Proceedings

Failure Analysis of Wire Bonding on Strain Gauge Contact Pads using FIB, SEM and Elemental Mapping †

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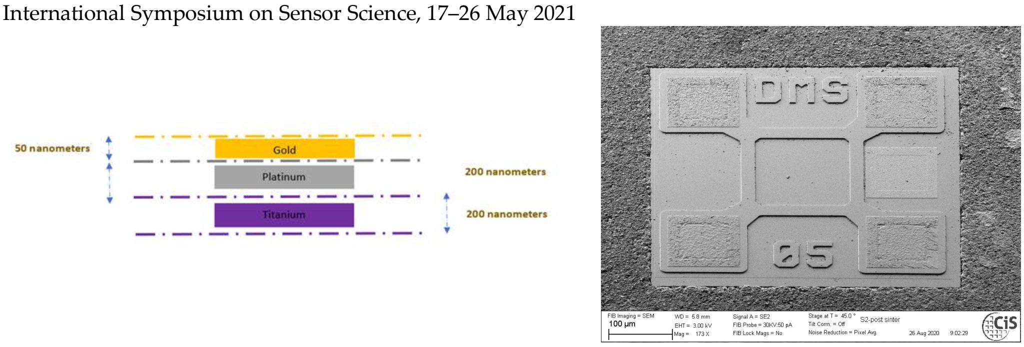
Abstract: Stacks consisting of titanium, platinum, and gold layers constitute a popular metallization system for the bond pads of semiconductor chips. Wire bonding on such layer stacks at dif-ferent temperatures has extensively been investigated in the past. However, reliable information on the bondability of this metallization system after a high-temperature sintering process is still missing. When performing wire bonding after pressure sintering at, e.g., 875 °C, bonding failures may occur that have to be identified and analyzed. In the present study, focused ion beam (FIB), scanning electron microscopy (SEM), and elemental mapping are utilized to characterize the root cause of failure. As probable root cause, infusion of metallization layers is found which causes an agglomerate formation at the interface of approximately 2 µm height difference on strain gauge contact pads and possibly an inhomogeneous mixing of layers as a consequence of the high-temperature sintering process. Potential treatment to tackle this agglomeration with the removal of above-mentioned height difference during the process of contact pad structuring and alternative electrical interconnect methodologies are hereby suggested in this paper.

Keywords: wire bonding; FIB; SEM; metallization system; elemental mapping; sintering

1. Introduction

Traditional mechanical treatment of samples like grinding and polishing for subsequent structure analysis results in deformations and artifacts that make the visualization of the material structure difficult or even impossible [1,2]. Focused ion beam (FIB) tools are a popular alternative for analysis. Three functions are employed when using FIB, which are partial etching, partial metal deposition, and scanning ion/electron microscopy. Partial etching by FIB can be used for cross sectioning on chip contact pads and scanning ion/electron microscopy can be included in in-situ observations as suggested by Kaito et al [3] and applied by Nikawa et al. [4]. In the present study, FIB, SEM and elemental mapping are used for the failure analysis of wire bonding on strain gauge contact pads on a cross section of almost 10 μm^2.

The 500 µm × 500 µm × 15 µm strain gauge with five contact pads is realized on silicon on insulator. Four wire-bondable contact pads are placed at the corner edges while the fifth pad is located on the insulator between two corner edge contact pads. The structure of the wire-bondable pads consisting of Ti/Pt/Au stacks is illustrated in Figure 1. The strain gauge itself is completely integrated within ceramic by pressure sintering at 875 °C.



(**a**) (**b**)

Figure 1. (**a**) Metallization stacks of the contact pads at corner edges; (**b**) Strain gauge integrated within ceramic**.**

Almost 100% failure of Au and Al wire bonding was observed on the wire-bondable corner contact pads with a non-adhesive behavior of ball and wedge bonds. Varying the bonding parameters such as ultrasonic time, power, and bond force did not yield sufficient bond strength to stick. Both optical and SEM inspections showed no obvious barrier at the surface of the contact pads during the bonding process. Therefore, the bonding process itself was excluded as a primary factor, and the contact pads of the strain gauge were presumed of being the reason for failure.

