[II~24] [초청]

Formation of TiN barrier layer by the two-step rapid thermal conversion process for Cu Metallization

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TiN barrier layers have been formed on single-crystalline silicon substrates by thermal conversion of Ti films at various temperatures in an ammonia ambient using rapid thermal process with a sequential two-step temperature cycle. Especially, the first-step temperatures were in the low temperature range of 400 to 450℃ for 60-300 s to minimize the Ti/Si interaction while keeping reasonable interaction of Ti/NH_3 and nitrogen diffusion through the Ti layer for maximizing the thickness of the TiN layer. Then, the second-steps were carried out at relatively high temperatures of 700 to 1000℃ for 5-90 s to reduce the Ti/Si interaction of the silicidation process. By the first-steps of the low temperature process, the sheet resistances increased with annealing time up to 60 s due to deep penetration of nitrogen and its high concentration in the Ti film followed by the saturation at 60-120 s and monotonically decreased beyond 120 s. These sheet resistance increases were dominated by the nitrogen-rich Ti layer formed by the first-steps of long-time nitrogen diffusion. With the second-steps of high temperature process, nitrogen-enriched Ti layers were converted to Ti-rich TiN layers resulting in abrupt decreases in the sheet resistance due to the silicidation, the densification of TiN, and conversion of remaining Ti to the TiN layers. By the two-step rapid thermal conversion process of the 1000 Å Ti layer under the conditions of the long-time nitridation cycle with the optimum thermal conversion condition (first-step: 400℃/90 s ; second-step: 700℃/60 s), we obtained the TiN/$TiSi_2$ bilayers of thickness 700 Å/1500 Å with the TiN thickness ratio of above 30% to the totally converted layer. These results indicated that the thickness ratio of the TiN layer prepared by the two-step process to the totally converted layer doubled compared to that by the one-step process, also providing reduced total thickness of the thermally converted layer.