Sapphire Flip-chip Thermocompression and Eutectic Bonding for Dielectric Laser Accelerator

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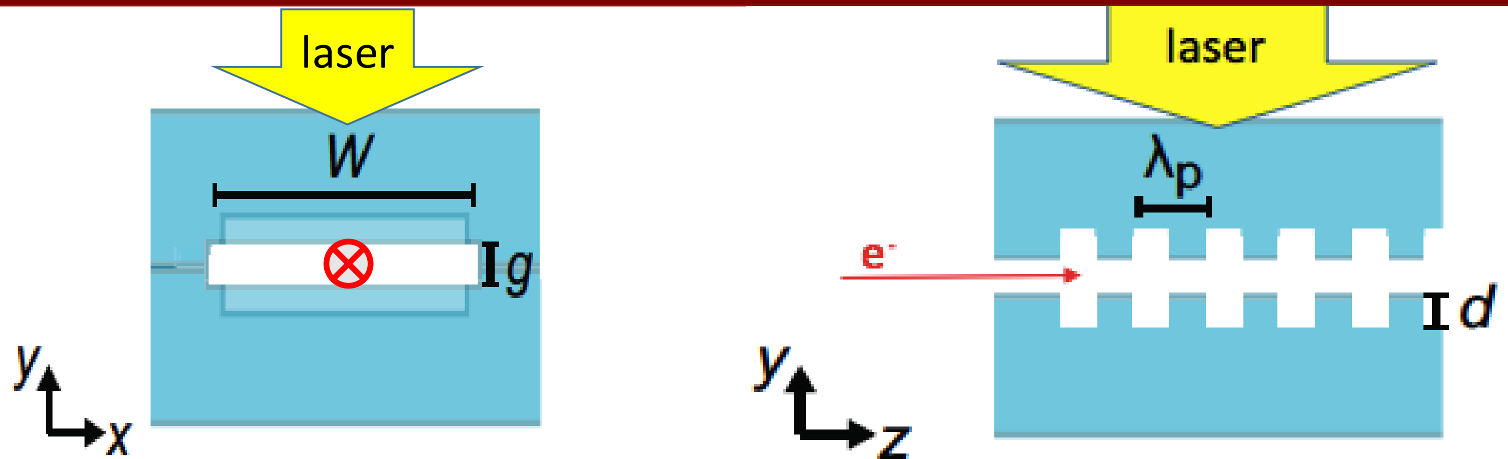
Outline

- Motivations
- Au/Au Thermocompression Bonding for Sapphire Chips
- Au/Sn Eutectic Bonding for Sapphire Chips
- Bonding Sapphire Chips for Dielectric Laser Accelerator
- Summary

Introduction

Double gratings can be used to accelerate electrons with laser

Motivation



SiO_2 --> Sapphire grating: high LIDT & high n

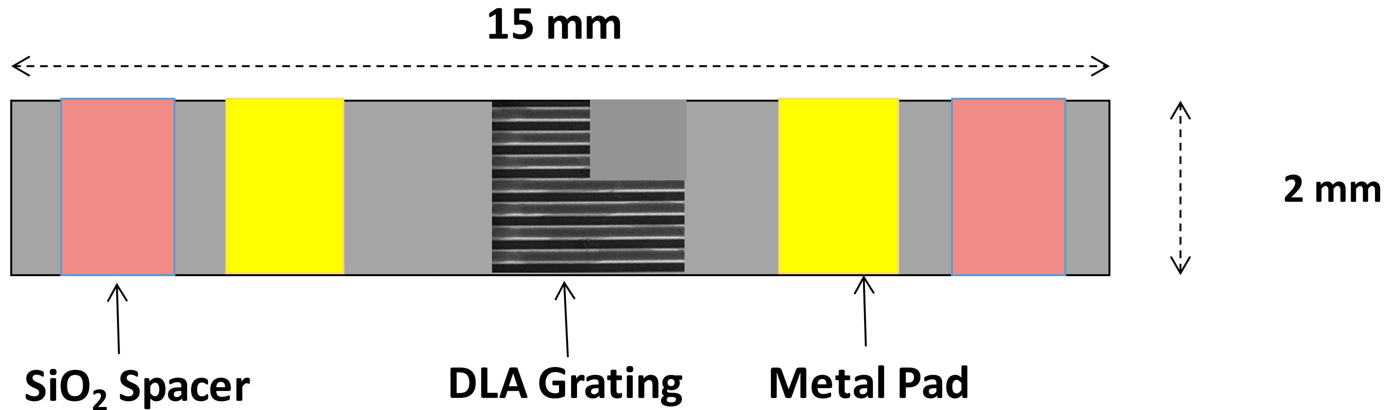
- Double grating better than single grating
- But difficult to fabricate double grating monolithically (sapphire hard to etch)

