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Super Fine Lead-Free Solder Powder for Fine Pitch Bump Applications

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Outline

- **Background**
  - * Low alpha solder materials
  - * Recent devices requiring fine bump pitch printing and their issues
- **Development of Super fine powder**
  - * Required powder size for fine pitch printing
  - * Production process of Super fine powder
  - * Feature of Super fine powder
- **Result of fine bump pitch application**
  - * Result of 80μm pitch bumps forming
  - * Other application

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Low Alpha Solder Materials

- Main Application:PC (CPU, GPU, Chip-set), Game, Mobile Phone, etc

FC-BGA

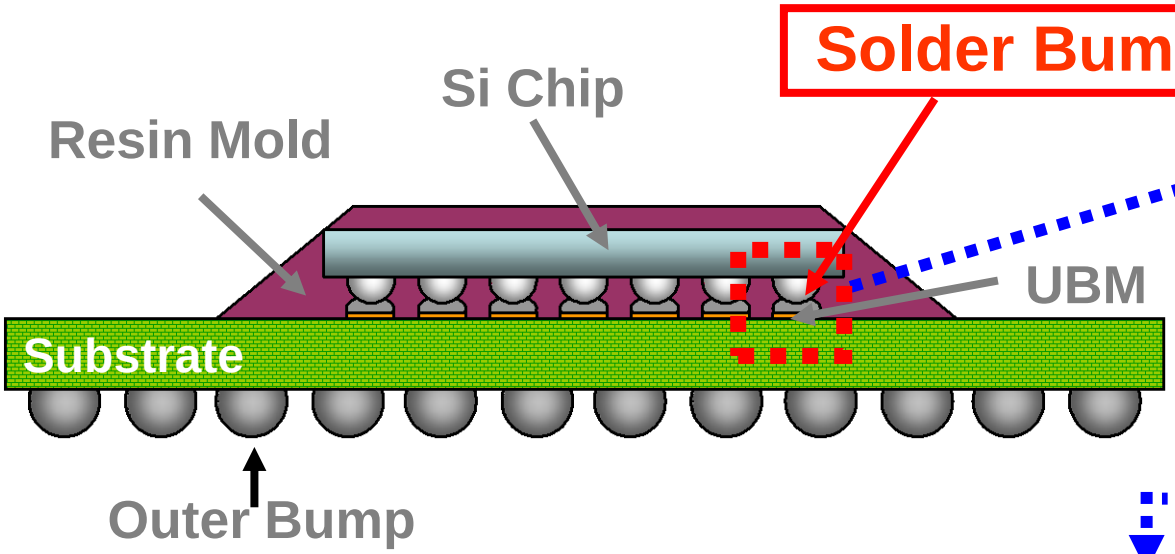
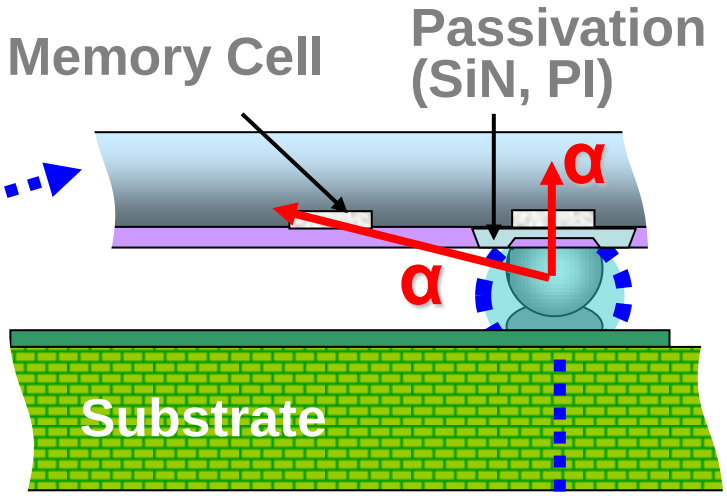
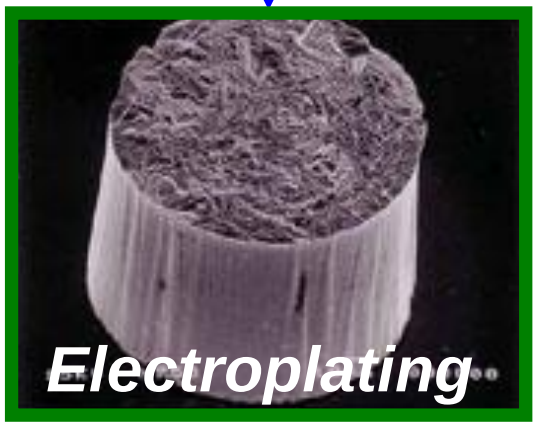
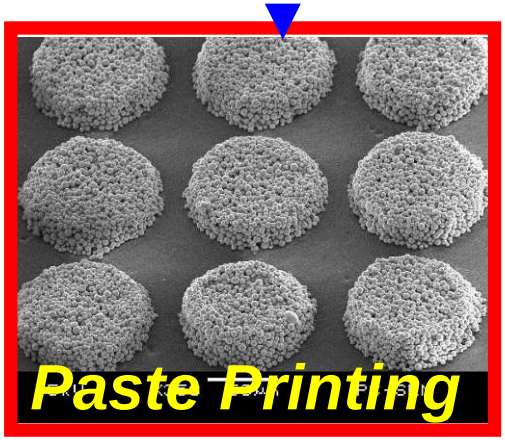


