Digest of Tech. Papers The 9th Conf. on Solid State Devices, Tokyo

A—2—2

A NEW MOS PROCESS USING $MoSi_2$ AS A GATE MATERIAL

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For the interconnecting material in LSI, low resistivity, high temperature resistance and capability of fine pattern definition have been more and more required. Refractory metals are generally poor against chemical reagents and oxidizing ambients used in LSI process. From the point of view, we have investigated moylbdenum silicide ($MoSi_2$) as a gate material of MOS LSI. It was revealed that the $MoSi_2$ films had higher conductivity and high oxidation resistance. A high speed ROM was developed using $MoSi_2$ as a gate metal.

$MoSi_2$ films were deposited by planar magnetron type sputtering in Ar ambients. The morphology and structure of $MoSi_2$ film have been investigated with both X-ray and electron diffraction analyses. The as-deposited films were amorphous and the films annealed in range of 800 to 1000°C were poly-crystalline with small grain (few hundred Angstroms). Resistivity of the as-deposited films was 7×10^{-4} ohm-cm and decreased to 1×10^{-4} ohm-cm after high temperature annealing (Resistivity of poly-Si is practically 1×10^{-3} ohm -cm). These were independent of thickness for thickness larger than 500Å. The set of results suggests that the resistivity reduction of $MoSi_2$ film is limited by the grain size.

Auger analysis was used to estimate in depth profiles when $MoSi_2/SiO_2/Si$ structures were both oxidized and diffused with phosphorus and boron. SiO_2 films were formed at the surface by oxidation. The oxidation rates of the films are shown in Fig. 1. The rates as low as that of silicon suggest that the oxidant is blocked by SiO_2 layer formed at the surface. The Auger in-depth profiles in the films oxidized at 1000°C in $POCl_3$ ambients are shown in Fig. 2. PSG formation at the surface are due to oxidation of Si in the $MoSi_2$ films. Molybdenum in the films is also oxidized, however, molybdenum oxide was not observed in the PSG. It is partly vaporized and partly piled up at the PSG/$MoSi_2$ interface, which is confirmed by back-scattering analysis. The masking effect of $MoSi_2$ for boron was also observed.

The $MoSi_2$ gate MOSFETs are fabricated using a conventional MOS process. V_{TH} is plotted against gate oxide thickness in Fig. 3. The work function of $MoSi_2$ was estimated to be 4.8 eV from V_{TH} vs. oxide thickness relationship. Electron and hole mobilities of MOSFETs were nearly the same as those of Si gate ones, respectively. Both in $MoSi_2$ and in Si gate MOSFETs subjected to bias-temperature stress test, the ionic shifts of V_{TH} were not observed but the small non-ionic V_{TH} shifts attributed to injection of electrons into neutral surface states were observed. There is no difference between characteristcs of $MoSi_2$ and Si gate MOSFETs except in work function and resistivity of gate electrode.

A $MoSi_2$ gate n-channel E/D 8k-bit ROM was successfully fabricated. Its access time measured was shown in Fig. 4. It is found that the access time of $MoSi_2$ gate ROM was nearly 30 ns smaller than that of Si gate ROM at the same power dissipation, which is explained in terms of the difference in resistivity between $MoSi_2$ and poly-Si used as interconnection.

$MoSi_2$ was confirmed to be excellent gate and interconnecting materials with the advantages over poly-Si and refractory metals. $MoSi_2$ gate process is also compatible with poly-Si gate process in LSI.

References

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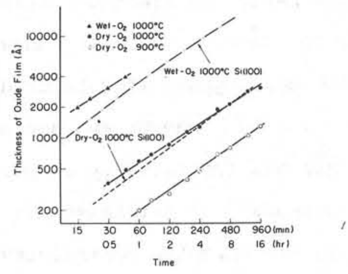

Fig.1. Oxidation rates of $MoSi_2$ films and Si.

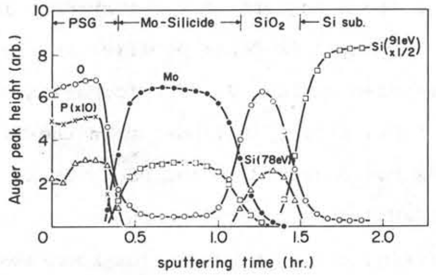

Fig. 2. Auger in-depth profiles of $MoSi_2$ film on SiO_2 after oxidation in $POCl_3$ ambients.

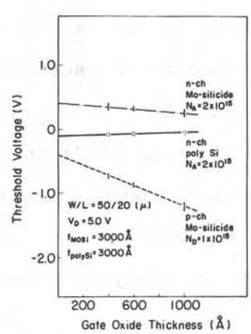

Fig. 3. Threshold voltage V_{TH} of $MoSi_2$ gate MOSFETs vs. gate oxide thickness.

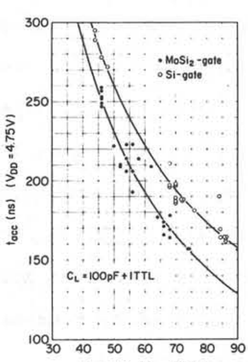

Fig. 4. Access time of $MoSi_2$ gate and Si gate n-channel E/D 8k-bit ROM.