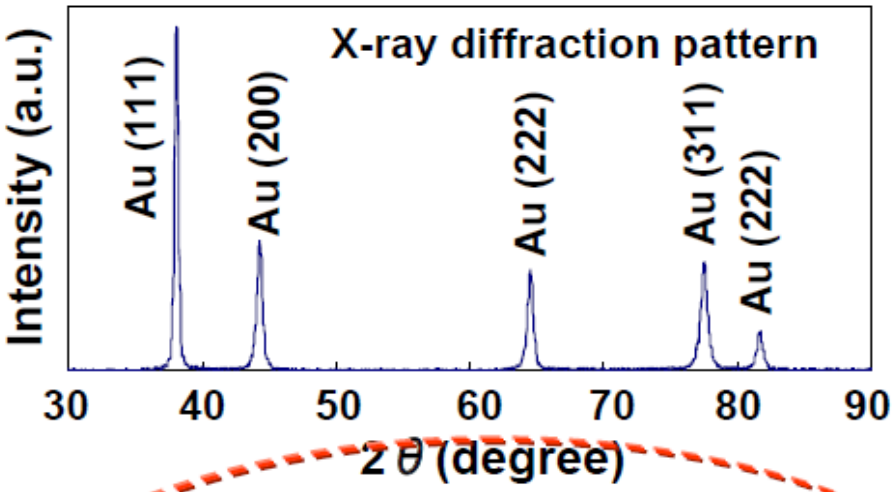
The Future is Precious. TANAKA

Introduction of Low Temperature Au-to-Au Submicron Bonding Material

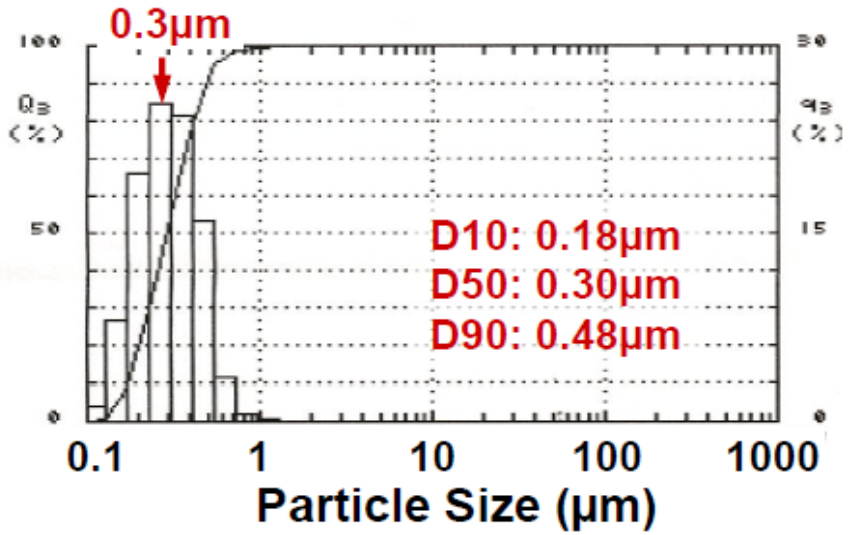
May 3, 2016

Characteristics of Sub-micron Au Particles

- **High Purity Au Particles**

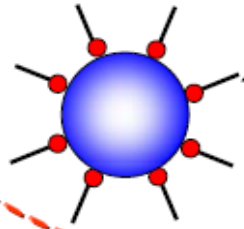


- **Particle Size Control**



- **Surface Preparation of Au Particles**

Sub-micron particles



Surface active agent
(Physically bonded)

- Can be removed at low temp ＞100℃

Nano-particles

Organic shell
(Chemically bonded)

- Need to heat up to higher temp. to remove

Low-temperature Bonding material AuRoFUSE™

- AuRoFUSE™ TR-191R
- 200Pa・s, 95mass%Au
- Distribution 0.2-0.5μm

- Screen printing
- Halogen free solvent
- No cleaning process
- RT. storage for 3 month

Typical Properties of AuRoFUSE™

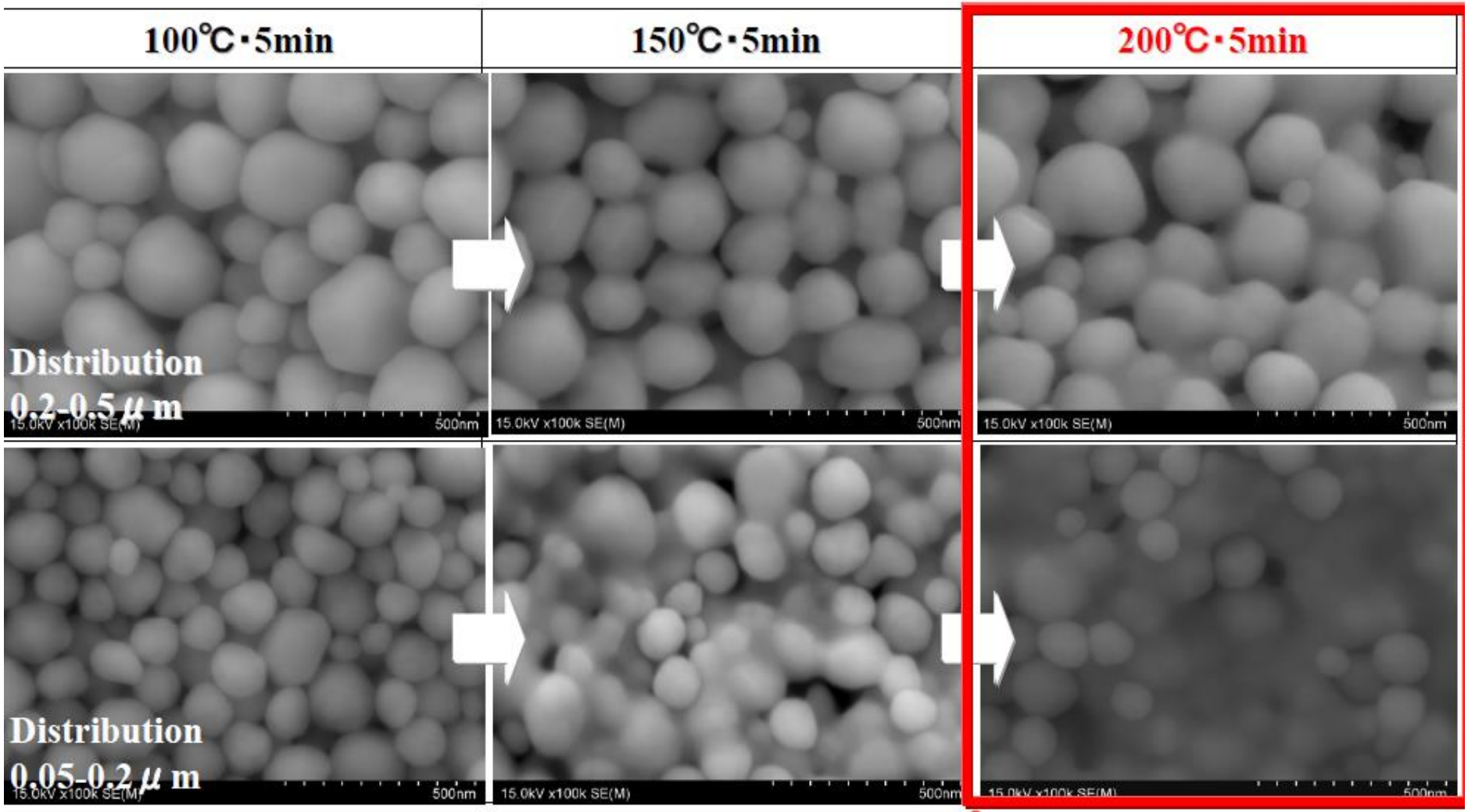
PASTE PROPERTIES	TR-191R	80Au20Sn (mass%)
Viscosity	200 Pa・s (Shear rate 20/s)	—
Au content	95 mass%	—
Au diameter	0.2-0.5 μm	—
Shelf life	3 Month (Jars, <25℃)	—
	3 Month (Syringes, <25℃)	—
Ionic impurities	Cl^- < 10ppm, K^+ < 10ppm, Br^+ < 10ppm Na^+, F^- : under investigation	—
BONDED PROPERTIES	**230℃ heating in air (No pressure)**	**300℃ soldering with Flux (No pressure)**
Electrical resistivity	5.4 μΩcm (25℃)	27.6 μΩcm (25℃)
Thermal conductivity	150 W / mK	57.3 W / mK
Heat-resistant	1064 ℃ (melting point)	278 ℃ (melting point)
Young's modulus	9.5 GPa (25℃)	60 GPa (25℃)
Shear strength	40 MPa ※1	100 MPa
Au content	99.95 mass%	80 mass%
UBM	Au finish	Au / Ni