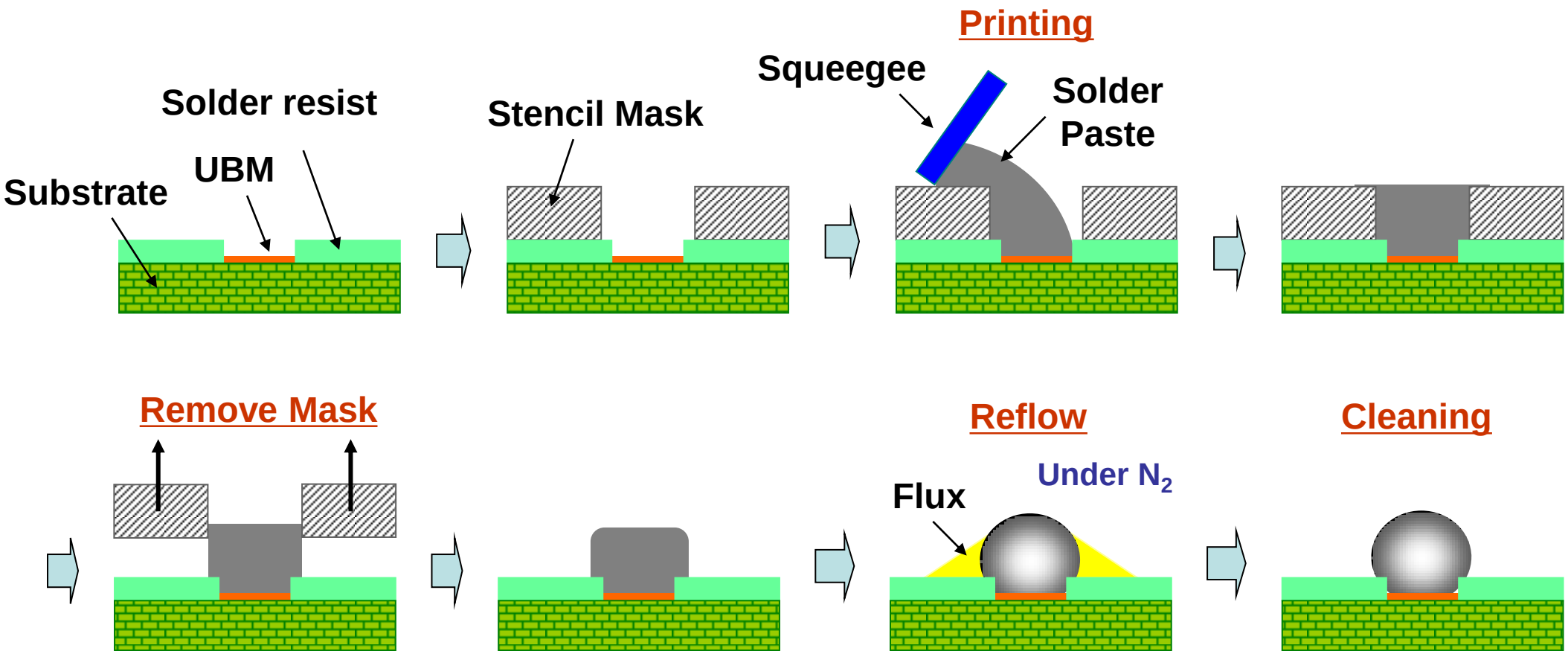
Image of Soft Error







Paste printing process for substrate bumping



Features of paste mainly depend on powder (size / shape), flux (type / content ratio)

Comparison of Substrate Bumping process

Items		Ball Mount	Paste Printing
Initial Cost		poor	excellent
Productivity		good	excellent
Material Cost		poor	excellent
Total Cost		poor	excellent
Quality of Bump	Voids	good	fair
	Height uniformity	excellent	fair
	Composition	excellent	excellent

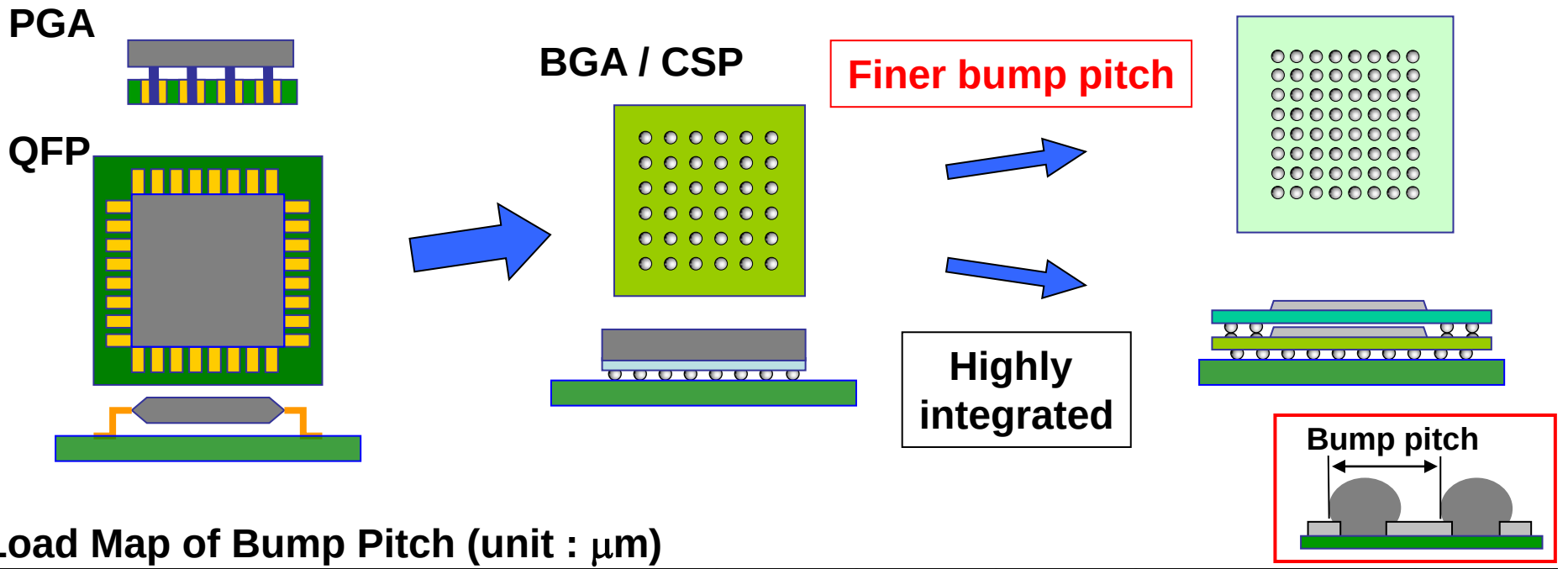
Paste Printing is the most cost-effective bumping process.

Downsizing of Electronic devices

Electronic devices
Downsizing
Densification

→

Chip and Substrate
Finer bump pitch
Highly integrated



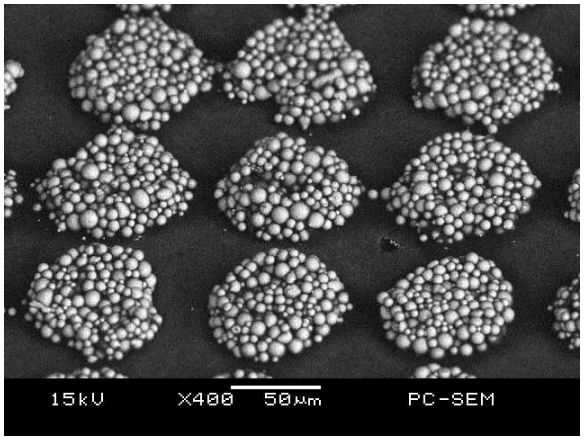
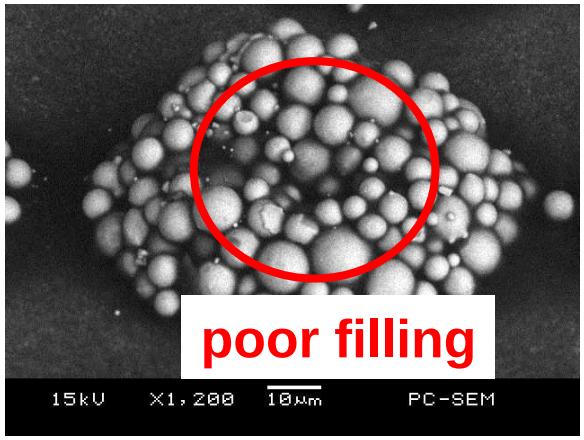
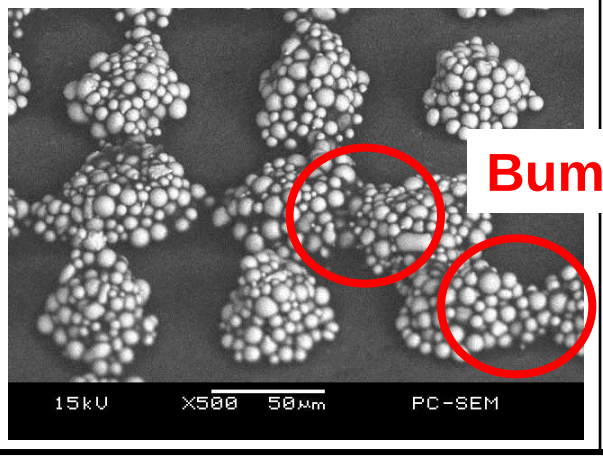
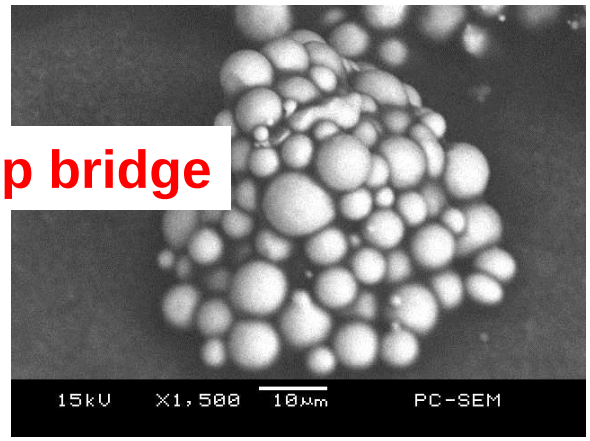
Load Map of Bump Pitch (unit : μm)

