ONTOS
Equipment Systems

Au-Au Direct Bonding

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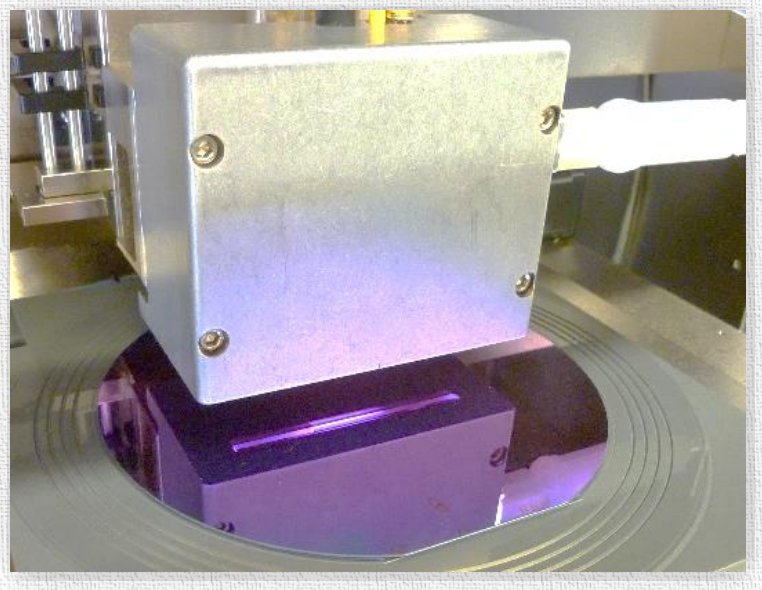
Surface Activation with Ontos7

This work was carried out on the first Generation Atmospheric plasma Ontos7 Developed and Manufactured by Ontos Equipment Systems

- Simple apparatus - no vacuum chamber.
- Plasma is **contained** entirely within the process head, never contacting the chip/wafer.
  - Downstream radical chemistry only.
  - No exposure to: arc discharges, charged particles, bombardment, re-deposition, or spalling particulates.
  - CMOS safe, Detector safe.



Gold-to-Gold Direct Bonding

- An unexpected bonding benefit was discovered while bonding Gold pads to Gold pads for a flip-chip configuration. Low-temperature compression bonding (necessitated by chip temperature restrictions to 200°C) had yielded very poor adhesion between Gold pads, even though there was significant visual pad-to-pad compression (Figure 1).

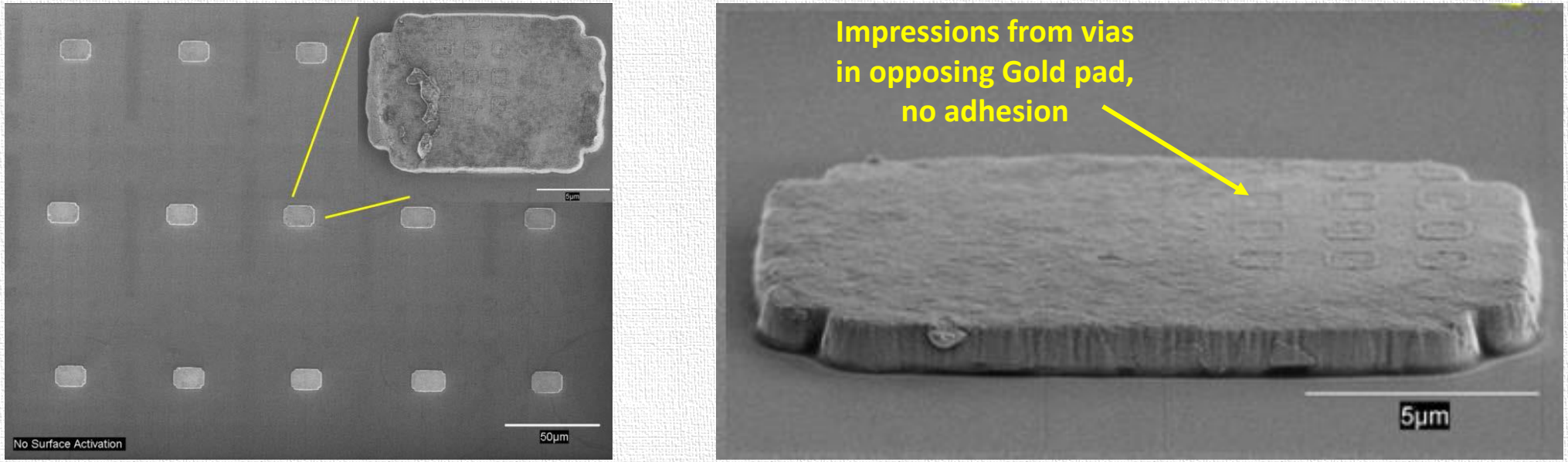


Figure 1 – Untreated Gold pads show adequate compression, but nearly zero adhesion following 200°C thermo-compression bonding and pull test.

