I 6 (초청강연)

## Feasibilities of TiNx in ULSI fabrication process

### (Formation of the large grain sized TiN layer on $SiO_2$ substrate and the epitaxial C49-$TiSi_2$ formation on (100)Si substrate)

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An investigation of the microstructural evolution of the TiNx, defined as an amorphous-like film consisting of the nanocrystalline Ti and TiN, has been carried out with emphasis on the crystalline nature of the resulting TiN and $TiSi_2$. The TiNx was deposited by reactive sputtering in a mixed ambient of argon and nitrogen. The nitrogen in Ti matrix relaxed the mechanical stress of the deposited film and limited the surface mobility during the deposition process, resulting in a nanocrystalline structure with extremely unform thickness.

After rapid thermal annealing, the TiNx deposited on $SiO_2$ substrate yielded the bilayer structure of TiN/$TiSi_xO_y$, in which the TiN showed (111) preferred texture, extremely smooth surface and large grain size without any columnar structure. In addition, the resistivity of the bilayered TiN was as low as 40 $\mu\Omega \cdot$ cm. In the TiN multilayered aluminum structure (i.e., TiN/Al/TiN), epitaxial continuity and the intermetallic component such as $TiAl_3$ were clearly observed at the aluminum/TiN interface. The multilayered structure showed better endurance against electromigration in comparison with the same structure using the conventional TiN.

The nitrogen atoms in the TiNx film deposited on (100)Si substrate limit the available Ti atoms involved in the reaction with silicon and enhance the nitridation of the film. Hence, the thickness of both an amorphous interlayer or titanium silicide are much thinner than those from pure Ti film after rapid thermal annealing at various temperatures. Upon thermal annealing at above 600 ℃, the TiNx film was divided into the bilayer structure of TiN/C49-$TiSi_2$, in which the thickness of $TiSi_2$ was far thinner and extremely uniform and the overlying TiN was relatively thick and uniform compared with the case of pure Ti. Moreover, the $TiSi_2$ was epitaxially grown on (100)Si substrate with the structural relationship of $[001]TiSi_2 \parallel [011]Si$, $(060)TiSi_2 \parallel (\bar{2}00)Si$, and $(200)TiSi_2 \parallel (0\bar{2}2)Si$. Also, the stable character of the epitaxial C49-$TiSi_2$ suppressed its transformation to C54-$TiSi_2$ even after thermal annealing at 800 ℃. Since the thickness of the $TiSi_2$ from the TiNx was relatively thin ane extremely uniform, the electrical properties of the TiNx contacted shallow junctions were superior to those of the conventional TiN/Ti contacted junctions.