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Differences in intermetallic phase growth in thermally aged alloyed gold bond interconnections on aluminium

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In microelectronics in many cases microchips are connected to their periphery by wire bond contacts. Common material combinations are gold wires, which are bonded on an aluminium metallization. In this case thermosonic wire bonding is used as the welding technique.

Elevated temperature during device operation causes accelerated interdiffusion of Au and Al at the bonded interface which leads to the formation of up to five intermetallic phases. Especially phases rich of gold ($AlAu_4$, Al_3Au_8) are relatively brittle and prone to chemical corrosion and oxidation processes due to the intrusion of impurities e.g. from the package. Additionally, mechanical shocks degrade the interconnection that may finally lead to a ball lift-off and failure of the whole device. To slow down the growth of vulnerable phases, wire manufacturers successfully add alloying elements to their gold wires. Although this has been applied for several years, the responsible mechanisms behind improved performance have not yet been explained in detail.

In the literature the formation of a diffusion barrier exhibiting a higher content of the alloying elements is commonly stated [1,2,3]. The present work aims at clarifying whether this is a matter of precipitation due to supersaturation or if solid-solutions are formed. Furthermore, the growth of ternary phases must not be disregarded. For this purpose, thermally aged ball bond contacts made of three different gold wire types are investigated. In comparison to a 4N Au reference wire (Wire A) a high reliability Au wire alloyed with ~1% Pd (Wire B) and an ultimate reliability wire alloyed with ~1% Pt and Cu (Wire C) are investigated.

Basically, STEM-EDS mappings of the reaction zone visualize the local distribution of the alloying elements. Electron backscatter diffraction (EBSD) was conducted to gain a general understanding of the different intermetallic phase growth processes with each wire type. For the EDS investigations a FEI Titan G3, equipped with a Super-X EDS detector system was used. TEM samples were prepared using an insitu lift-out technique within a Ga^+ FIB [4]. For EBSD measurements a ZEISS Supra 55VP equipped with a DIGIVIEW III detector was applied.

Figure 1 shows EBSD grain structure maps of the bond interface. Samples were thermally aged at 150°C for 500h. The different intermetallic Au-Al phases are colour coded. It can be seen, that with Wire A the intermetallic phase growth is already completed. Almost only the gold rich $AlAu_4$ is present. The EBSD map of Wire B shows a similar result with slightly more of Al_3Au_8, which is located between the gold ball and the $AlAu_4$ phase and at the border. Nevertheless, the intermetallic phase growth with Wire B is nearly completed. Compared to the previous results, using Wire C the intermetallic phase area contains much more of the Al_3Au_8 phase and a smaller amount of $AlAu_4$ located in contact to the gold ball. $AlAu_2$ is located at the outer rim. This means that until aging for 500h the intermetallic growth is not complete. Besides, there are incorrectly assigned grains below the gold ball. These gave rise for further TEM/STEM investigations.

Element maps of Wire B generated by STEM-EDS show distinct grains which are found to belong to a ternary phase with composition $Al_3Au_5Pd_2$ (Figure 2). Similar investigations of a Wire C sample show a thin layer containing grains with increased Cu content near the gold ball (Figure 3). Within this layer precipitates of Pt are visible at the grain boundaries.

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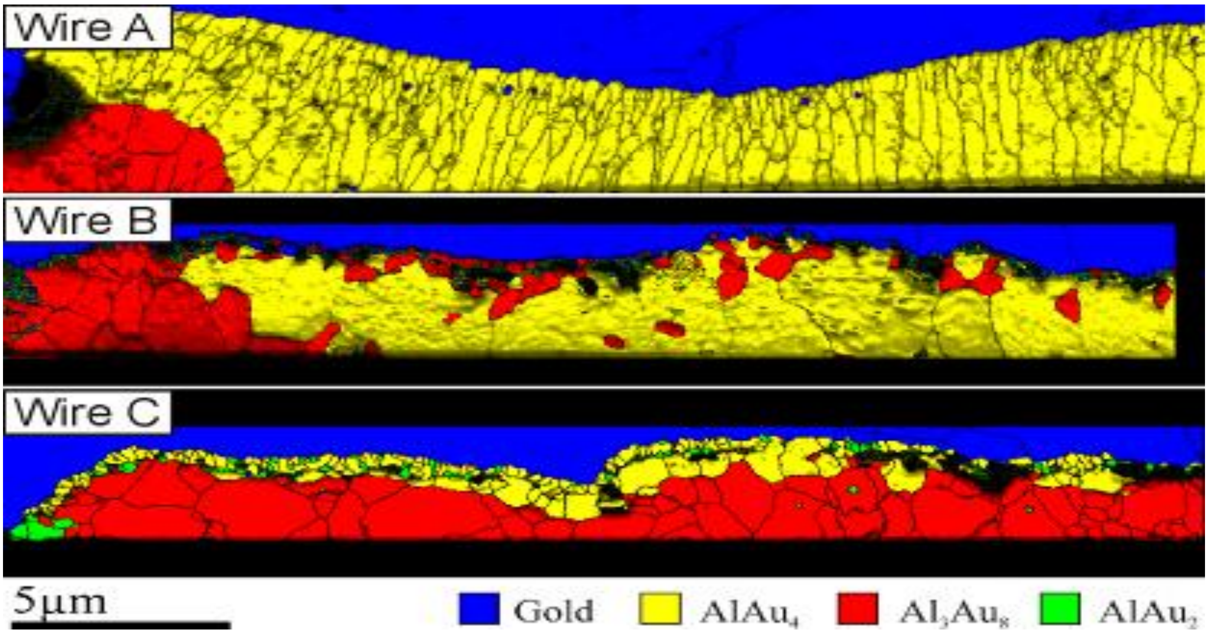