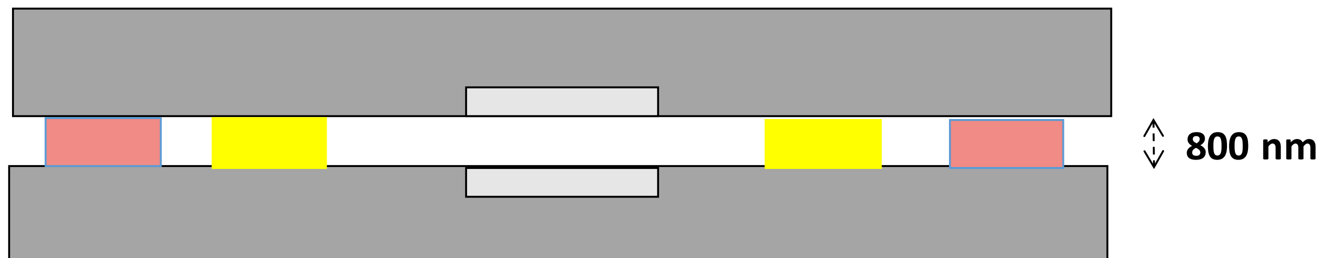
→ Fabricate two halves + Bonding

Project Goal

Bond Top Half to Bottom Half Using Intermediate Layers

(two chips do not fall apart during handling)



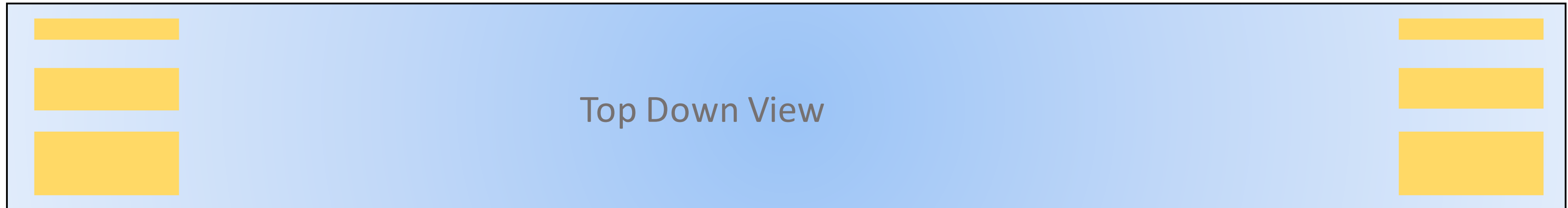


Finetech FINEPLACER Lamba Bonder

- Overlay vision alignment with fixed beam splitter
  Max field of view: 6.7 mm x 5.4 mm
  Sub-micron placement accuracy
- Bonding Force: 0.1 - 20 N
- Heating temperature: 400˚C max
  Below 380˚C is the allowed range
- Real time process observation camera
- Chip size: 0.1x0.1mm - 15x15mm
- N_2 box

Au/Au Thermocompression Bonding

- Au/Au brought into atomic contact applying force and heat simultaneously
- The atoms migrate from one crystal lattice to the other one based on crystal lattice vibration due to atoms motion
- 20nm Ti/ 450nm Au on each side



Temperature Profile

Au/Au Thermocompression Bonding Results

	cleaning	pressure	bonding
1st	x	166KPa	x
2nd	✓	166KPa	✓
3rd	✓	1MPa	✓✓

Successful bonding @ Max Time (45min) + Max Temperature (380˚C)