※1) "Ar plasma cleaning" against bonding surface of Au finish is recommended to eliminate the surface contamination such as some oxidations of under barrier metals Ni, Cu, Ti etc., resulting in the increment of shear strength.

Motivation of Sub-micron Au Particles to Interconnections of Functional Device

Features of Au particles	Features of interconnections
Low temperature bonding due to the sintering behavior of Au particles.	•Reduced heat damage of components •Lower residual stress to devices •Small pitch and multiple bonding with no pressure
Sintered compact consists of a number of *Au/Au metal joints.*	•Low electrical resistance (< 5 × 10-6 Ω cm) •High thermal conductance (> 150W/m・K) •Heat resistance of joint (mp:1063℃) ⇒ *Die-bonding application*
Compressive deformation of sintered compact leads to *a densely structure*	•Hermetic sealing (leak rate< 1x10-13Pa·m3/s) •Tolerance of surface roughness (<±3um) ⇒ *Hermetic sealing application*

Sintering Behavior of Sub-micron Au Particles



Necking of Au particles is observed above 150℃ in air with no pressure.

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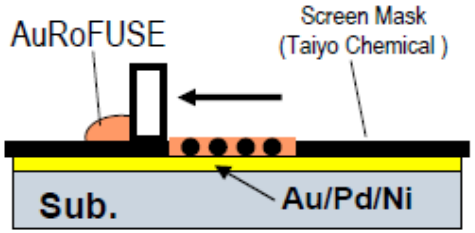
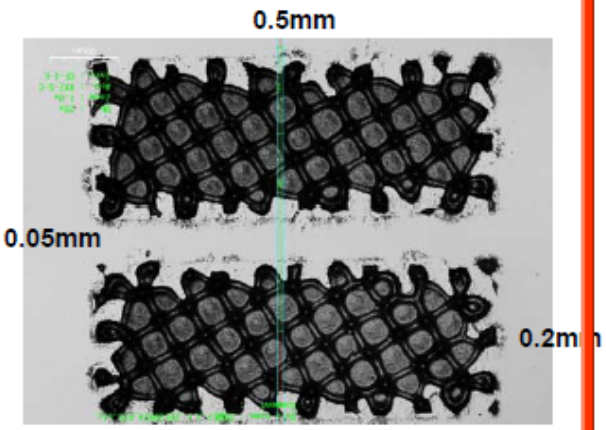
Development of Die-bonding for LED

High-precision Screen Printing (LS-150, NEWLONG)