2. Method and Materials

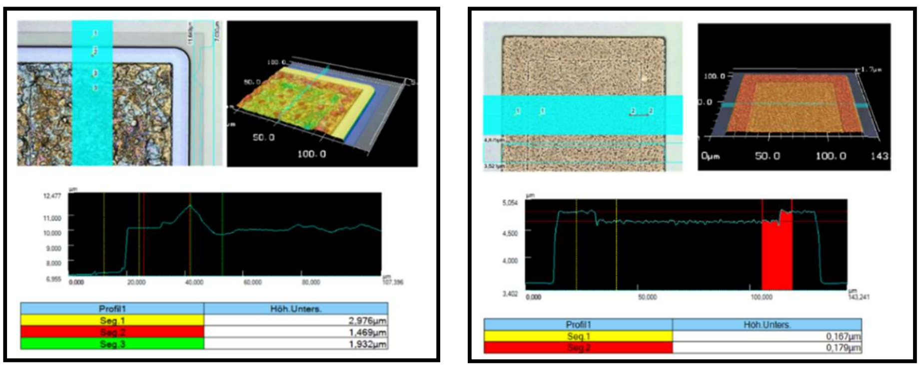
For the investigation of the underlying cause of the failure, we began the SEM and EDX analysis in combination with the elemental mapping. Laser microscope profilometry using a Keyence 3D confocal microscope (model VK–X 200) has been performed in order to observe the surface topology of the contact pads.

2.1. Contact Pads at Corner Edges

The corner contact pads have been structured in a way that the corner edges have a predefined height difference of 1.932 µm. This height difference is probably due to the various etching steps for contact pads structuring, which is not straightforward to control.

2.2. Contact Pads on Insulator

Laser profilometry yielded a height difference of 0.179 µm for the contact pad on insulator. This is insignificant compared to the height difference of the corner contact pads. Therefore, we investigated this corner pad height difference at the interface, considering the earlier mentioned fact that there was no apparent sign of any obvious barrier or oxide formation at the surface of contact pads.

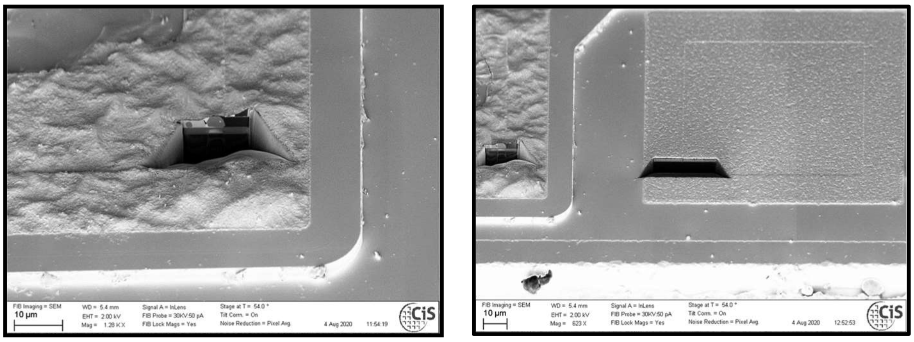


(**a**) (**b**)

Figure 2. (**a**) Laser profilometry on corner contact pads; (**b**) Laser profilometry on centre contact pad**.**

2.3. FIB Cross-Sectioning and SEM/EDX Analysis

To study the interface height difference, a cross sectioning is performed on a 10 µm² area on both contact pads. Since it is critical to perform the cross sectioning by mechanical grinding and polishing (pads will be damaged or peeled during the process), a precise cross sectioning using FIB is performed. Because of the conductivity of the Au on top of the pad, charging effect during the FIB process could be avoided without dispensing conductive material [5]. A coarse chemically enhanced etching with fine milling was performed using 2.0 KeV Ar+ ion beam milling with a IM 4000 system. Finally, the cross section was fine-polished using a low current [6].



(**a**) (**b**)

Figure 3. (**a**) FIB cross section at corner contact pad; (**b**) FIB cross section at centre contact pad**.**

2.4. Combined EDX Analysis

Combining a SEM image and EDX elemental mapping provides a unique analytical perspective for determining the exact composition. Cross-sectioned bond pads were analyzed by a Hitachi S-4100 setup and elemental mapping was done at 0.5–3.5 KeV to accurately determine the composition at the focussed SEM image. Four corner pads were studied at a total of 16 locations by cross sectioning right at the height difference interface.