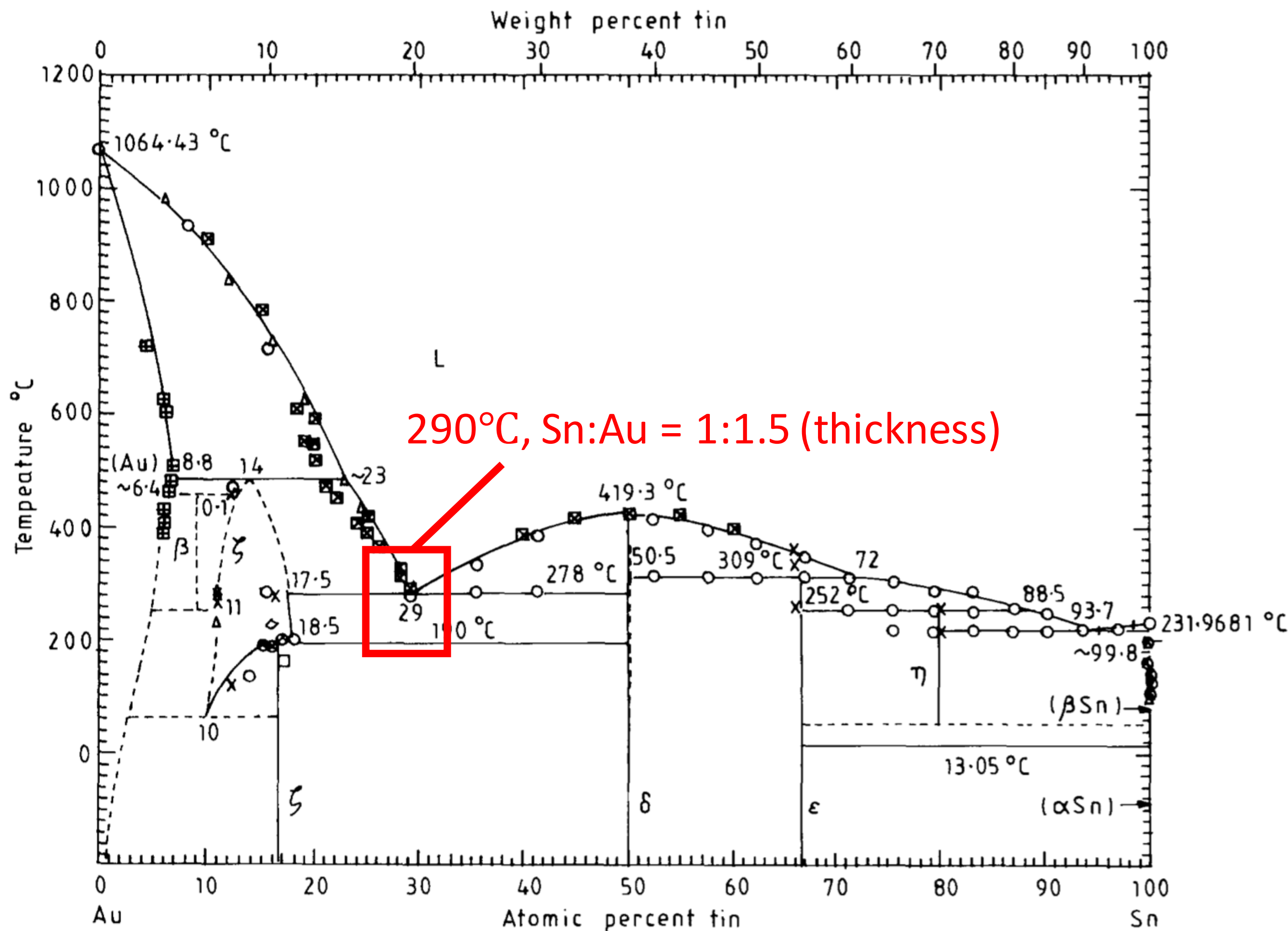
✓Cleaning is criticle (O_2 plasma + SRS100@70˚C 30min +wear gowning);

✓Higher pressure -> Better thermocompression bonding

- Requires very long bonding time
- Bonding strength good, but could be improved

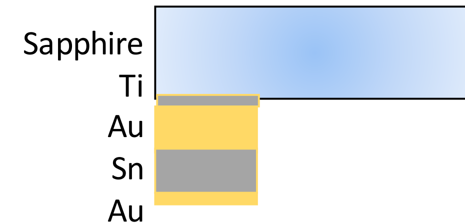
Au/Sn Eutectic Bonding

- An intermediate metal layer produces a eutectic system.
- Eutectic metals are alloys that transform directly from solid to liquid state
- At a specific composition and temperature without passing a two-phase equilibrium



Matijasevic, Goran S., Chin C. Lee, and Chen Y. Wang. "Au/ Sn alloy phase diagram and properties related to its use as a bonding medium." *Thin Solid Films* 223.2 (1993): 276-287.