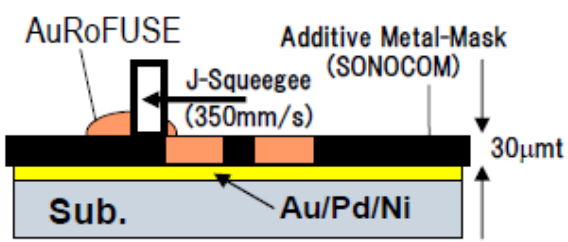
Film Printing

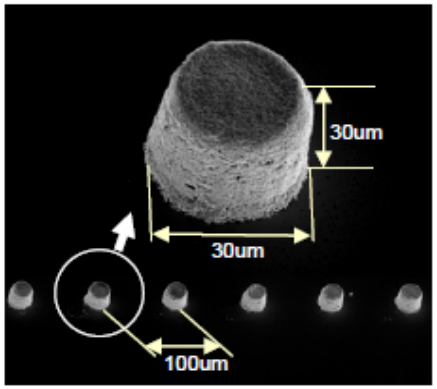




Die-bond joint for LED, P/D

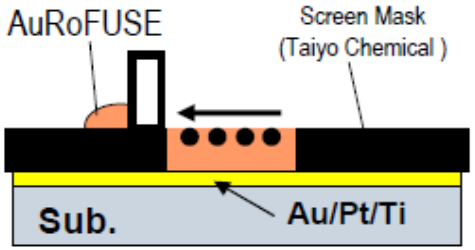
Bump Printing

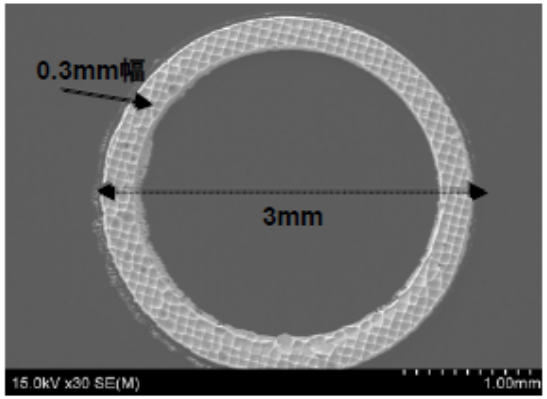




FC joint for LED

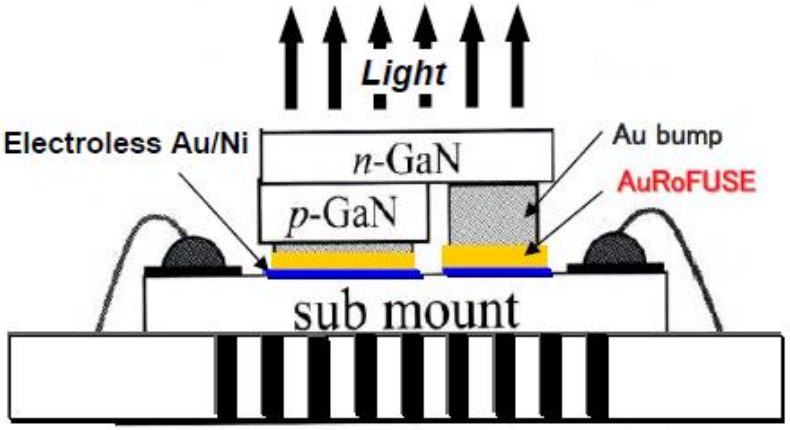
Ring Printing

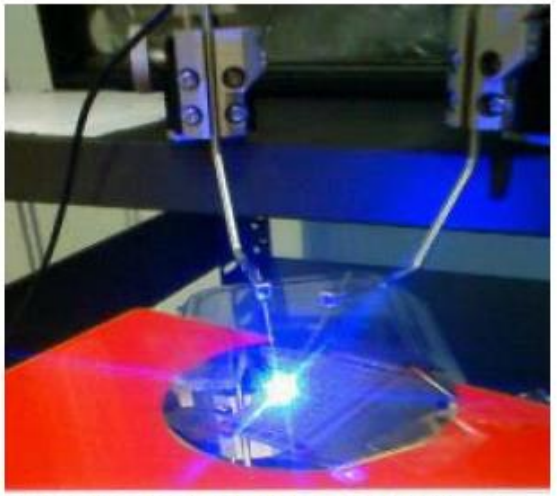




Hermetic sealing for MEMS

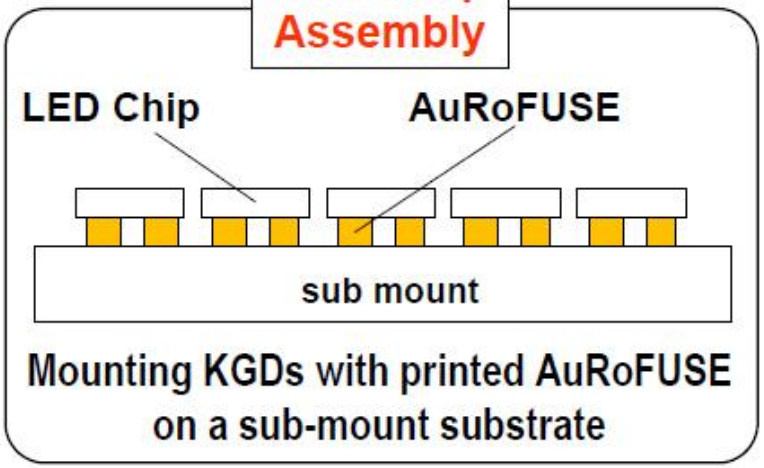
Assemble of Flip-Chip LED





Lightening of 200mW LED chip

Multi Chip Assembly

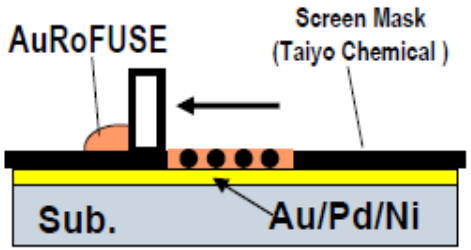


Mounting KGDs with printed AuRoFUSE on a sub-mount substrate

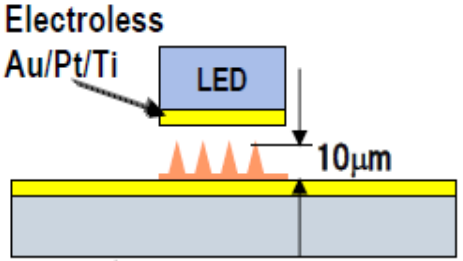
Reliability Tests	
Die Shear Strength (MPa)	4 items
Thermal Transient (K/W)	2 items
Electric Resistance (Ω)	3 items

Film Printing of TR-191R for Die-bonding

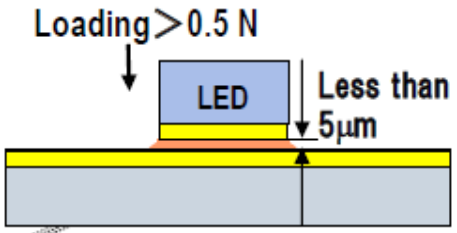
1. Printing (off-contact)