	2010	2011	2012	2014	2017	2020
Organic, Ceramic substrate for ASIC	130	120	110	100	95	90
Organic substrate for CPU, GPU, Chipset	150	150	130	130	110	100

** Chip-to-package Substrate Technology Requirements (Flip Chip Area Array), ITRS2009*

Issue of fine-pitch printing

Powder size : D_{50}= 8μm , Gas atomization process

Bump pitch	**100μm**		
	80μm		

Bump bridge and poor filling issue have occurred.

Relationship between Powder size and Mask Spec / Bump Pitch

- **Bump Pitch and Mask Spec (opening size)**

Bump Pitch (μm)	180	150	120	100	80
Mask Opening size (μm)	126	113	96	75	60

To obtain good filling ability

Powder size are required 1/15 of opening size.

Bump Pitch (μm)	180	150	120	100	80
Required Powder size (μm)	8.4	7.5	6.4	4.9	4.0

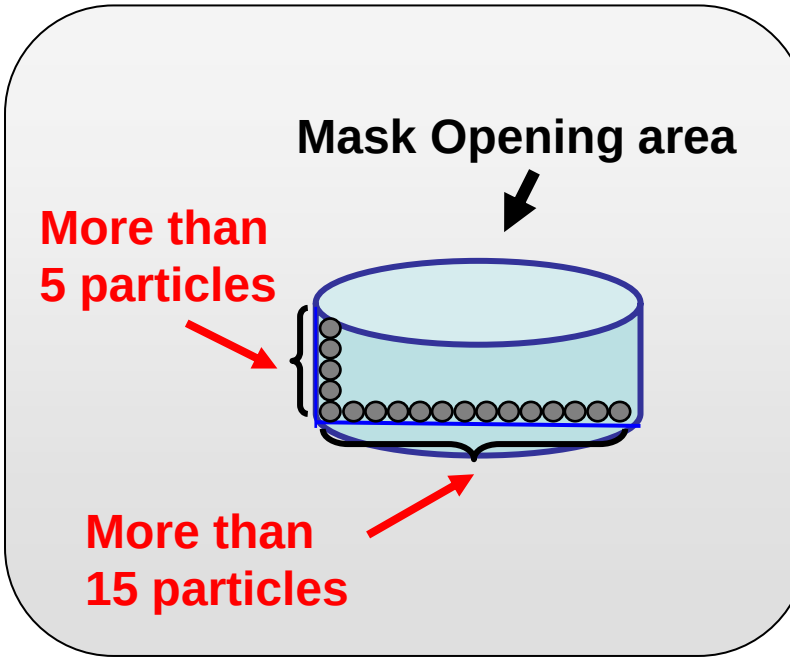


Fig. Image of required particles

Fine pitch bumps need less than 4μm powder.

Outline

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- **Development of Super fine powder**
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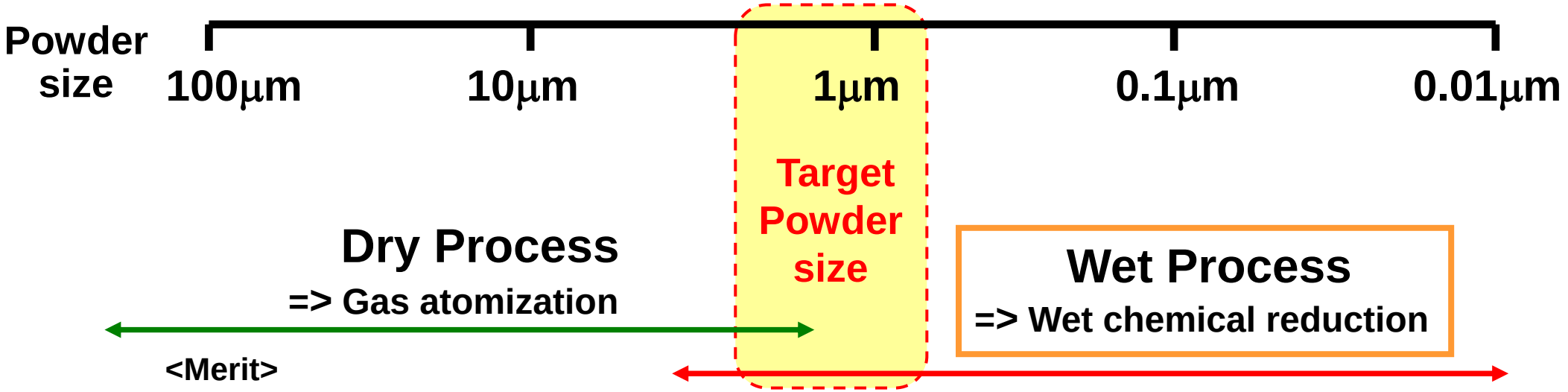
  * **Production process of Super fine powder**
  * **Feature of Super fine powder**

- Result of fine bump pitch application
  * Result of 80μm pitch bumps forming
  * Other application

