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New Generalized Method for the TEM Examination of Buried Interfaces with Application to the Copper Bond Wire – Aluminum Pad System

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For more than forty years the electrical connection between IC packages and the silicon device has been accomplished by means of gold bond wires. In the past five years, the industry has been moving rapidly to replace this well understood but expensive metallurgical solution with a lower cost alternative, i. e. copper bond wires. This change is a major one and a full understanding of the reaction kinetics and intermetallic phase formation is of considerable interest. The principle difficulty(s) in the examination of the reaction products are: 1) the small feature size (sub-micron) 2) the unfavorable mechanical [1] polishing characteristics 3) the need for quantified phase identification on the nanometer scale**.** All of these difficulties point to Transmission Electron Microscopy as the most comprehensive analytical method. Because Focused Ion Beam (FIB) avoids the problem of sample damage introduced by mechanical polishing, it is the specimen preparation technique of choice. However, the bonding pad is at least 4X larger than the nominal 20 micron size of most FIB samples. Additionally, the interface of interest is a buried one, some tens of microns into the pad and covered by essentially an infinitely thick copper wire. Using a conventional FIB to prepare TEM samples from such a buried interface would involve multiple hours. In addition, FIB cross-sectioning the wire ball bond suffers from severe curtaining or waterfall effect. Such a lengthy time for specimen preparation is clearly undesirable, and has been one of the motivations for the development (JHT Instruments) of a new high current, plasma-based, ion beam source [2] which has a milling rate at least 10X of the more conventional Gallium beams.
Recognizing that conventional metallography exposes the buried interface of interest, we thought to apply the FIB lift out technique normal to the plane of polish, thus extracting a damage-free section deep within the buried structure. The main reason(s) to make these sections is to look for defects such as voiding, cracking, and the extent of intermetallic compound (IMC) formation as well as elemental analysis post reliability stress. However, the unambiguous identification of such defects from the polished cross section is difficult due to the highly ductile nature of the parent metals (very pure Cu and Al). These metals are prone to smearing [1] and the polished cross section does not lend itself to phase identification, though it does seem reasonable to expect that Electron Backscattered Diffraction (EBSD), could be applied to the phase ID problem, at least in principle. Additionally, there is a very recent publication [3] in which outstanding metallographic cross sections of the Cu wire – Al bond pad interface are presented . Unfortunately, the authors we not at liberty to disclose the proprietary chemistry and techniques used in their method. Previous TEM studies of the Cu-Al interface using “Wedge Polishing” have been reported at well (3). Our method, which we feel is general for all buried interfaces, uses conventional metallographic to expose the interface of interest and then applies the FIB lift

out technique [4] to extract a damage-free TEM sample which is well suited for site-specific TEM EDS for stoichiometry and nanobeam diffraction for phase ID.
Figure 1 shows the as-polished metallographic cross section with the FIB cut. This figure demonstrates that it is possible to prepare a TEM sample some 40 microns into a buried interface. Figure 2 shows the beneficial effect of FIB preparation for the examination of the Cu wire – Al pad interface. The presence of interfacial voids and extensive intermetallic compound formation is unambigouous. Figure 3 is the bright field image of the 400hr 150C anneal sample. Nearly all the bond pad Al has been converted to IMC. Figure 4 is the EDS spectra of the IMC. Standard less quantification of these spectra indicates an IMC composition of Cu_2Al_3.

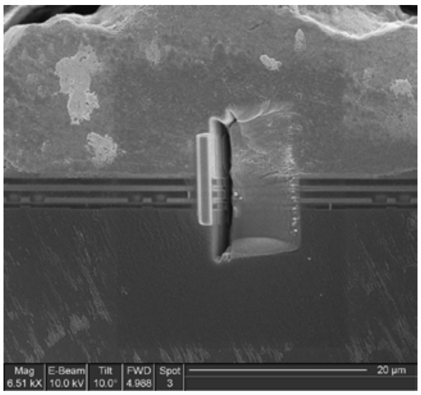

Figure 1 Polished XC with FIB cut

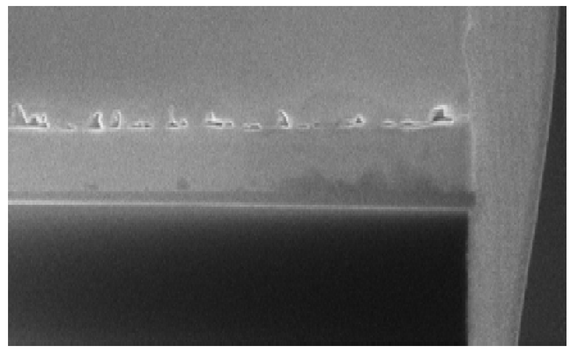
Figure 2 Voids at Cu-IMC interface

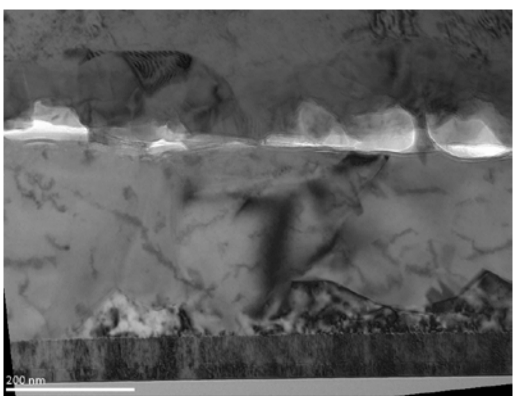

Figure 3 Bright Field image of IMC

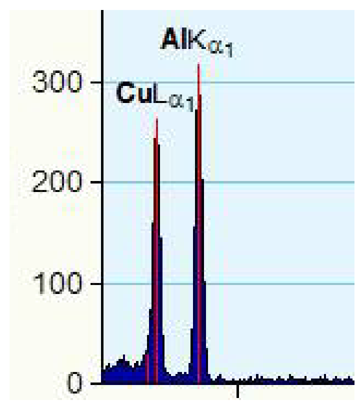

Figure 4 STEM/EDS spectra of IMC

In this paper we present a simple extension of conventional metallography and the FIB lift out method which enables TEM samples to be prepared in a straightforward manner to examine buried interfaces by TEM. This method was applied successfully to study IMC formation at the Cu-Al bond pad interface. Following a 400hr anneal at 150C, nearly all the Al was consumed during the formation of the intermetallic phase. TEM EDS analysis suggests the stoichiometry of this phase to be Cu_2Al_3.

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