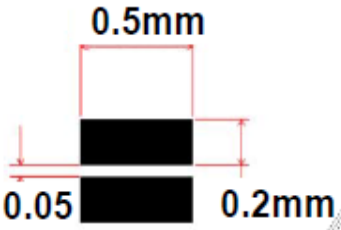


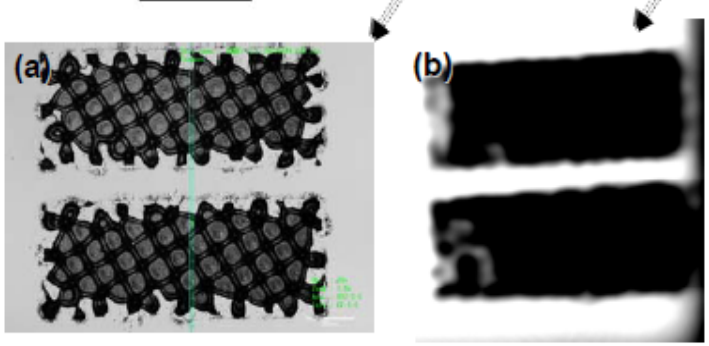
2. Alignment



3. Mounting (RT)

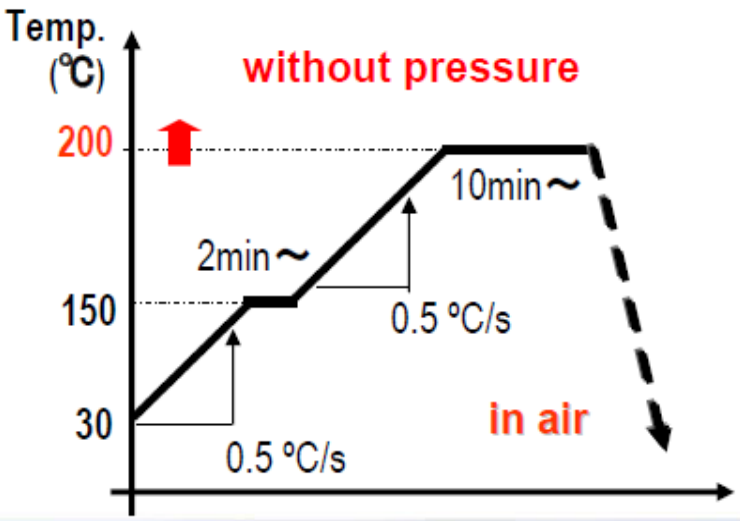




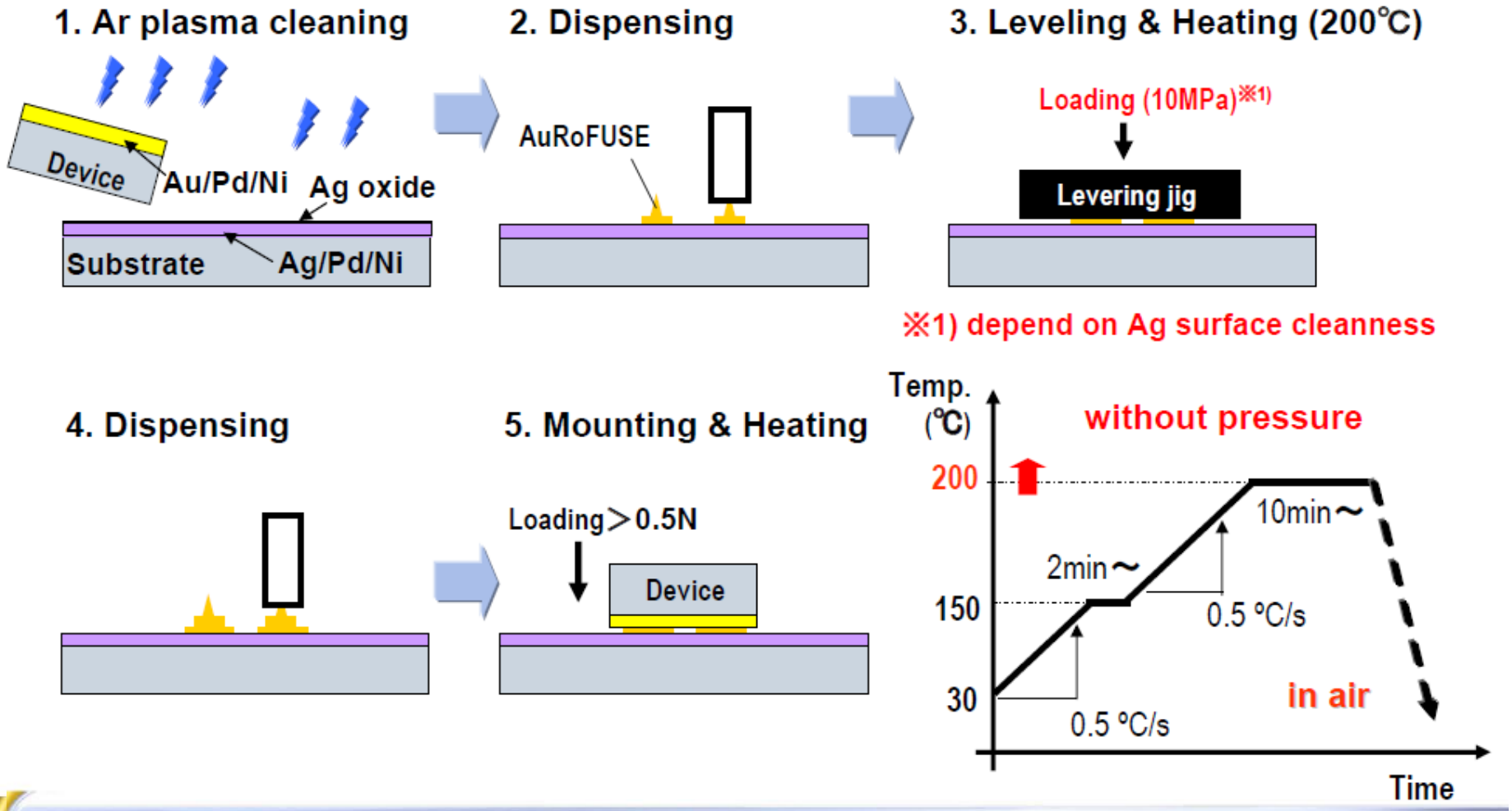


Before (a) and after (b) mounting of LED electrode size and pitch

4. Heating

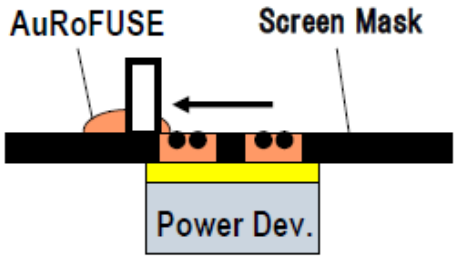


Dispensing of TR-191R for FC joints having Ag finished electrodes

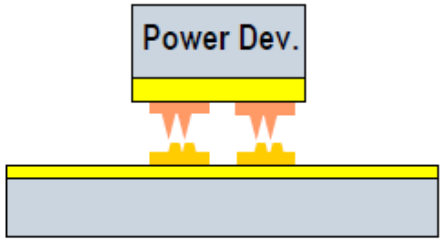


Film Printing of TR-191R for die-bonding

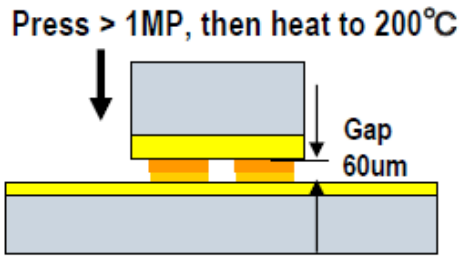
3. Printing (off-contact)



