In situ Observation of Voiding in Aluminum Metallization by High Voltage Electron Microscopy

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So called stress-induced voiding in Al metallization, occurring in the passivation film deposition process and the ceramic packaging glass sealing process, is a serious problem in LSI fabrication. Although several mechanisms for voiding were proposed[1-4], no appropriate mechanism for it has yet been determined.

In situ observation of voiding is one of the effective approaches to clarifying the voiding mechanism. Only one paper concerning it was published, where optical microscopy was used in the in situ observation of voiding for wide (7 µm and 20 µm wide) Al-1% Si metallization[9]. Although void volume as a function of time was determined by the in situ observation, no information regarding the initial stage of void growth and effects of grain boundaries on voiding were obtained, because of limitations in resolution and functions inherent in an optical microscope.

The authors have made in situ observation of voiding in fine (~1 µm wide) Al metallization using high-voltage electron microscopy (HVEM) for the first time. This paper reports results obtained by the in situ observation.

Samples used in this experiment consisted of sputtered pure Al metallization and a bilayer of PECVD SiN and PSG for passivation (Fig. 1). The silicon substrate was thinned for HVEM observation. The Al metallization width was ~1 µm, which corresponds to line widths foreseen to be used in near future LSIs. Such a fine Al metallization led to a bamboo structure. HVEM observation was carried out at a 2MV acceleration voltage.

The TEM micrographs, shown in Fig. 2, show typical void growth, observed at ~500°C. From TEM micrographs similar to those shown in Fig. 2, the following conclusions were drawn:
1) There was a tendency for voids to grow along the PSG/Al interfaces at the initial stage in void growth.
2) Initial small voids grew, when they intersected grain boundaries, but they did not grow when they did not intersect grain boundaries.
3) Grain boundary migration, trapping and detrapping at voids occurred.
4) Voids grew linearly with time at the initial stage and then saturated (Fig. 3).

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References
Fig. 1. Cross-sectional diagram of a sample used in HVEM observation.

Fig. 2. TEM micrographs, taken by in situ observation at ~500°C, showing void growth.

Fig. 3. Void area as a function of time. The origin in the time axis was placed at the intersection between the extrapolated experimental curve and the time axis.