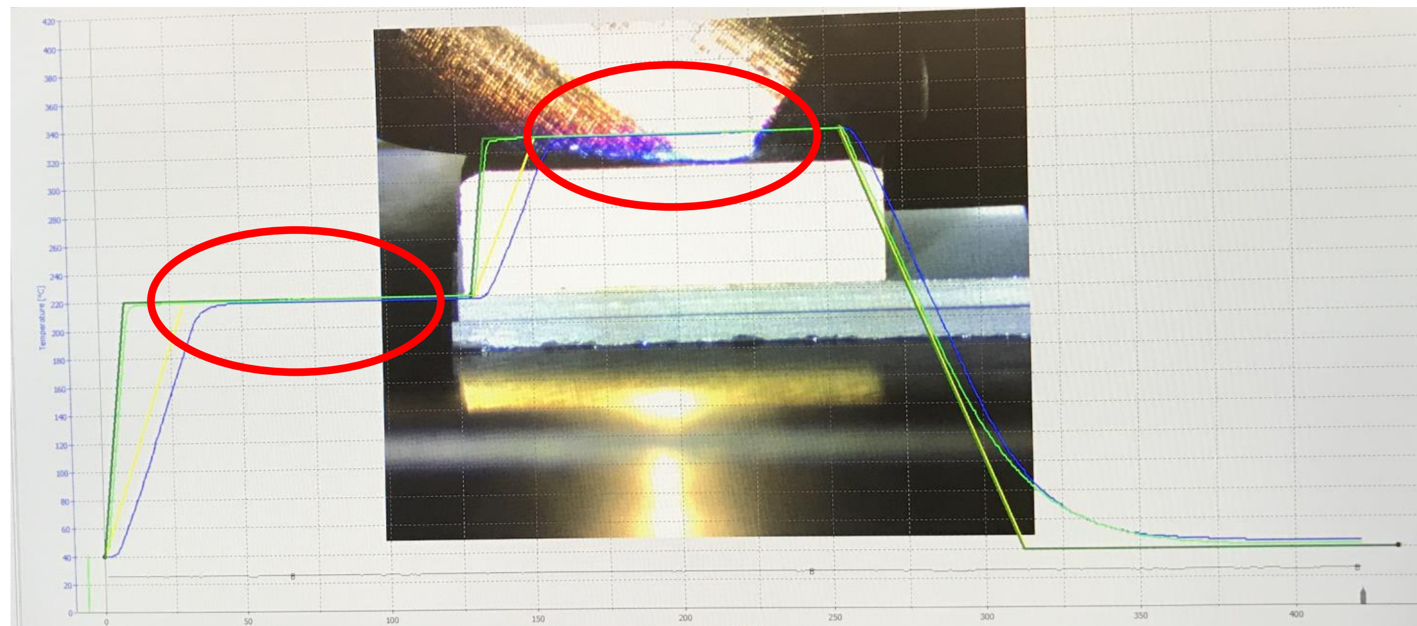
Sn/Au Eutectic Bonding



- 20nm Ti/450nm Au/320nm Sn/30nm Au

Processes:

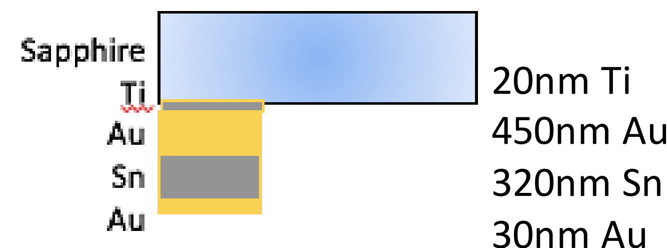
1. Deposit metal stack
2. O_2 plasma + SRS 100 + wear gowning
3. Pre-heat the sample during the bonding process
4. 20N of max bonding force



Au/Sn Eutectic Bonding Results

Dropping test from 1.2m high table

	280°C	290°C	300°C	340°C
5min	1	2	2	2
7min		**5**	1	1
9min	1	1		



Successful eutectic bonding with metal stack

✓ Obvious melting and eutectic forming;

✓ Optimal recipe: 290˚C 7min (repeated 4 times, 4-7 drops);

✓ Bonding time is shorter & temperature is lower;