Gold-to-Gold Adhesion with Ontos

- Sister die were treated with ONTOS Atmospheric Plasma Surface Preparation process and then bonded under identical conditions, yielding remarkable Gold-to-Gold adhesion. Pull-apart tests showed metallurgical tensile rupture within the Gold bulk, and adhesion was so good that many Gold bond pads were ripped away from the substrate, taking chunks of underlying Silicon with them (Figure 2).

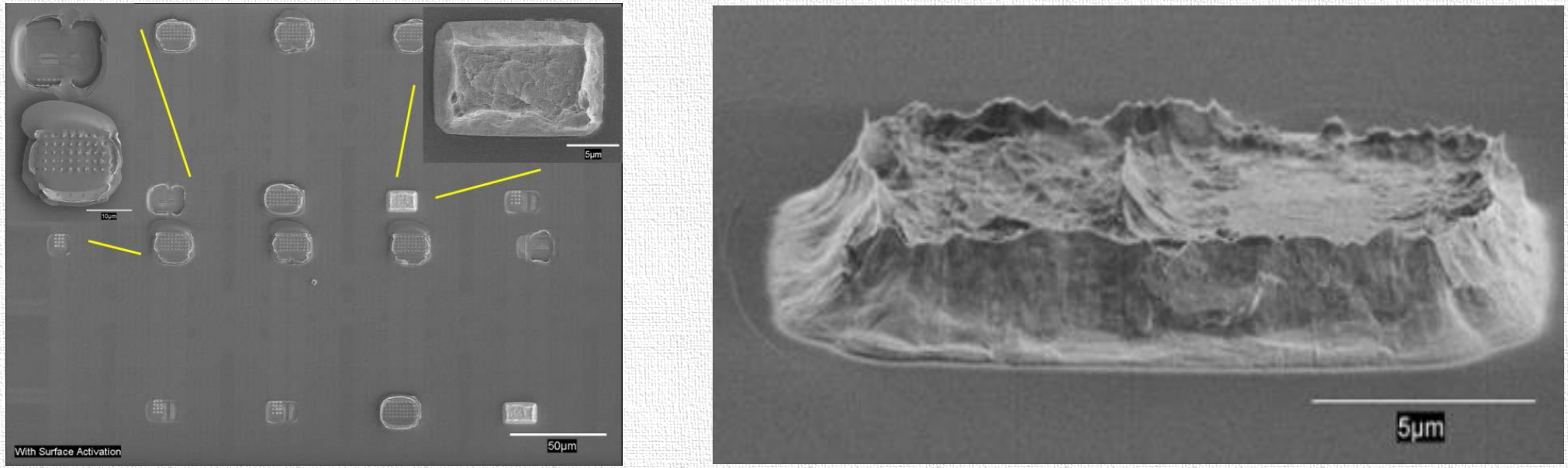
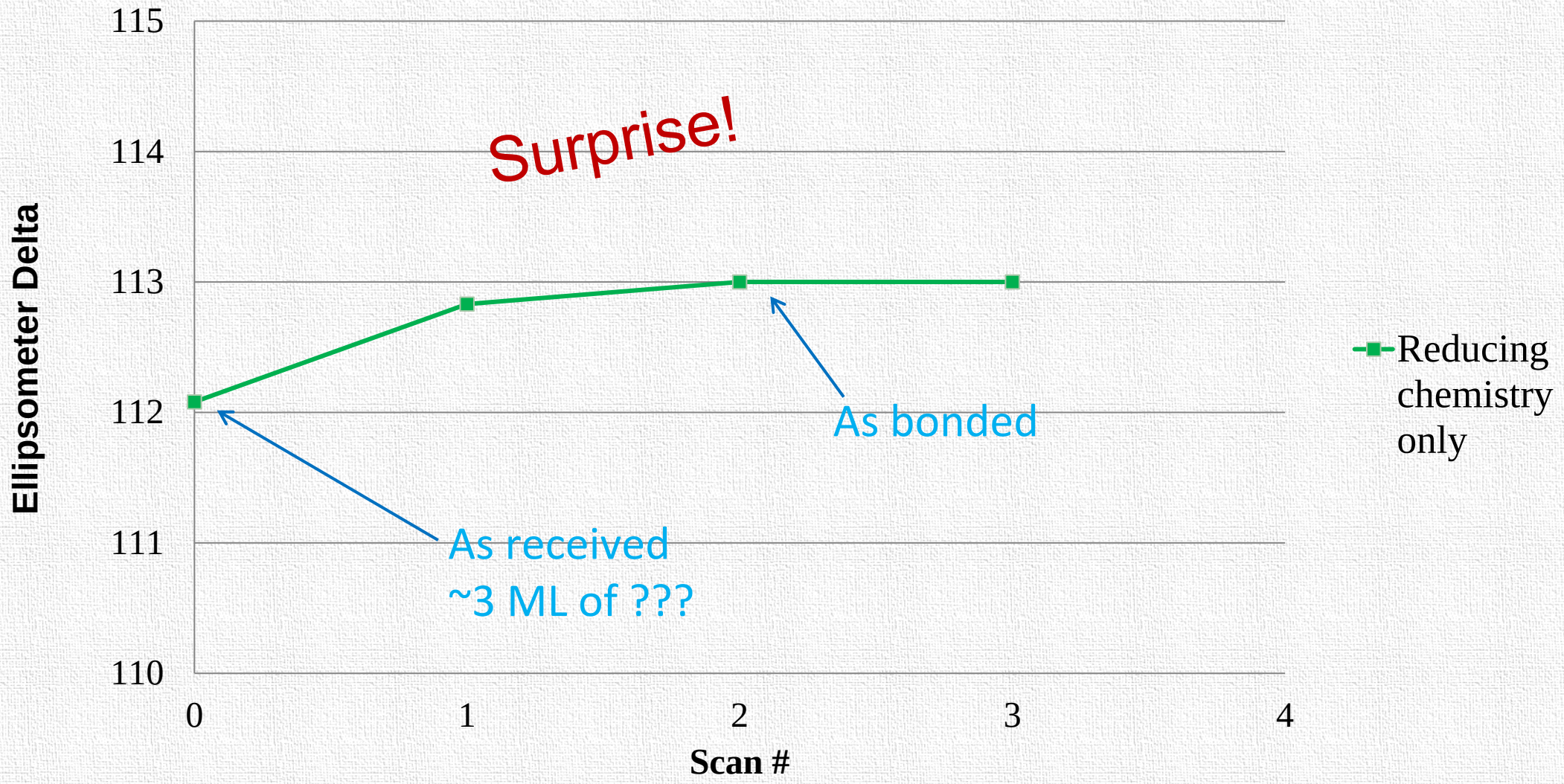