3. Results and Discussions

For the corner contact pads, at the intersection of 1.932 µm height difference a metallic alloy agglomerate formation was observed as illustrated in Figure 4. It appears that the high temperature sintering at 875 °C forces Ti, Pt and Au to move at the interface leading to an agglomerate. This alloy formation leads to an altering pad morphology, that ultimately adds to the surface roughness and may affect the wire bond adhesiveness [7].

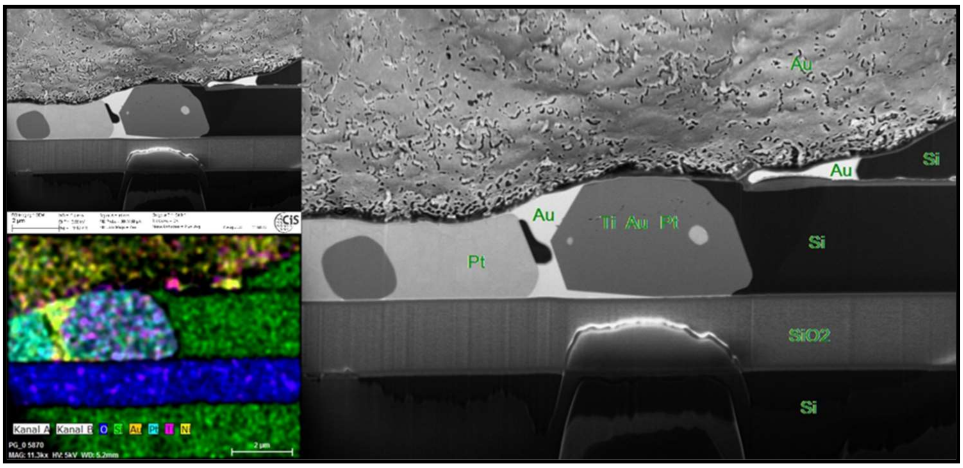


Figure 4. Agglomerate formation on edge contact pads at the interface**.**

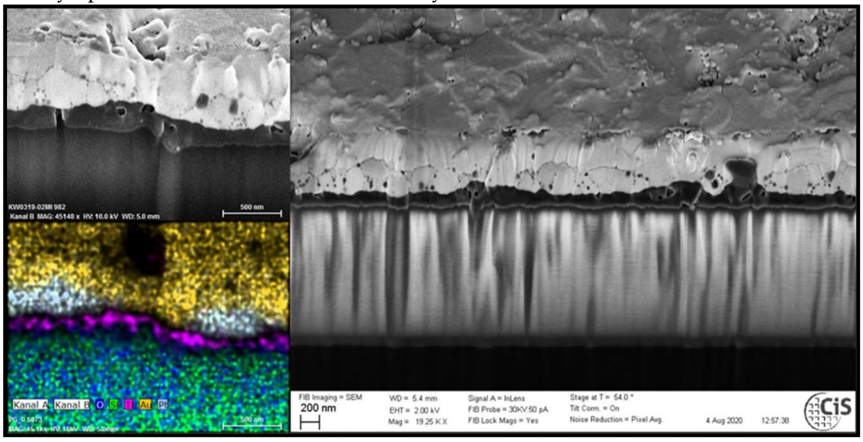


Figure 5. Segregated metallization layers on contact pad on insulator**.**

A significantly different situation is observed for the contact pad on insulator. Here, the 3 metal layers are segregated in between each other, and a more uniform metallization is realized even after firing at high temperature.

4. Conclusion

FIB, SEM, and EDX analysis showed that the likely mechanism for Au and Al wire bond failure problem could be the metallic alloy agglomerate formation underneath the contact pads due to infusion. To confirm the failure mechanism, further experimentation is deemed necessary. An alternative to overcome this problem can be to make these metallization layers flatter during structuring or add an additional Au metal layer at the top in order to suppress the negative impact of agglomerate formation at bottom. Possibly screen printing can be investigated as alternative electrical interconnect methodology.

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Conflicts of Interest: The authors declare no conflict of interest.

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