Solder Powder Size and Production Process



Dry Process
=> Gas atomization

<Merit>
- Simple Process
- Alloying is easy

<Demerit>
- Low yield for fine powder size
- High initial investment

Wet Process
=> Wet chemical reduction

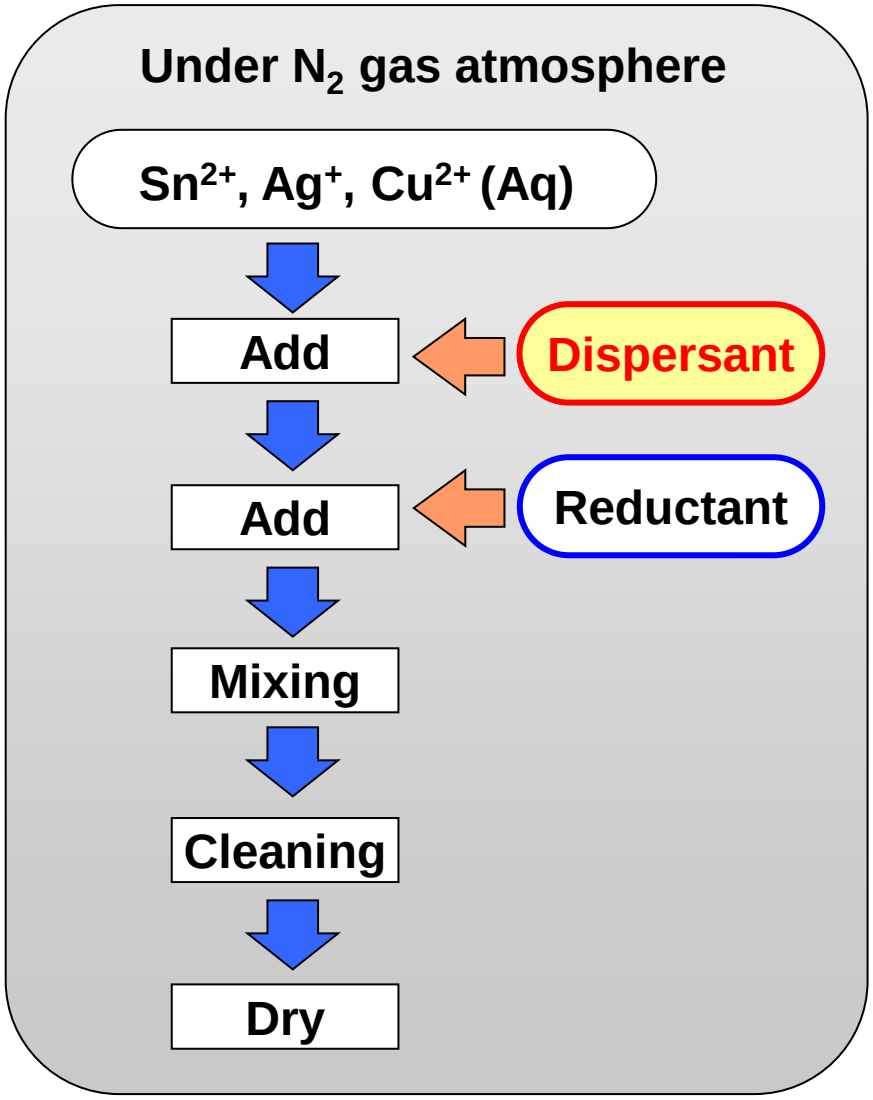
<Merit>
- High yield for fine powder size
- Narrow distribution of powder
- Low initial investment

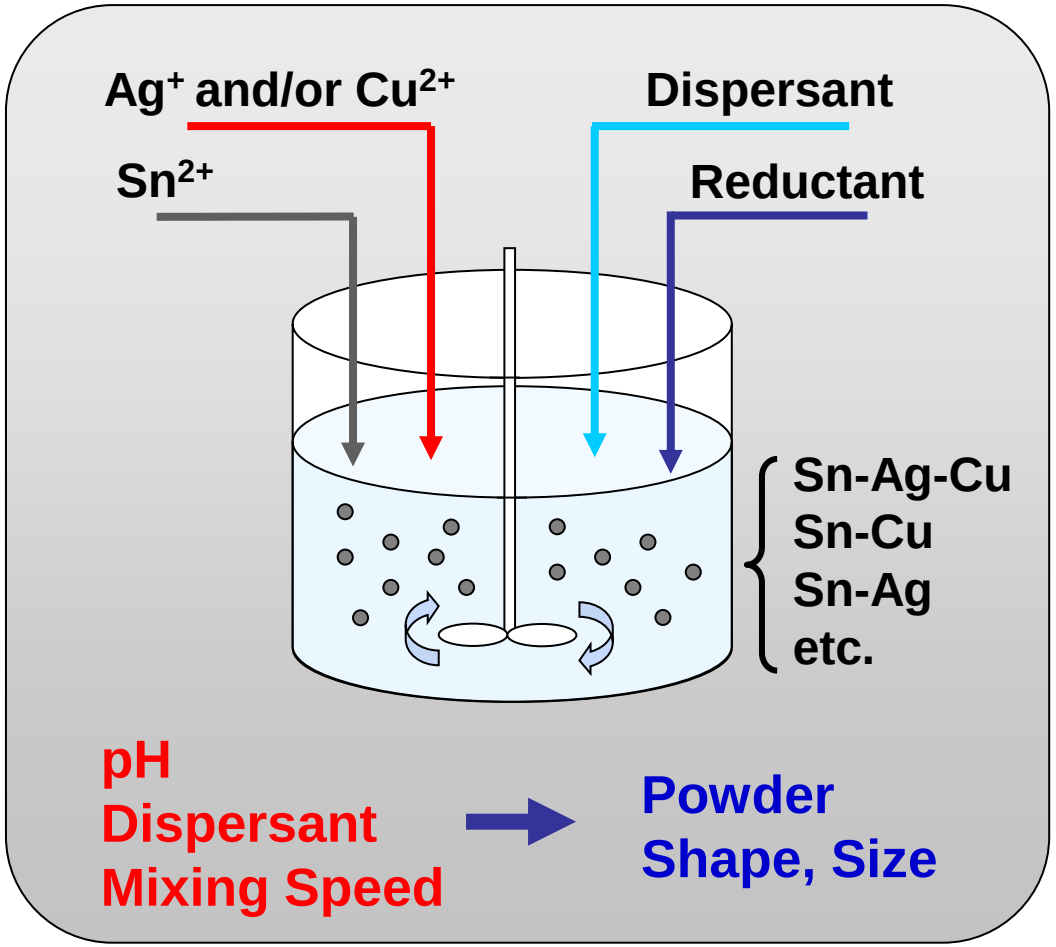
<Demerit>
- Oxidation of powder surface

< Our Target >
- Wet Process : Wet chemical Reduction process (Wet reduction)
- Powder size : D_{50}= 2-3 μm
- Powder composition : Sn-3.0Ag-0.5Cu, etc

Production Process of Super Fine Powder

- **Schematic diagram of wet chemical reduction process**





Composition of powder depends on ratio of each metal ion concentrations.