4. Alignment by flip-chip bonder



5. Mounting (RT) & pre-sintering (200℃)



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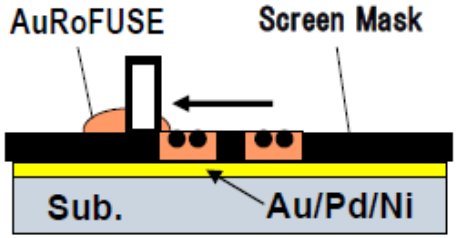
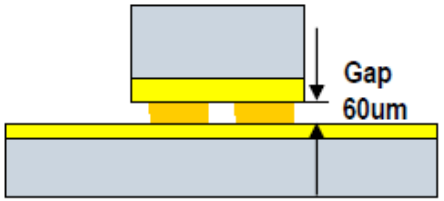
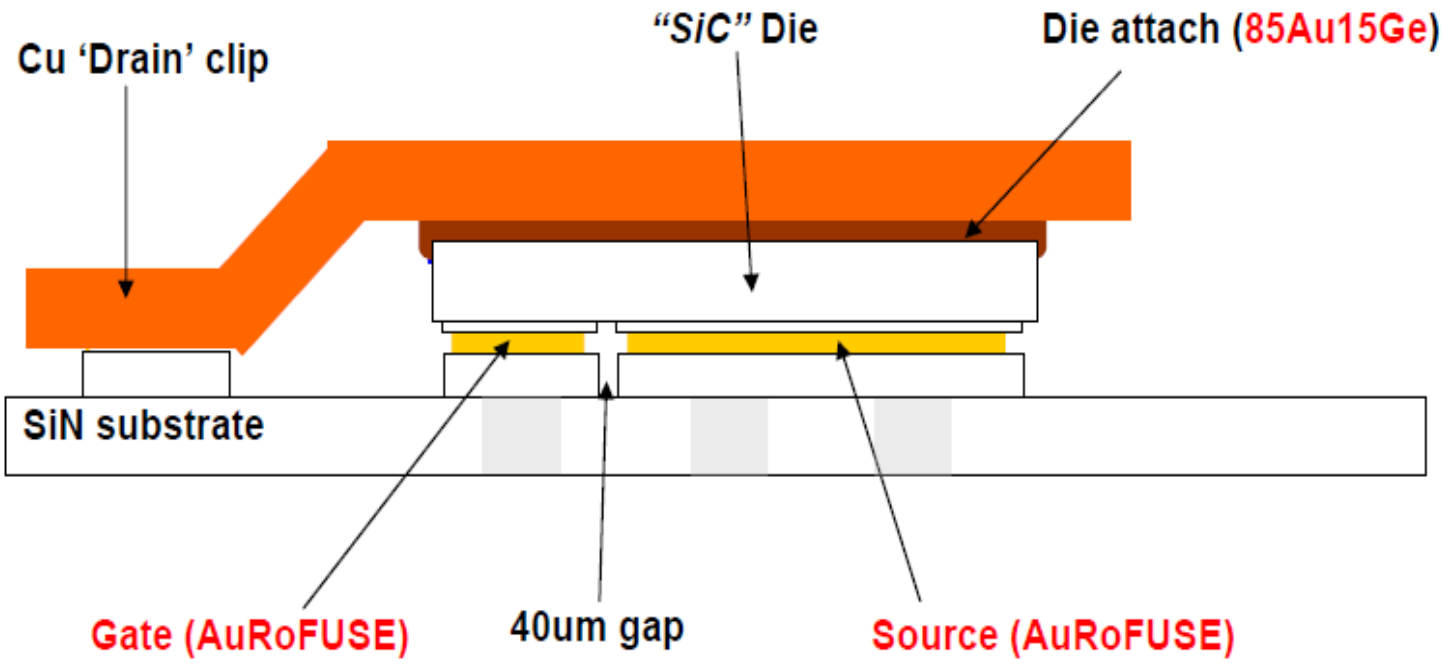


2. Pre-sintering (200℃) & levering

6.Sintering(250℃2h) by oven furnace



Structure of Double-Side Bonded Power Module



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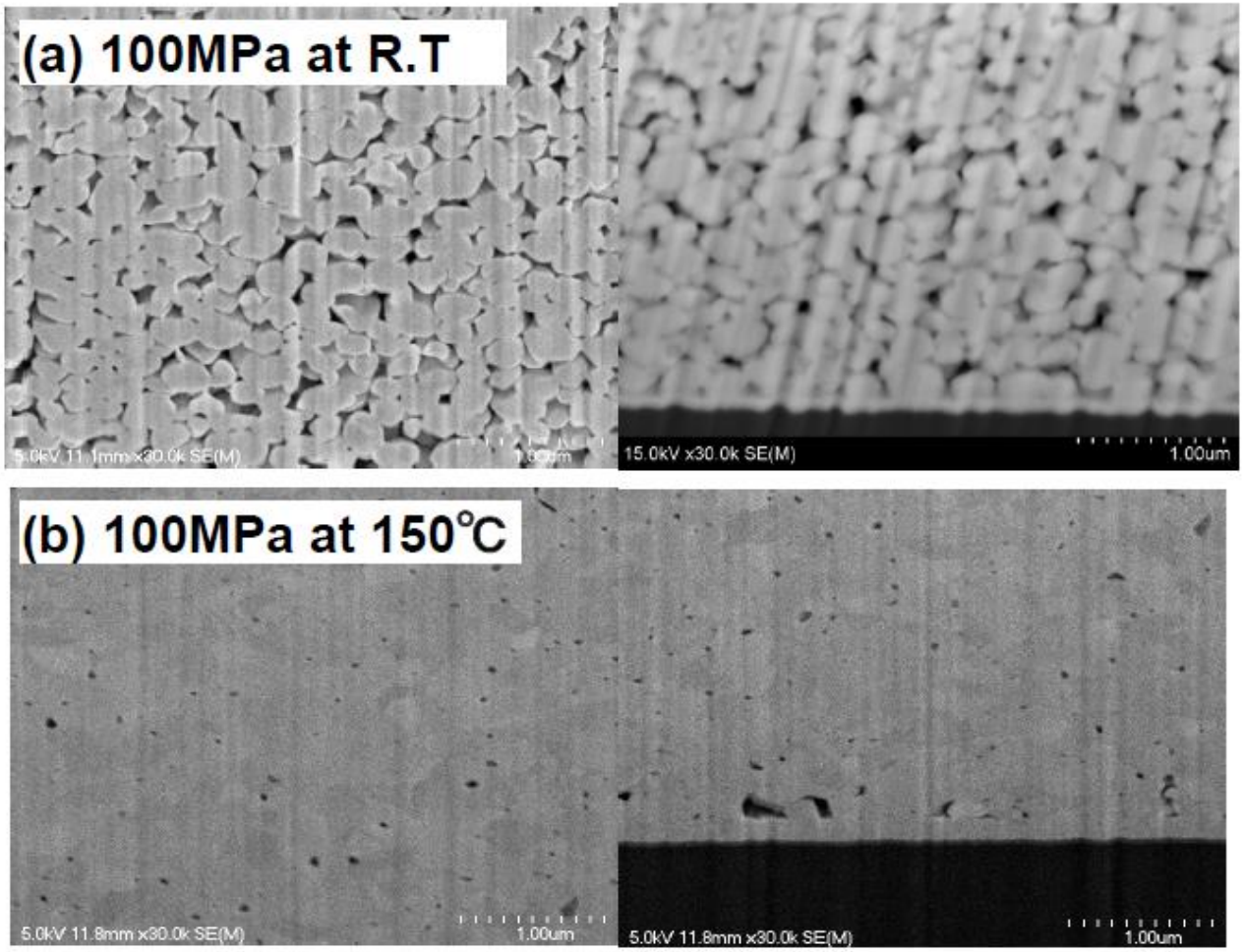
Development of Hermetic Sealing MEMS

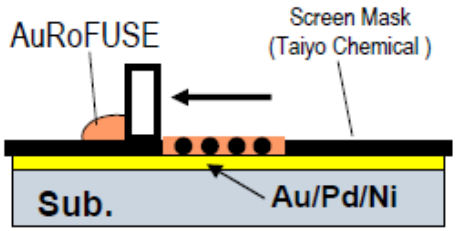
What's Hermetic Sealing by Au Sintered Compacts?