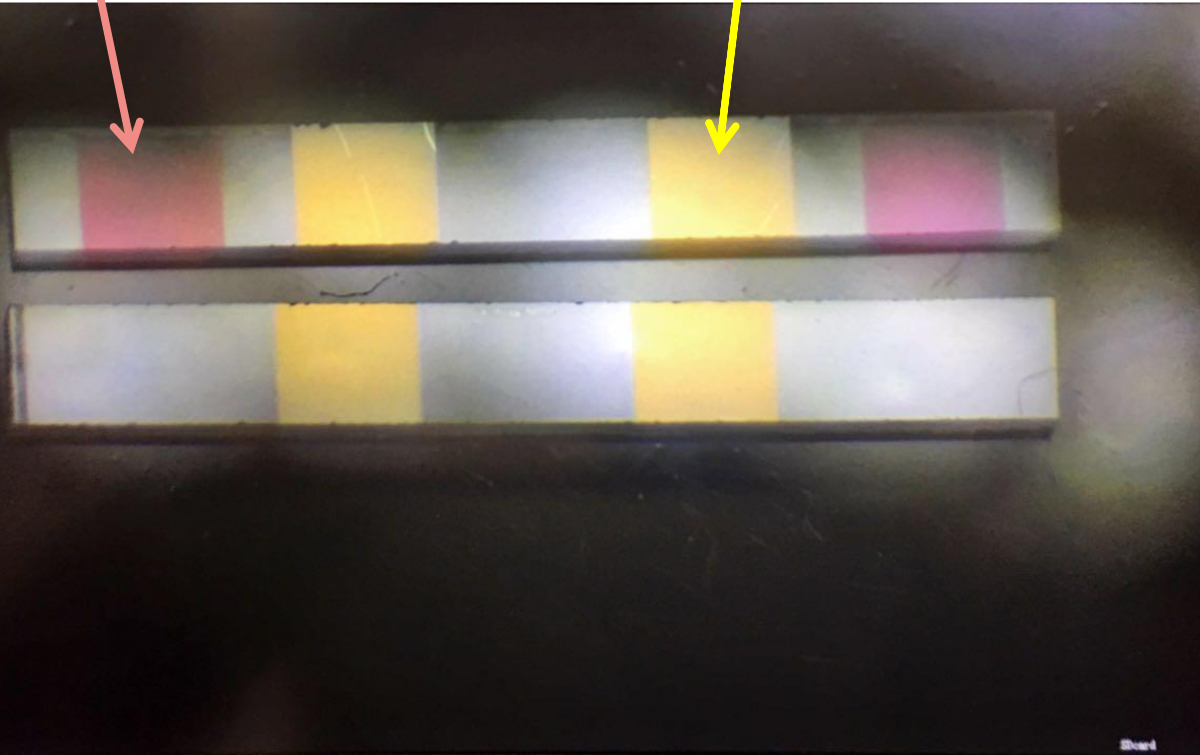
- Cleaning is very critical;
  - no cleaning -> no bond;
  - cleaning -> good bond;
  - cleaning-> sit 5 days -> no bond -> redo cleaning -> good bond
- Top layer of 30nm Au is critical (prevent Sn->SnO_2);

Sapphire Dielectric Laser Accelerator

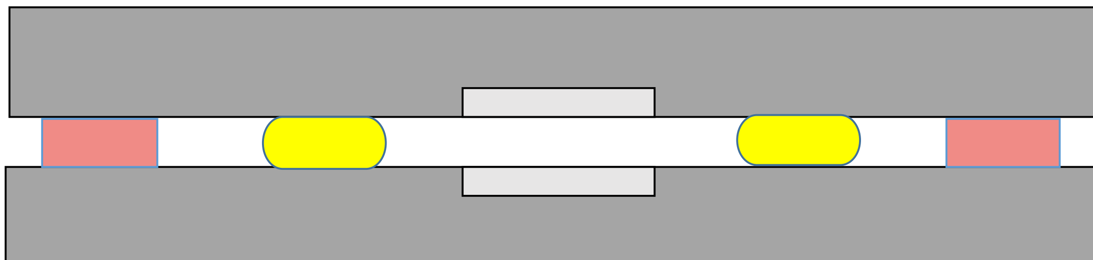
Spacer: accurately control the gap to be 800nm