SEM image and powder distribution

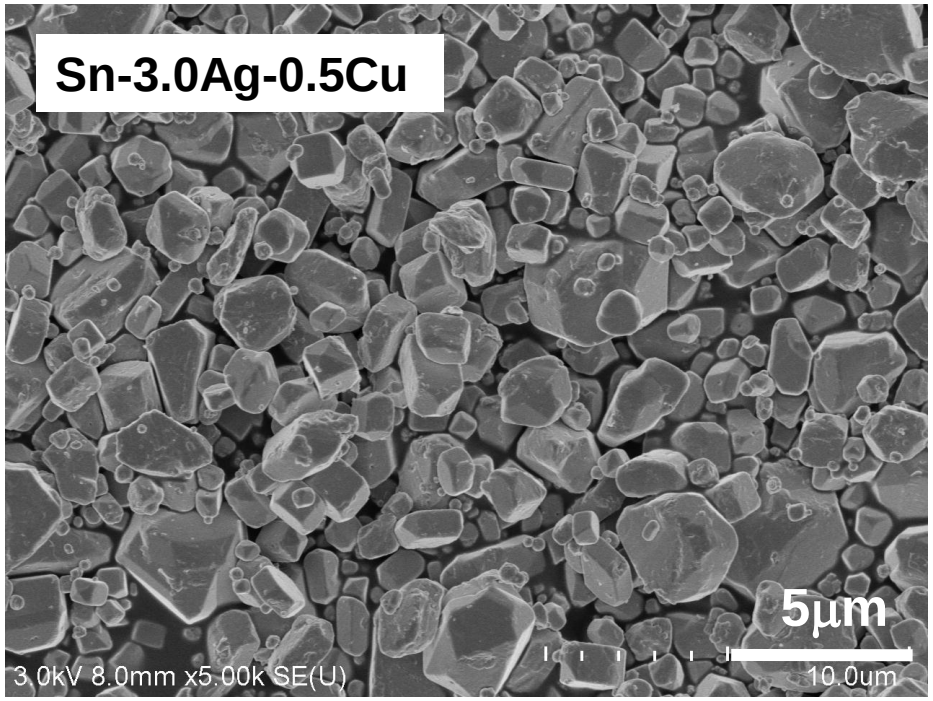


Fig. SEM image of Super fine powder

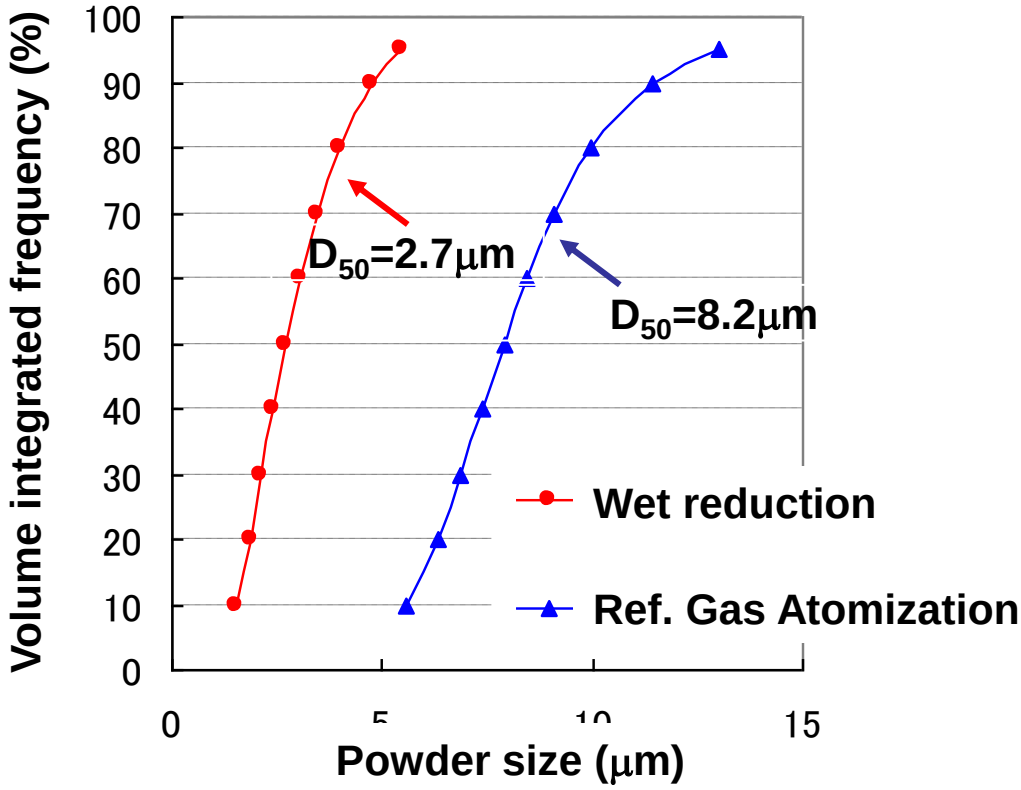


Fig. Powder distribution

- Powder size D_{50}= 2.7μm
- Anisotropic shape / Narrow distribution
- High production yield (classification free)

Chemical and Physical properties

- **Chemical and Physical Properties data**

Composition	Process	Ag(%)*	Cu(%)*	C(ppm)**	O(ppm)**	D_{50}(μm)	BET(m^2/g)
Sn-3.0Ag-0.5Cu	Wet reduction	2.95	0.51	600	1,900	2.7	0.65
	Gas atomization	2.97	0.50	200	1,200	2.9	0.32