Figure 1. EBSD grain structure maps showing local phase distribution of the three wires after 500h of annealing at 150°C

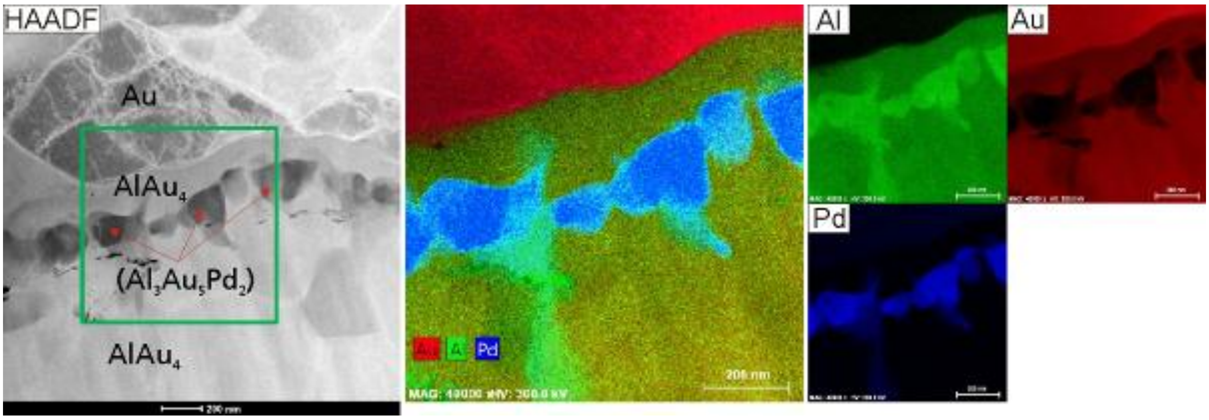

Figure 2. STEM-EDS investigation of a Wire B bond contact after annealing for 500h at 150°C

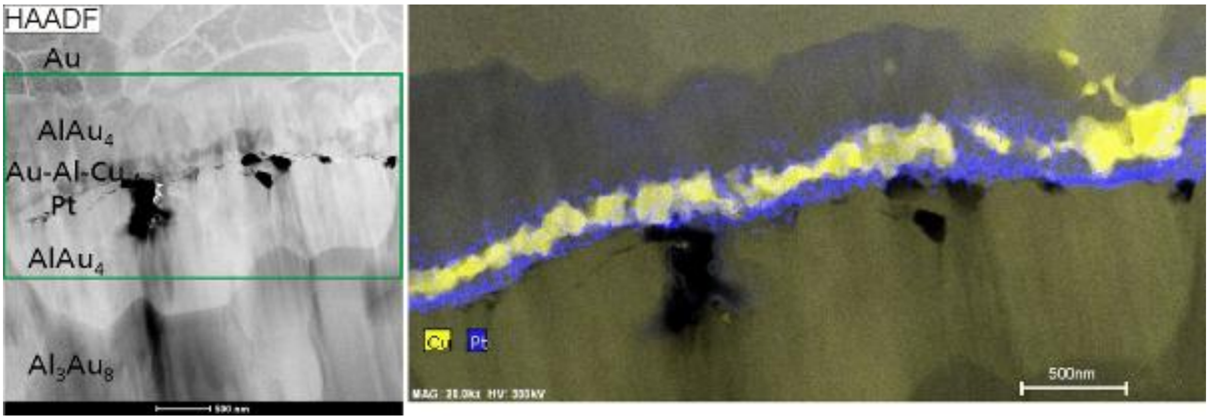

Figure 3. STEM-EDS investigation of a Wire C bond contact after annealing for 500h at 150°C