800nm SiO_2

20nm Ti/450nm Au/320nm Sn/30nm Au



- ✓ Metal stack for eutectic bonding
- ✓ HDPCVD oxide spacer

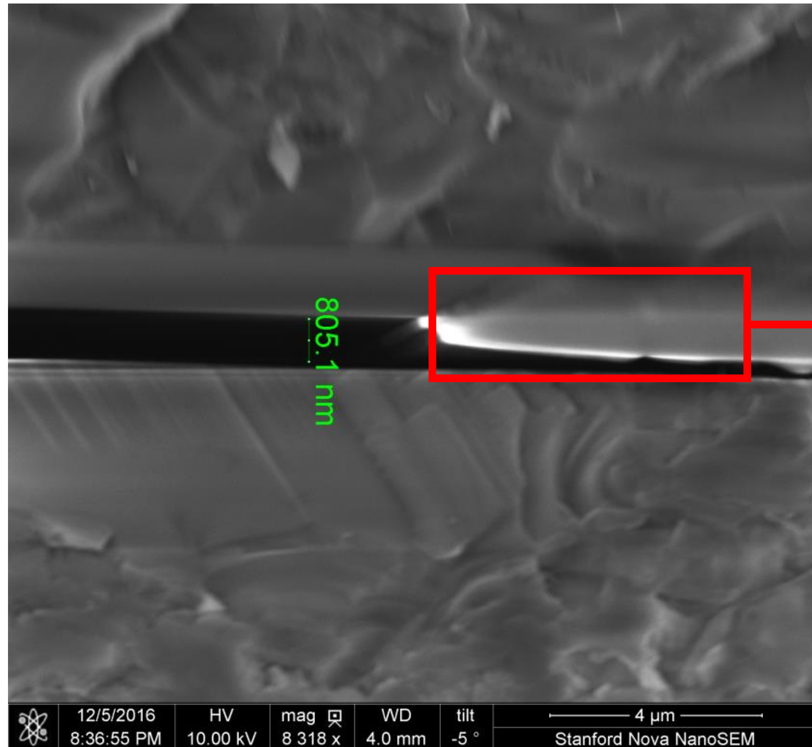


Chips well bonded

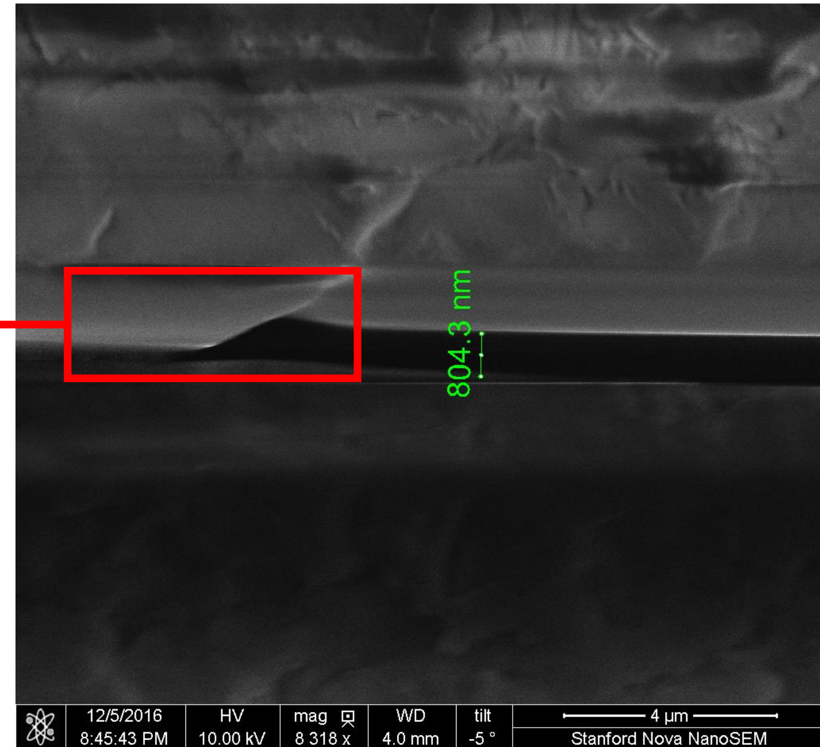
Top View

Cross-section View

Cross-section SEM to Check 800nm Gap



Spacer



Summary

Successful thermocompression and eutectic bonding

✓ Cleaning is critical for bonding

✓Au/Sn eutectic bonding performs better than Au/Au thermocompression bonding in this flip-chip bonder

X particles + not enough pressure

-> higher pressure (other model 400N) + better environment

✓Top layer of Au is critical for eutectic bonding metal stack

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