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Observation of Inverse Blech Length Effect during Electromigration of Cu Thin Film

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Abstract : Scaling of transistors and, hence, interconnects is very important for the enhanced performance of microelectronic devices. Scaling of devices creates significant complexity, especially in the multilevel interconnect architectures, wherein current crowding occurs at the corners of interconnects. Such a current crowding creates hot-spots at the respective corners, resulting in non-uniform temperature distribution in the interconnect as well. This non-uniform temperature distribution, which is exuberated with continued scaling of devices, creates a temperature gradient in the interconnect. In particular, the increased current density at corners and the associated temperature rise due to Joule heating accelerate the electromigration induced failures in interconnects, especially at corners. This has been the classic reliability issue associated with metallic interconnects. Herein, it is generally understood that electromigration induced damages can be avoided if the length of interconnect is smaller than a critical length, often termed as Blech length. Interestingly, the effect of non-negligible temperature gradients generated at these corners in terms of thermomigration and electromigration-thermomigration coupling has not attracted enough attention. Accordingly, in this work, the interplay between the electromigration and temperature gradient induced mass transport was studied using standard Blech structure. In this particular sample structure, the majority of the current is forcefully directed into the low resistivity metallic film from a high resistivity underlayer film, resulting in current crowding at the edges of the metallic film. In this study, 150 nm thick Cu metallic film was deposited on 30 nm thick W underlayer film in the configuration of Blech structure. Series of Cu thin strips, with lengths of 10, 20, 50, 100, 150 and 200 µm, were fabricated. Current density of $\approx 4 \times 1010$ A/m^2 was passed through Cu and W films at a temperature of 250ºC. Herein, along with expected forward migration of Cu atoms from the cathode to the anode at the cathode end of the Cu film, backward migration from the anode towards the center of Cu film was also observed. Interestingly, smaller length samples consistently showed enhanced migration at the cathode end, thus indicating the existence of inverse Blech length effect in presence of temperature gradient. A finite element based model showing the interplay between electromigration and thermomigration driving forces has been developed to explain this observation.

Keywords : Blech structure, electromigration, temperature gradient, thin films
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