* ICP(Indutively Coupled Plasma), ** Chemical Analysis

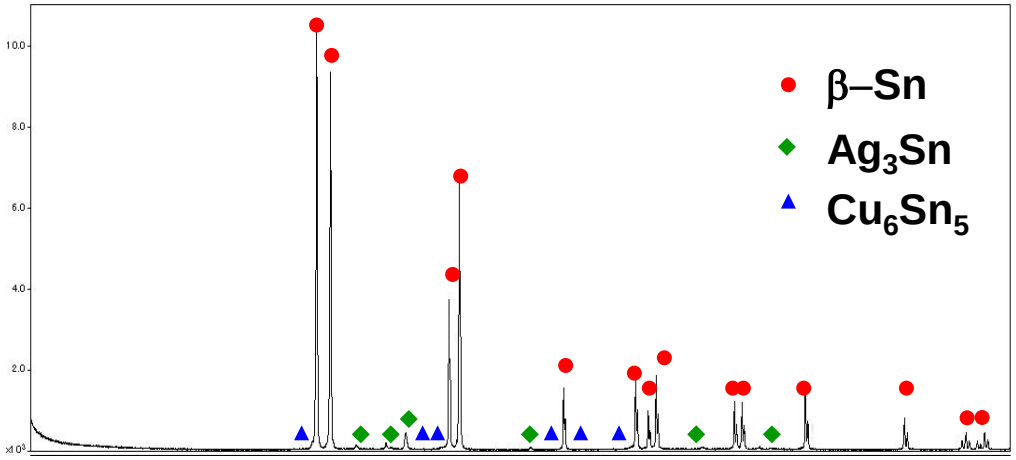


Fig. XRD data

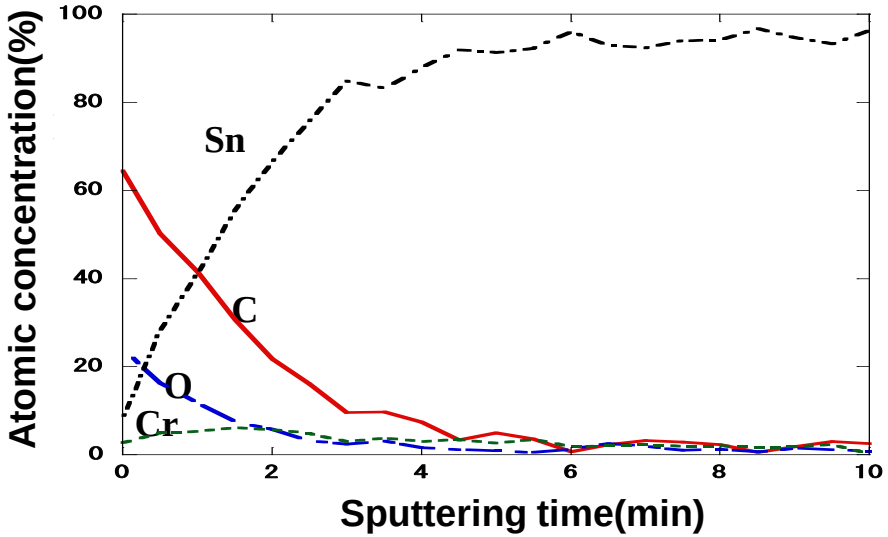
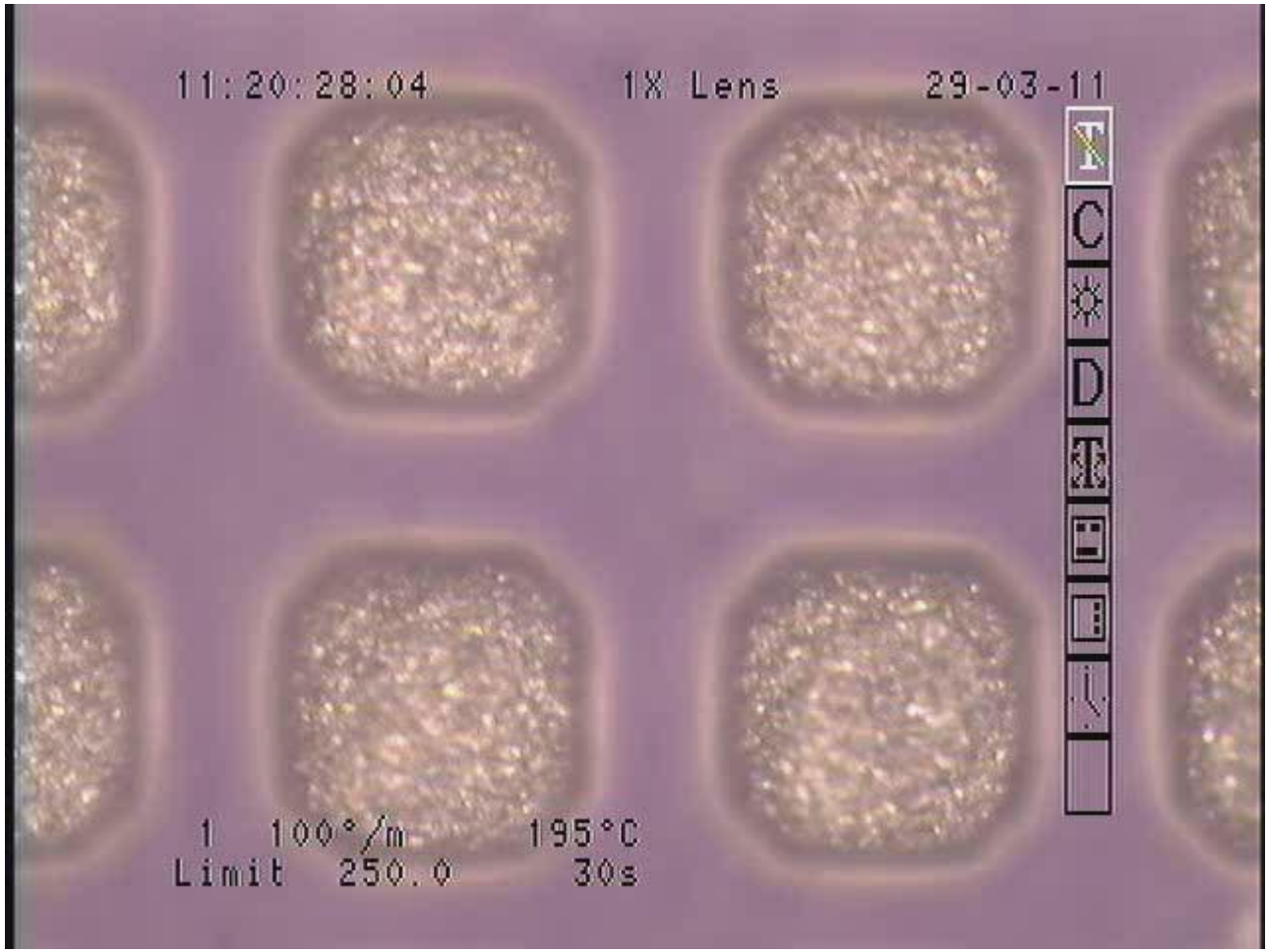


Fig. Depth profile of powder (AES)

- **No composition drift of Super fine powder**
- **High Carbon and Oxygen level =>But they existed only surface of powder.**
- **High BET value => It caused by anisotropic shape of powder.**

MULOS CHALLENGE TO ZERO ALPHA

Melting ability of Super fine powder



Super fine powder shows good melting ability.
（wet reduction process）

Melting point and Metallographic structure

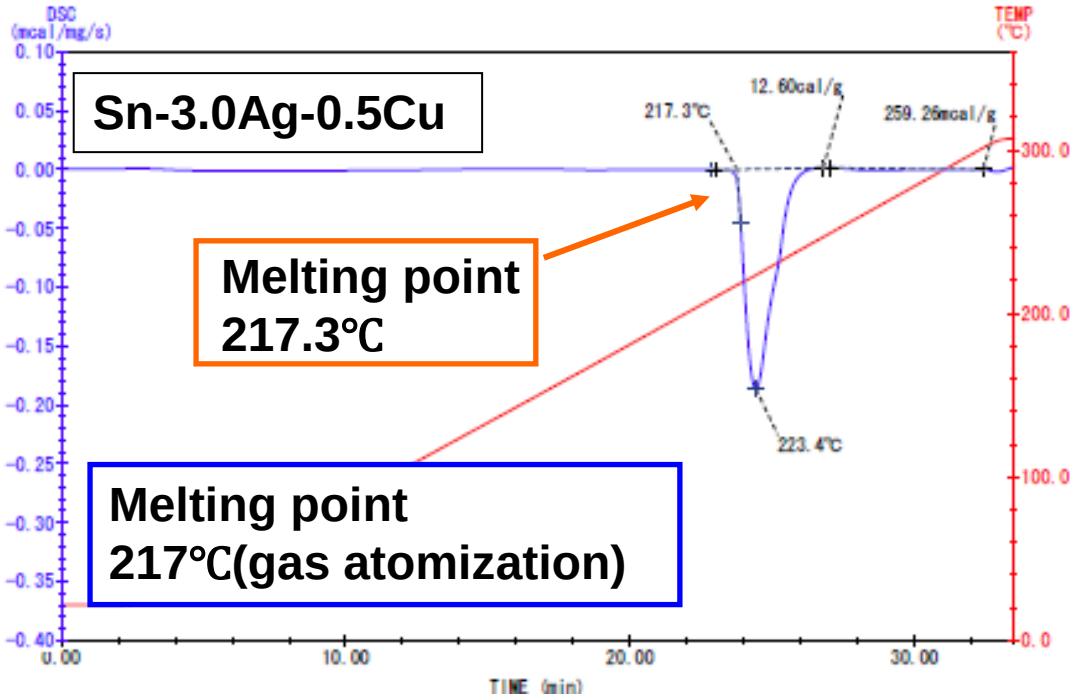


Fig. Measurement of Melting point (by DSC)

