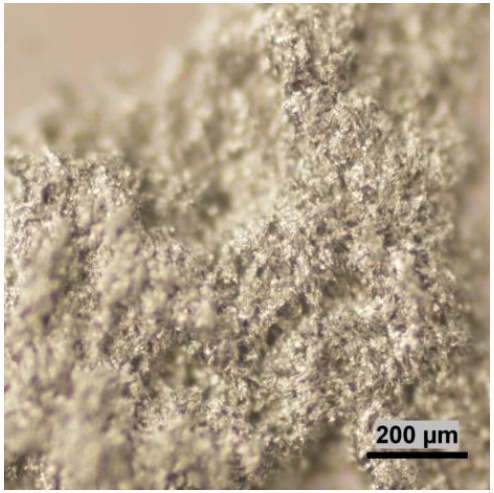


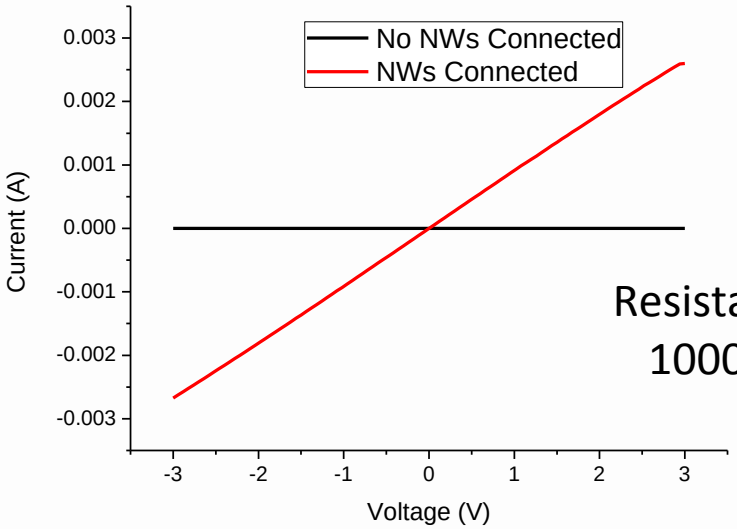
F. Gao, Z. Gu. *Nanotechnology* 21 (2010) 115604 (7pp)

Solder Joint Formation

Electrical Property







Resistant Range:
1000-1200 Ω

Left: optical microscope images of assembled ordered nanowires

Right: electrical measurement by probe-station

F. Gao, Z. Gu. *Nanotechnology* 21 (2010) 115604 (7pp)

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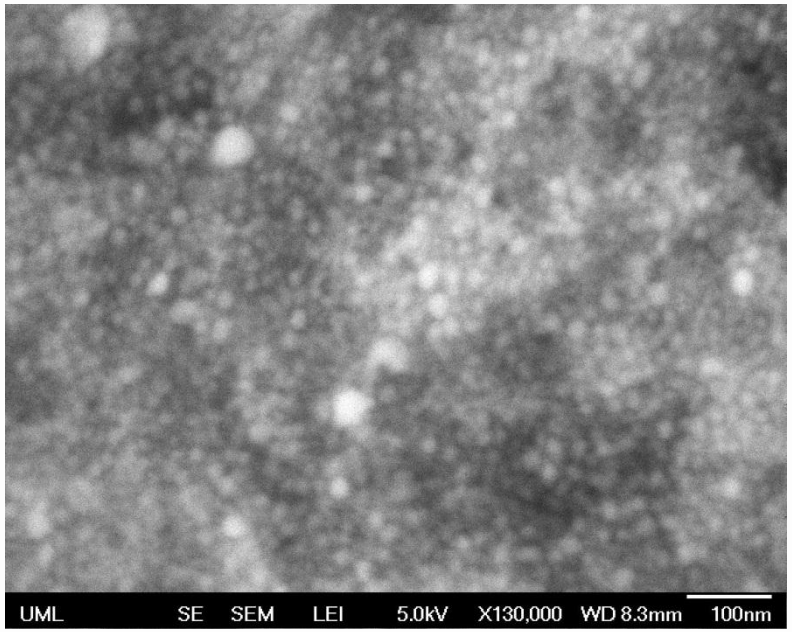
Nanoparticle-based Nanosolder Paste

Sn/Ag, Sn/In alloy nanoparticle synthesis: Chemical Reduction Method



SEM image of Sn/Ag nanoparticle
Size range: 20-40 nm

Nanoparticle-based Nanosolder Paste

Prepared Nanosolder Paste

Nanosolder Paste Formulation:

- Lead-free nanoparticles
- Flux ratio varies between 20%-40wt%
- Nanoparticle loading
- Halogen-free water soluble fluxes

Nanosolder Processing:

- Printing with stencil (much smaller size)
- Modification of reflow profile (Peak Temp and time)

Reliability test:

- Shear test
- Intermetallic formation and growth

Conclusion

- ✓ Nanosolder on multi-segment nanowires have been successfully fabricated by electrodeposition method;
- ✓ Flux assisted environment enhanced reflow result and micron scale solder spheroids formed on non-wetting Si substrate;
- ✓ 1-D interdiffusion on Cu-Sn two-segment nanowire were observed through the thermal heating;
- ✓ Individual nanojoints formed between nanowires and a network was constructed;
- ✓ Sn/Ag Nanoparticle based nanosolder paste is developing for practical application.

Future Work

Material

- 1-D diffusion study of confined nanowire in one-dimension;
- Nanosolder size effect for melting temperature depression;
- Different nanoparticle solder materials for real applications.

Processing and Applications

- Joint formation between nanowires for device packaging;
- Joint reliability study (individual nanojoint and paste formed joint);
- Real device testing, e.g., nano-wire bonding.

Acknowledgement

Collaborators

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- Dr. Guangwen Zhou, State University of New York (SUNY)
- Pamela Eliason, Dr. Gregory Morose, Toxics Use Reduction Institute (TURI)
- Robert Farrell, Benchmark Electronics

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Thank you!

New England Lead Free Consortium Members 2000-2013

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Interested in Joining proposed Nano Solder Development Consortium in 2014?

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