Figure 2 – 200°C Gold-to-Gold bonding after ONTOS atmospheric surface treatment showed exceptional adhesion.

Gold Response to Ontos Atmospheric Plasma Treatment



Discussion

- Small 1 degree change in Delta corresponds to approximately 2.5~3 monolayers of…?
  - Au_2O_3?
  - Organic residue from previous photoresist liftoff?, dicing protect?
  - Perhaps a monolayer or two of adsorbed H_2O, OH, or general atmosphere organics?
  - Need before/after XPS data.

Whatever the mechanism, Ontos Atmospheric Plasma surface treatment does an excellent job of cleaning and activating the Gold surface for metal-metal Thermo-Compression bonding.

- Since the afore-mentioned tests we have bonded more Gold to Gold samples and have determined the following temperatures for Au-Au bonding:
  - Sputtered or evaporated Gold: As low as 100°C
  - Electroplated Gold: As low as 125°C
  - Electroless Gold: As low as 150°C

Discussion (cont'd)

- Strong Gold to Gold bonding requires sufficient deformation of the Gold to form a continuous (or nearly so) contact "footprint" at the bond interface. This is very difficult to do with continuous Gold layers, because the bond force is distributed across the entire chip surface, which can include high and low spots.
- It is recommended that Gold bumps are patterned on one side or the other to concentrate the bond force and thus achieve decent deformation.
- Practically speaking, you will want to limit the Gold thickness to a few microns, therefore, the Gold bumps should be in the range of 10-20 microns, smaller is better. Space them out by at least 5 microns to allow spreading upon compression. Wider spacing reduces required compression force.
- As seen in the previous slide, the quality of the Gold (contaminant level) is critical to achieving low-temperature bonding. While electroless Gold is tempting to form thicker Gold layers, the quality varies widely, requiring more force and temperature to provide reasonable process margin.
- Nanoporous Gold (Fraunhofer IZM) is an interesting alternative, and shown to benefit from Ontos treatment.