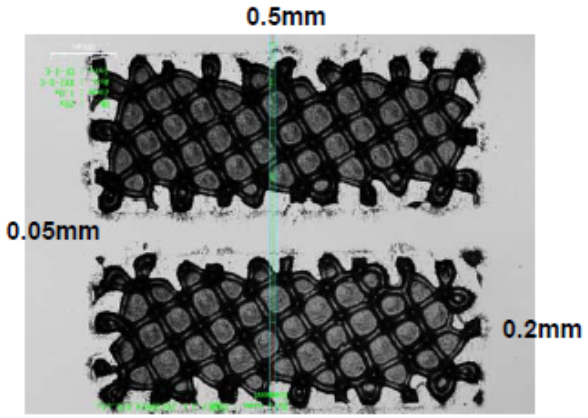


To get a densely structure changing from open pore state to closed pore state by thermo-compression bonding.

High-precision screen printing (LS-150, NEWLONG)

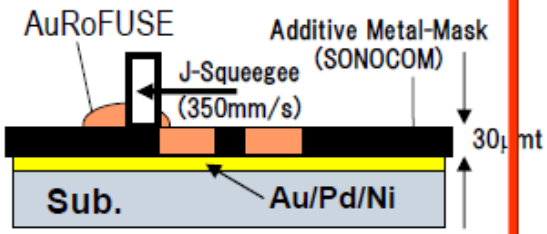
Film Printing

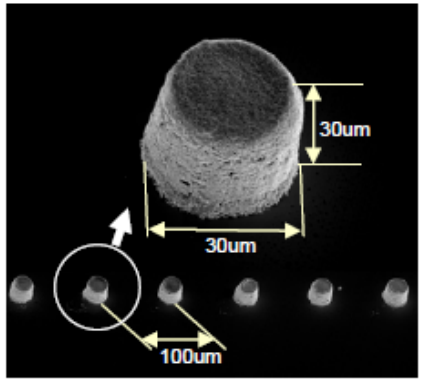




Die-bond joint for LED, P/D

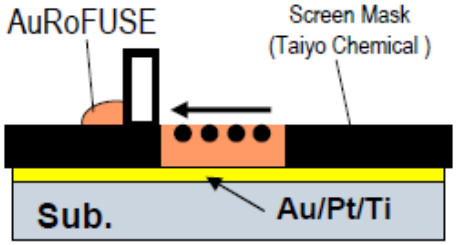
Bump Printing

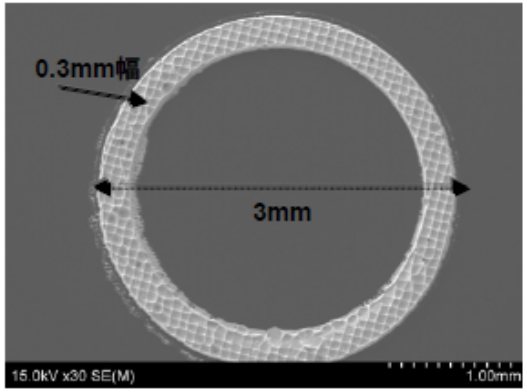




FC joint for LED

Ring Printing

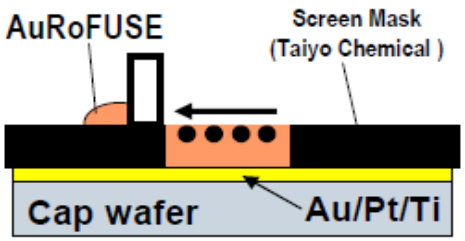




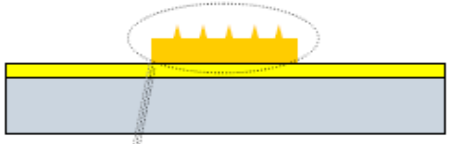
Hermetic sealing for MEMS

Ring Printing of TR-191R for Hermetic Sealing

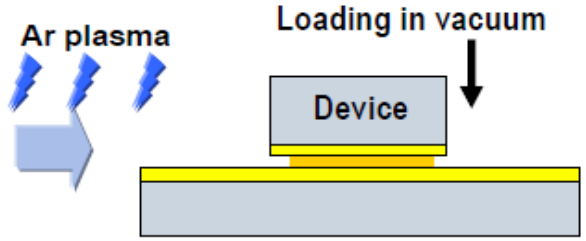
1. Printing (off-contact)

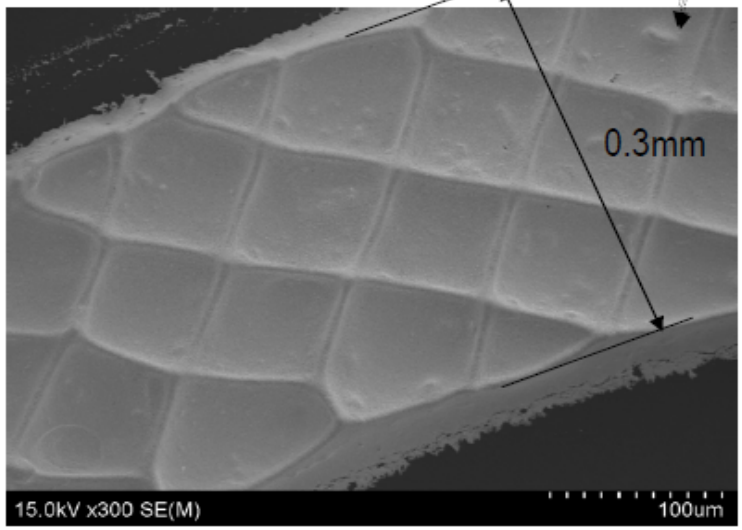


2. Pre-sintering & outgas reduction (200℃, Ar-4%H2, cycle purge)



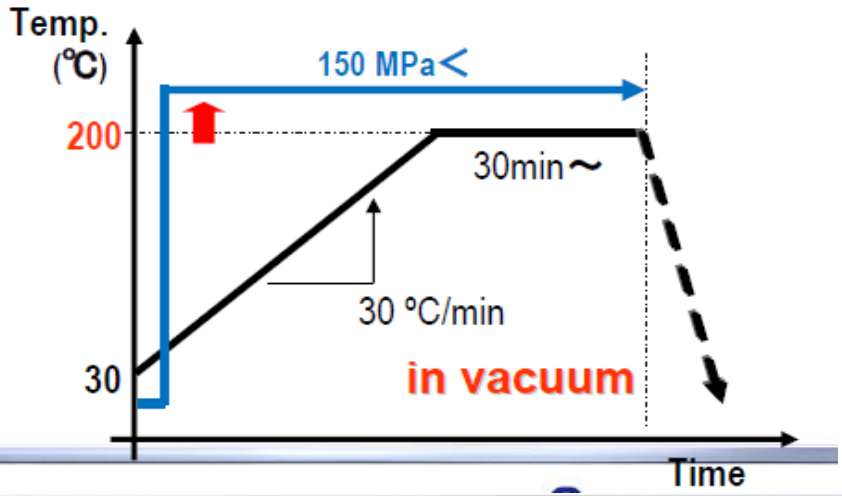
3. Alignment (RT) & bonding(200℃)