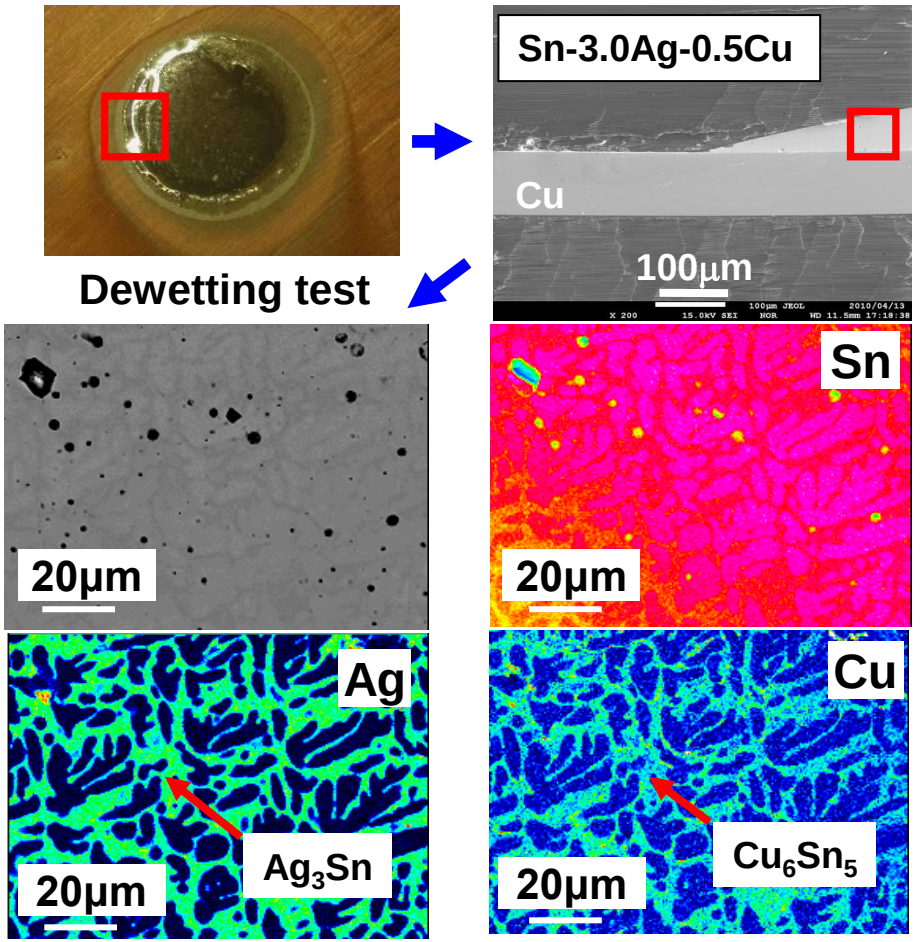


Fig. Observation of metallographic structure (by EPMA)

Melting point and Metallographic structure of Super fine powder were as same as that of gas atomization powder.

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Result of 80μm pitch bumps forming

- Properties of Paste for Super fine powder

Composition	Powder size: D_{50}	Flux ratio	Paste viscosity*	TI value*
Sn-3.0Ag-0.5Cu	2.7μm	12wt%	267Pa·s	0.65

* Malcom viscometer

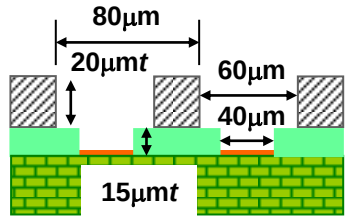
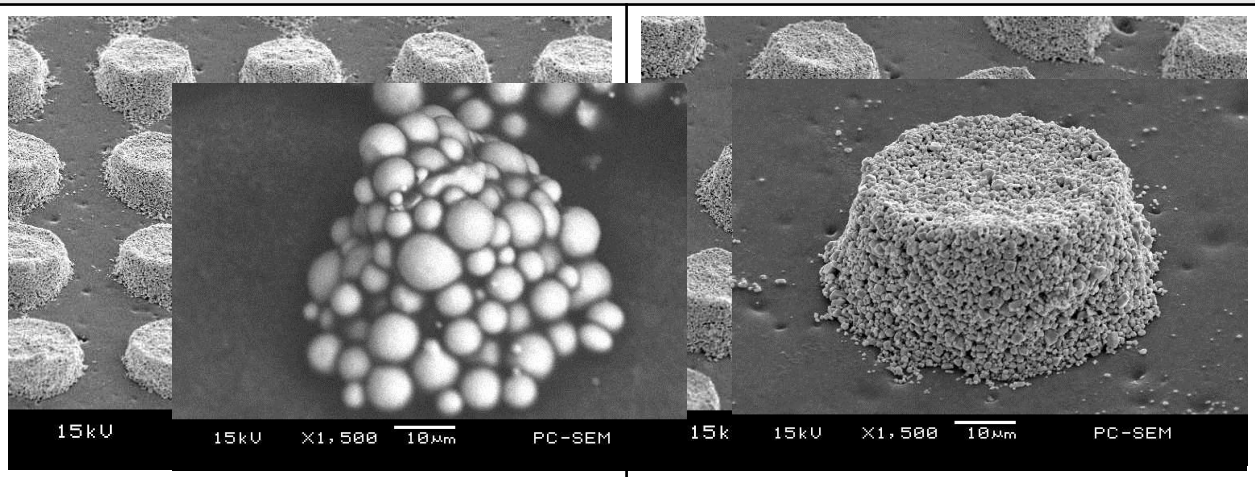
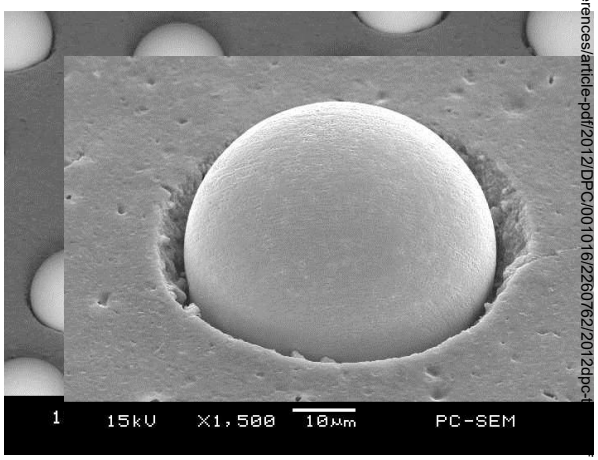


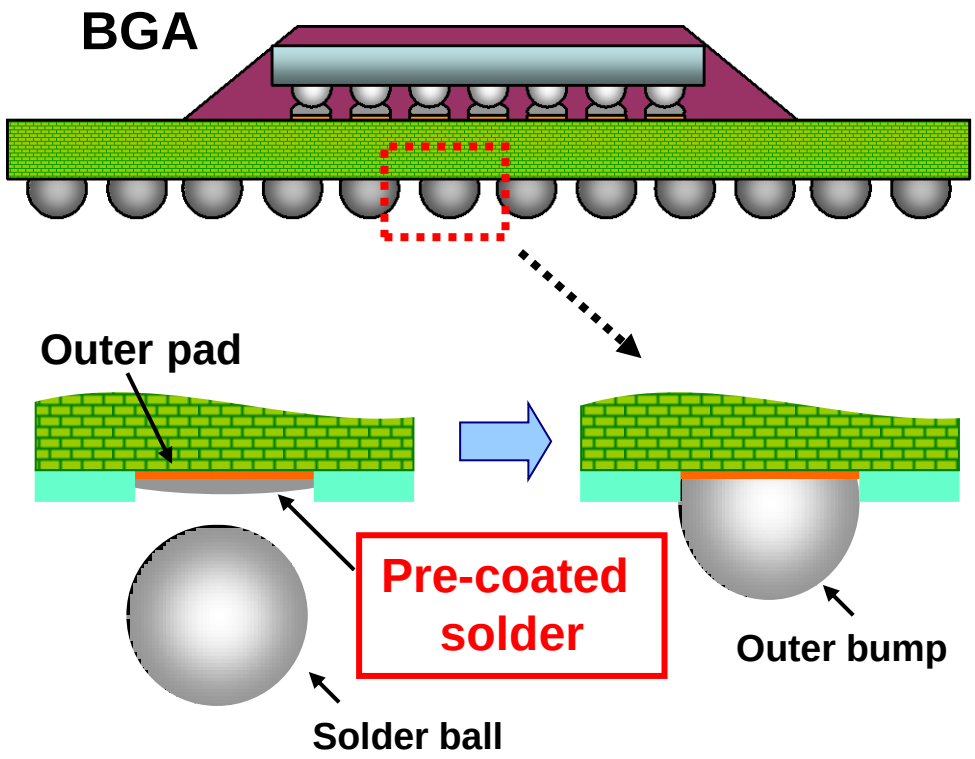
Fig. Design of mask and substrate

- SEM image of bumps

	After printing		After reflow (cleaning)
Printing Speed 50mm/s			
MAX Voids			Less than 30%

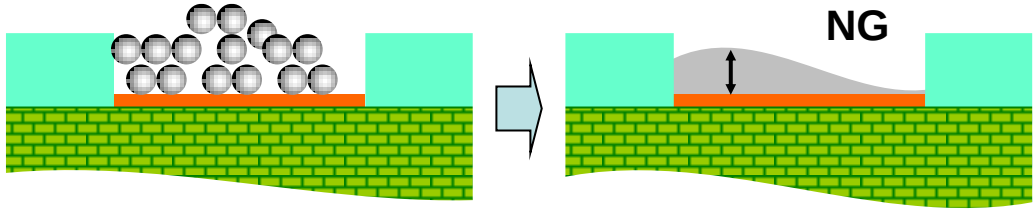
Super fine powder showed excellent fine pitch printability, soldering ability and voids performance.

