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In Situ TEM Investigation of Electrical Current Effect on Aluminum Interconnect

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Interconnect is a thin wire of copper or aluminum alloy which makes electrical contact between devices, typically on Si substrate. Electro-migration is the phenomenon that metallic atoms are transported by electron wind due to high electrical current density in the metal line. Ever since Blech [1,2] reported a relationship between interconnect length and the rate of electromigration-induced drift, other factors like crystallographic texture [3-6], grain size and its distribution [7-10], and grain boundary structures [8,9,11-14] have been extensively documented to have a major impact on electron-migration induced plasticity. The continuous scaling down in the dimensions of typical integrated circuits leads to increasing electric current density in interconnects lines. Consequently, understanding the exact mechanism and evolution of electrical current effect on interconnect has become critical than ever for designing reliable devices.

When interconnect's dimension shrinks into submiro- and even nano-meter range, it will become electron transparent inside transmission electron microscope. Consequently, in situ TEM will become the best tool for studying the microstructure evolution of interconnects under the effect of electrical current. In this work, we developed a novel method for preparing samples that can be studied in situ inside a TEM under the effect of electrical current. Figure 1 is the schematic for the sample preparation. By employing a Hysitron PI95 ECR type holder, we found that the defects density inside the Al grains can be reduced dramatically by the applied current (Fig. 2) which we termed as electrical annealing [15].

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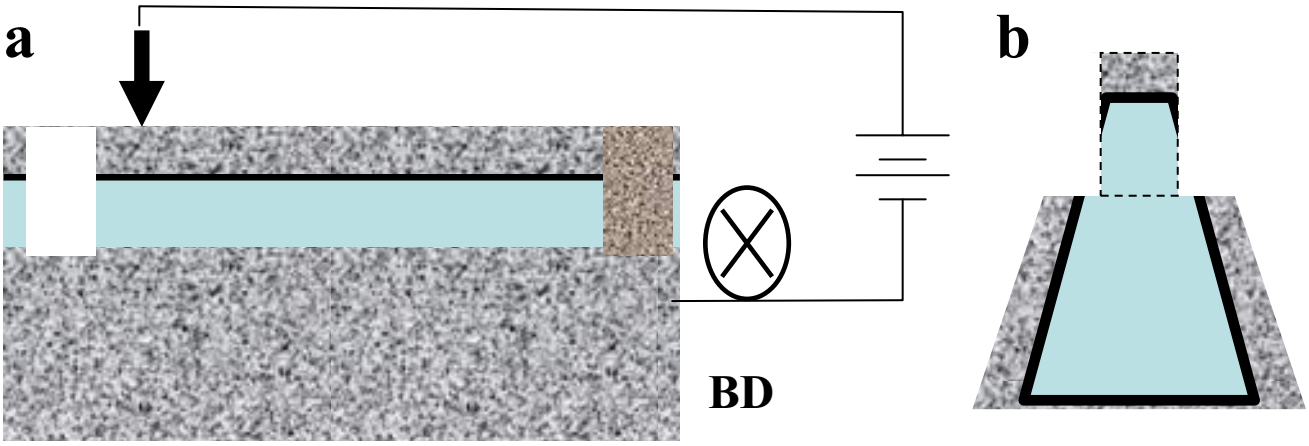

FIG. 1. Schematic of the sample design. a) View from the electron beam direction (BD). The black arrow represents the movable electrical probe; the marble-like, black and azure colors represent the Aluminum, SiO2 and Si, respectively. The Si used has been doped with boron with its conductance less than 0.01 ohm.cm. b) Cross-section view of the sample.

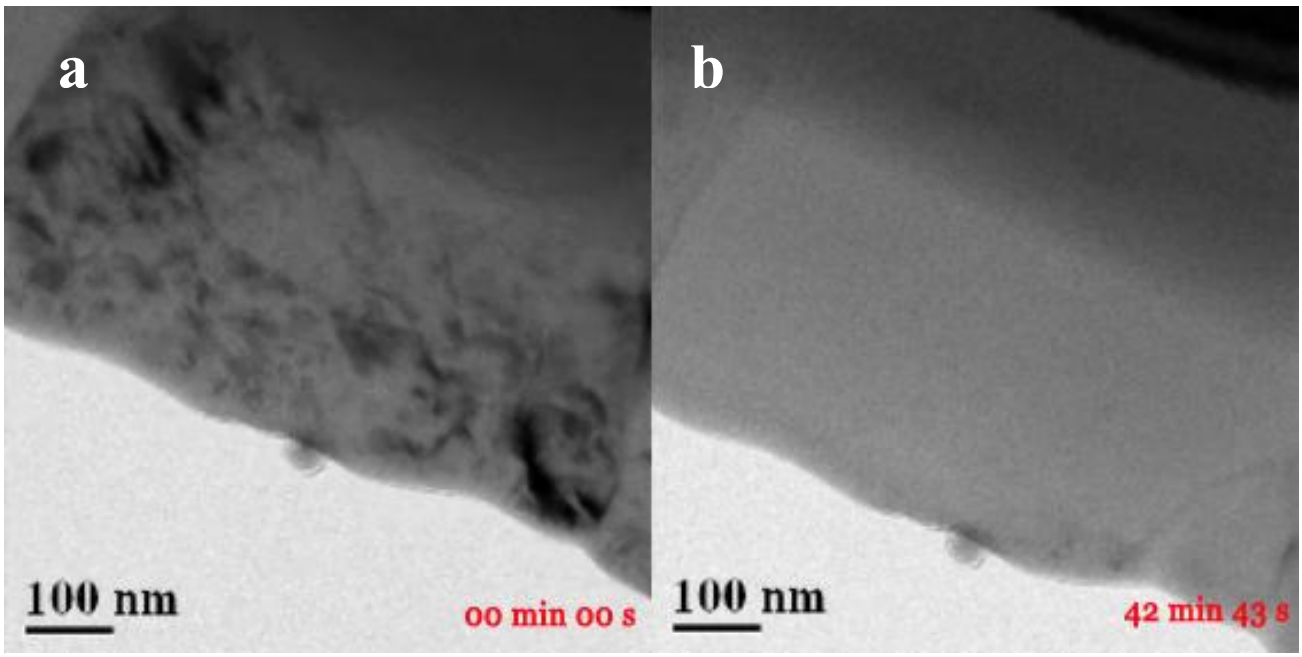

FIG. 2. Bright field TEM images of a Al grain before (a) and after (b) the applied electrical current. The defects density decreased dramatically after the treatment with electron current, a phenomena we have termed as electrical annealing.

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