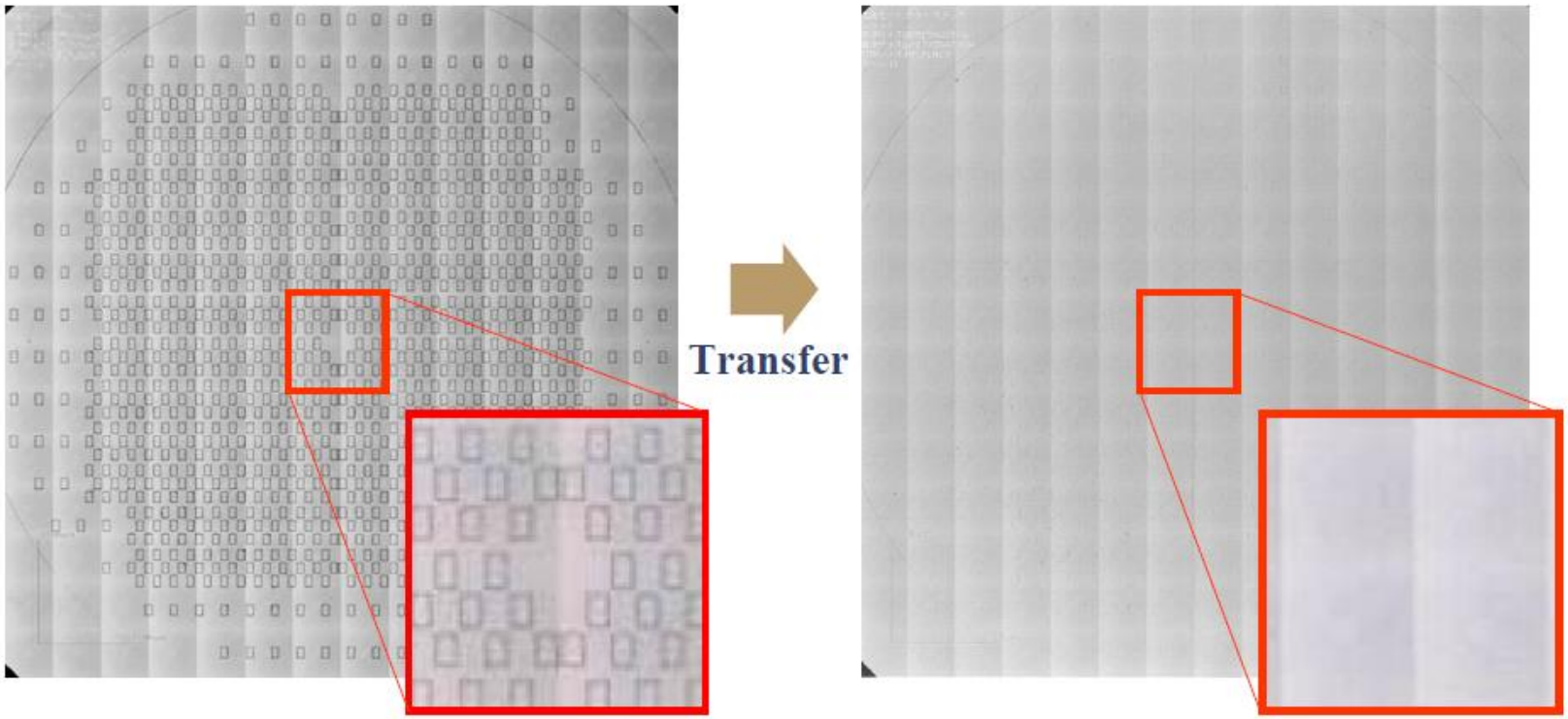
Printed network structure

4. Bonding profile for hermetic sealing



Ring Patterns of Au sintered Compacts by Screen Printing on 4 in. wafer

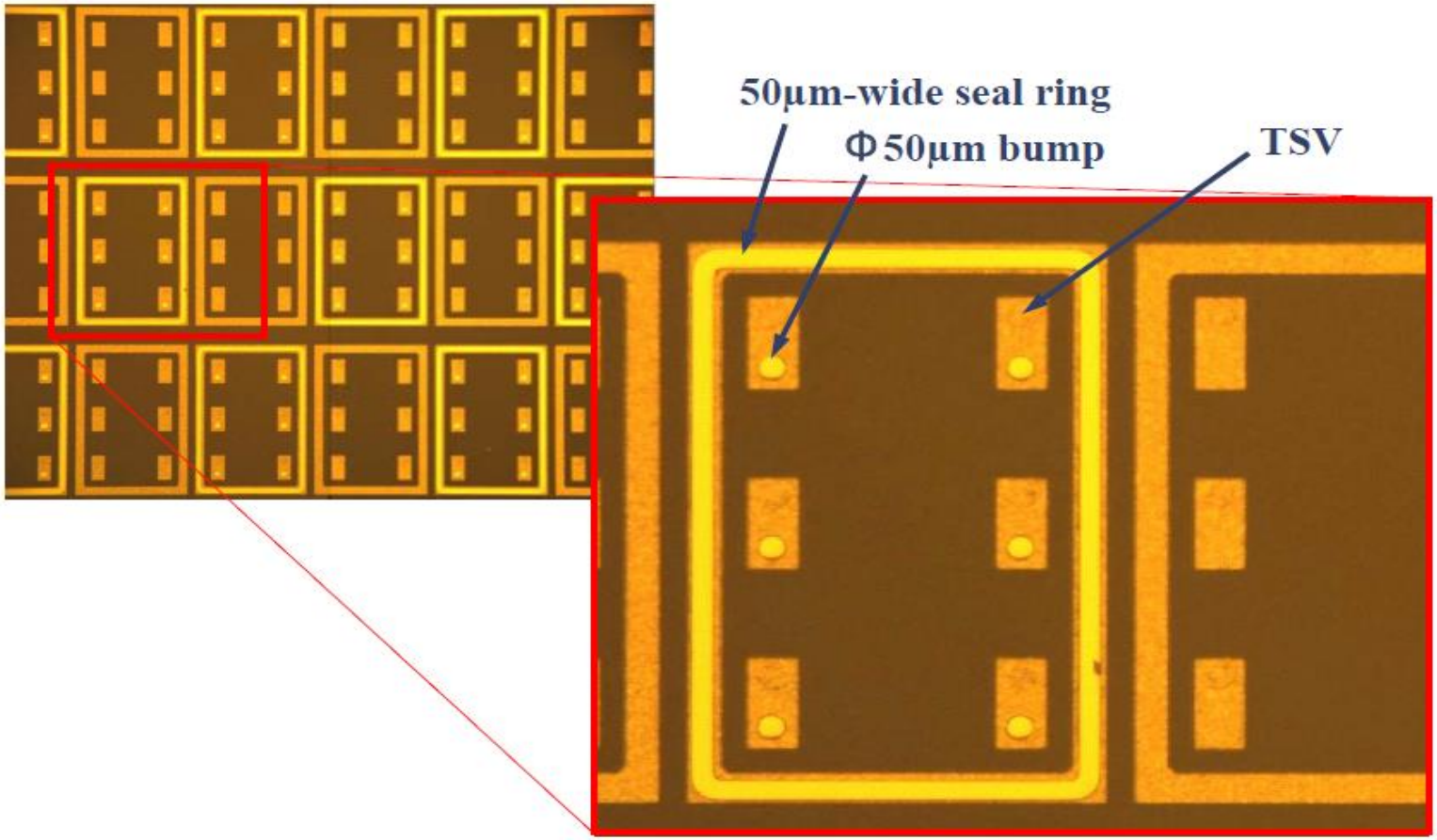
Wafer level Au pattern transfer for hermetic seal rings