Other application
Pre-coated solder paste

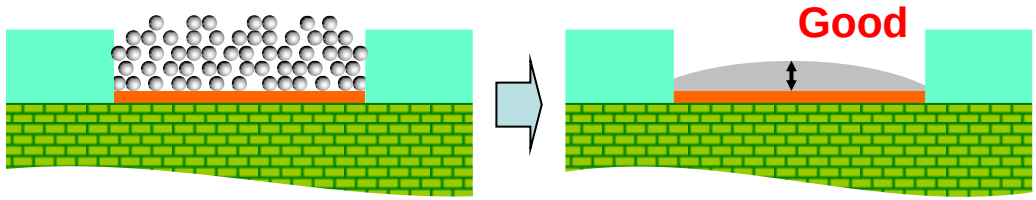


Pre-coated solder is required ;
- **Good solder coverage over outer pad**
- **Flat surface of solder**

Coarse powder (>8μm)
- **Poor solder coverage**
- **Wavelike surface**



Super fine powder (<3μm)
- **Good solder coverage**
- **Flat surface**



Super fine powder is a good solution for pre-coated paste.

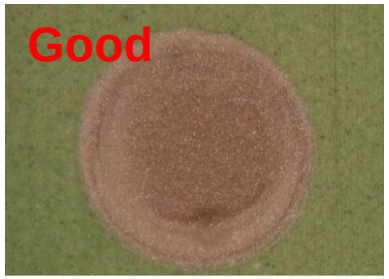
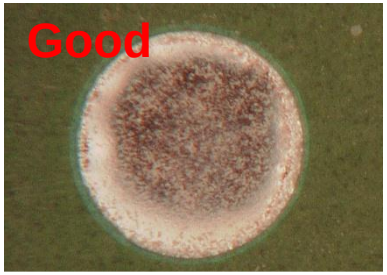
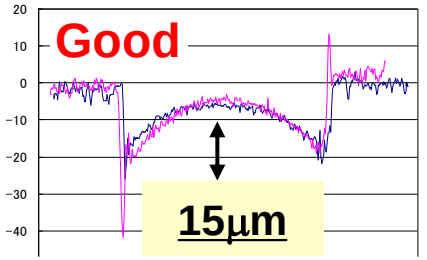
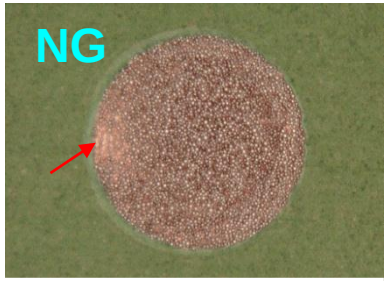
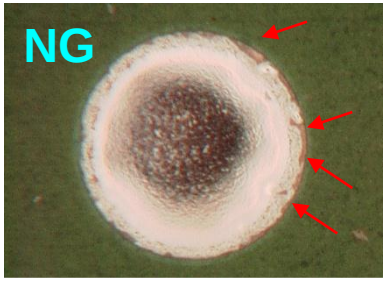
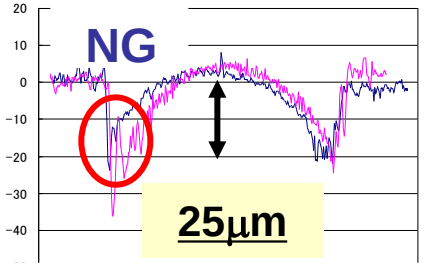
Evaluation results of pre-coated paste

• Properties of Paste

Composition	Process	Powder size:D_{50}	Flux ratio	Paste viscosity*	TI value*
Sn-3.0Ag-0.5Cu	Wet reduction	2.7μm	35wt%	90Pa·s	0.56
	Gas atomization	8.2μm	30wt%	87Pa·s	0.53

* Malcom viscometer

• Evaluation result

Powder	After printing	After reflow (cleaning)	
	Microscope image	Microscope image	Cross section profile
Wet Reduction D_{50} : 2.7μm "Super fine powder"	 Good coverage	 Good coverage	 Flat surface
Gas atomization D_{50} : 8.2μm	 poor coverage	 poor coverage	 Wavelike surface

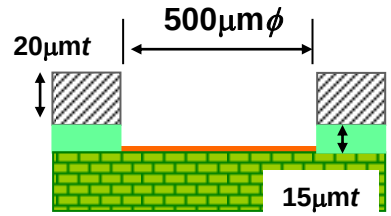
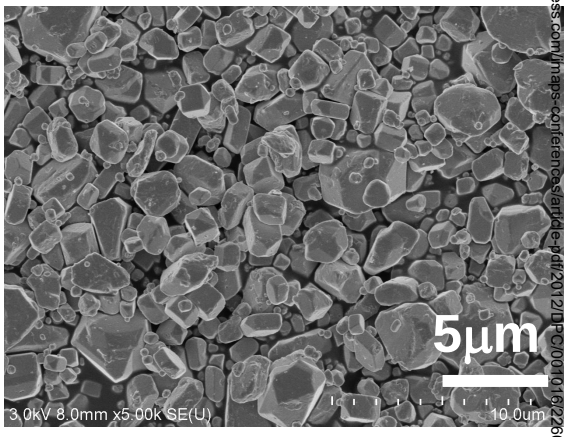


Fig. Design of mask and substrate

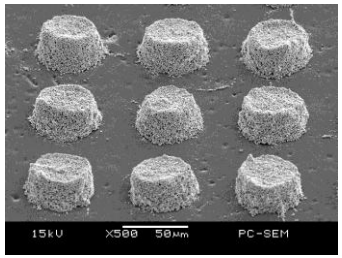
Super fine powder showed excellent performance for pre-coated paste.

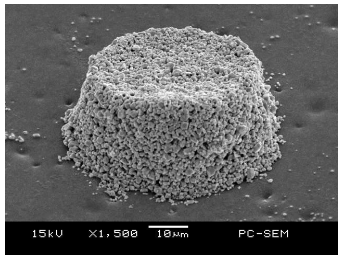
Conclusion

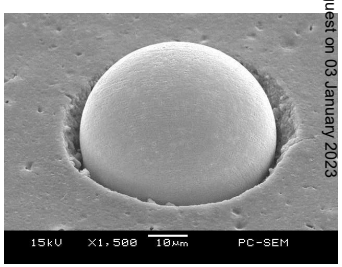
- By wet process (wet chemical reduction process), we have succeeded to develop novel super fine solder powder (D_{50}=2.7μm).
- Features of this super fine powder were as follows;
  - * Chemical composition : Sn-3.0Ag-0.5Cu
  - * Narrow powder distribution / Anisotropic shape
  - * High production yield
  - * Melting point and metallographic structure were as same as gas atomization powder.



- This super fine powder could apply for fine pitch printing (80μm bump pitch). And it also showed excellent performance for pre-coated solder application.







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