Development of the Aluminium Hybrid Bonding

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Aluminium-to-aluminium (Al–Al) direct bonding offers a CMOS compatible alternative to gold (Au–Au) and copper (Cu–Cu) bonding, avoiding metal cross-contamination in semiconductor process lines. While Au and Cu bonding benefit from negligible or controllable oxide formation, aluminium rapidly forms a native oxide upon air exposure, posing significant challenges for low-temperature bonding. Overcoming this limitation would enable heterogeneous integration of diverse sensors directly onto CMOS wafers.

Efforts have been made towards homogeneous and low temperature bonding with Al-Al surfaces. For instance, an EVG® 580 ComBond® tool (developed by EV Group), which enables low temperature (~ 100 °C to 150 °C) bonding under a high vacuum between two metal surfaces [1]. However, it has not yet demonstrated a hybrid bonding approach with this tool using a combination of dielectric and metal materials. Another bonding approach utilised a thin passivation layer made of titanium (Ti) and Palladium (Pd) [2]. Metals enable good adhesion to Al and have been used as bonding interfaces to overcome oxide formation at the Al interface [3-4]. The next approach, native oxide layer passivation using the plasma process, has been investigated to delay the oxide formation on the Al surface and thus establish the Al-Al bond [5].

In this work, we present key processes for aluminium hybrid bonding, including aluminium electroplating in variable via sizes, surface oxide removal and passivation, along with preliminary studies of Chemical Mechanical Planarization of Aluminium vias (see Figure 1). The studies will allow metallic bonding to be achieved at temperatures below 300 °C under ambient conditions, demonstrating the feasibility of aluminium hybrid bonding for CMOS-compatible sensor integration.

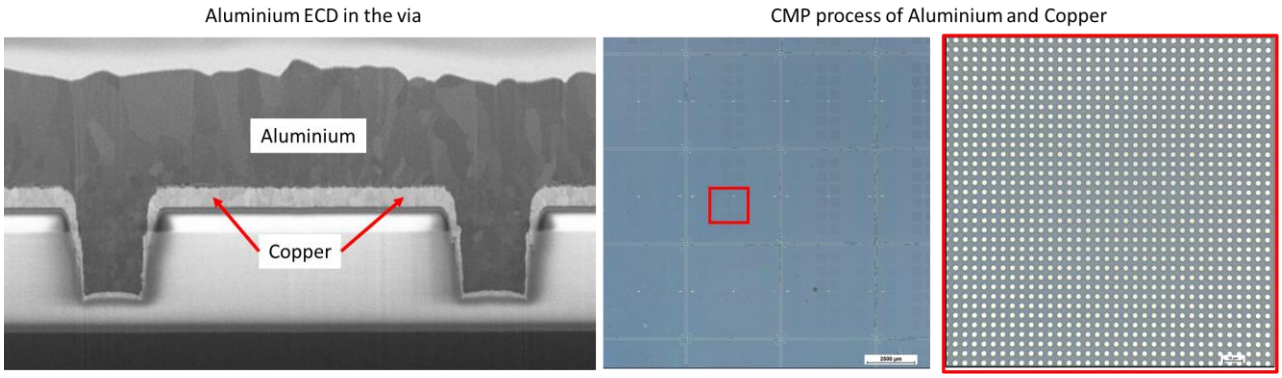

Figure 1 Aluminium electrochemical deposition (left) and Aluminium and Copper Chemical Mechanical Planarization

References

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