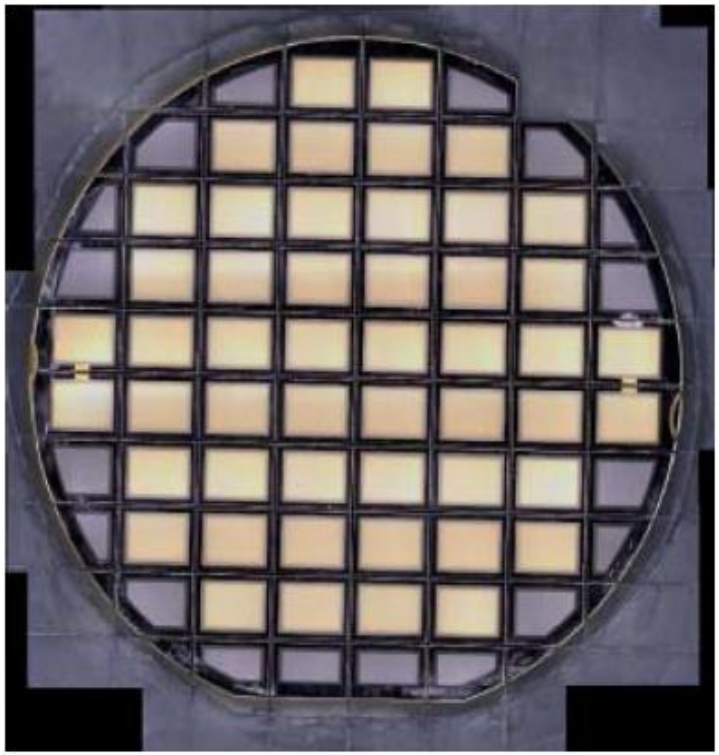
Initial Transfer Wafer
(before transfer)

After Transfer

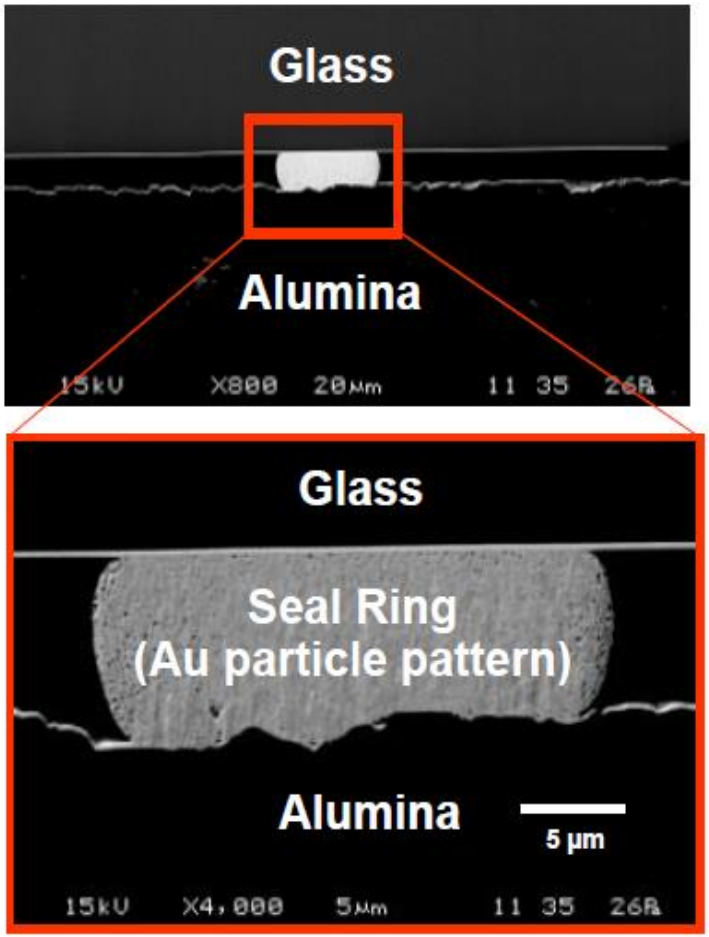
Transferred Pattern Result:
Sealing Lines and Bumps onto Ceramic Substrate



Surface-Compliant Behavior of Sub-Micron Au Particle Patterns



Φ2” bonded pair (glass + alumina)
at 200°C, 200MPa, 30min.
Blade-dicing was successfully done.
He leak rate < 1x10-13 Pa·m3/s



Cross-section SEM images of
a 20µm-wide seal ring

Conclusions

1. Low temperature sintering of sub-micron Au particles is suited to low temperature bonding with no pressure leading to less damage of functional devices.

2. Au/Au metal joint of sub-micron Au particles showing a low electrical resistance, high thermal conductance is applied to LED and P/D assembly.

3. Wafer-level packaging was successfully performed due to easy deformation of porous structure, and He leak rate of $< 1x10^{-13}$ $Pa \cdot m^3/s$ was obtained for the bonded pairs between glass and Al2O3 wafers even if it has a surface irregularity.

Thank You For Your Attention!