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Changes in Amorphous Molybdenum Disilicide Thin Films Caused by Electrical Current Stressing

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Summary:
We investigated the influence of electrical current on amorphous molybdenum disilicide layers. In our experiments we observed that current stressing causes a change of the layer composition of lines and aluminum electromigration from the contact pads into the top of the test structure.

Keywords: electromigration, molybdenum disilicide, amorphous, thin film, SIMS

Background and Motivation

Molybdenum disilicide ($MoSi_2$) has a high melting point [1] which causes its widespread use in heating devices such as MEMS micro hotplates [2, 3]. Electromigration and diffusion of metals from contact pads into $MoSi_2$ layers and electromigration within a $MoSi_2$ layer have been previously observed [3]. Electromigration in $MoSi_2$ thin films has not yet been investigated in detail. Some findings of electromigration in $MoSi_2$ show the electromigration of aluminum through $MoSi_2$ [4 - 7]. In this study we report findings of electromigration experiments conducted on amorphous lines under test.

Experiments

P-doped silicon wafers with <100> orientation were used as substrates. A thin silicon oxide layer (70nm) was grown using a dry oxidation process with HCl, followed by the deposition of a silicon nitride layer (500 nm) with reduced mechanical stress and a high temperature silicon oxide layer (40 nm) as adhesion layer. Finally, a $MoSi_2$ layer (60 nm) was magnetron sputtered on top of the dielectric layers. The annealing of the $MoSi_2$ layer was performed at 500°C for 60 min in a hydrogen atmosphere, causing the layer to be amorphous. A polycrystalline $MoSi_2$ layer was obtained via heat treatment in nitrogen atmosphere at 500°C for 60 min followed by a treatment at 900°C for 120min. The contact pads were made of aluminum.

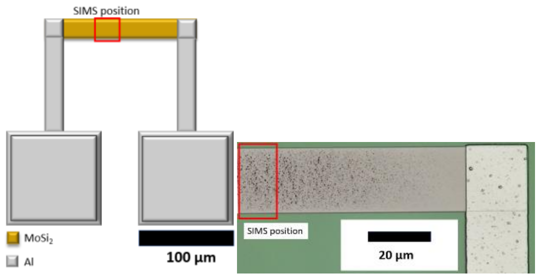

Fig. 1. Schematic of the line under test and light microscopy image of line after test.

The test structure shown in Fig. 1 was stressed with 3.47E+9 A/m² for 7 min under ambient air. The grain structure influences the electromigration [6, 7]. In amorphous $MoSi_2$ the electromigration may exceed the electromigration in polycrystalline lines stressed under higher current densities. Laser scanning microscopy (Keyence VK-X200 series, objective lens CF Plan Apo 150X/ 0,95, wavelength 408 nm) was used to measure the surface of the contact of $MoSi_2$ to aluminum before and after stressing and to determine the volume of the hillocks which is the deviation.

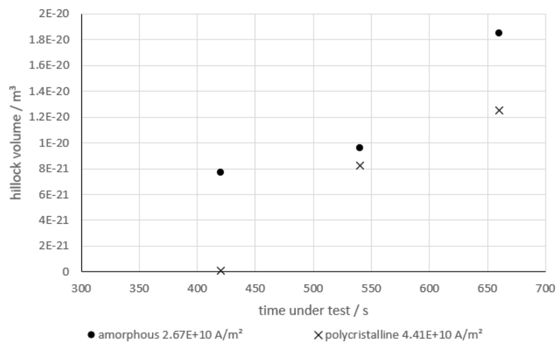

Fig. 2. Comparison of the volume of electromigrated hillocks of polycrystalline and amorphous $MoSi_2$ lines.

Secondary ion mass spectrometry (IMS7f auto by Cameca) was employed to investigate any changes of the test structure caused by stress. The systematic error for signal detection if repeated under same measurement conditions on a homogenous sample is less than 2%.

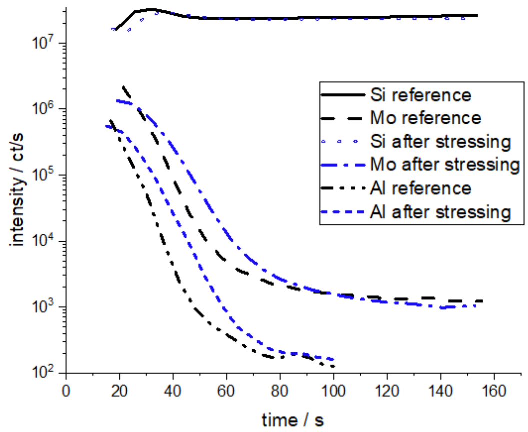

Fig. 3. Intensity of molybdenum, silicon, and aluminum detected via SIMS in ct/s over time in s.

A thin gold film (38 nm) was applied to avoid charging during SIMS analysis. Because of artefacts and the time required to reach the sputter equilibrium, the recorded element profiles of the first ~12 s do not reflect the actual depth profiles and are therefore not shown in the following data graphs.

Results

Fig. 3 shows the measured SIMS profiles of the $MoSi_2$ layer before (reference) and after stress. The Mo profile of the stressed layer is broadened and decreased in intensity at the surface compared to the one of the reference sample, pointing to a change in the contribution of Mo and hence, the Mo/Si ratio in the surface near region due to stress. In the recorded Al profiles, it can be seen, that after stress application the penetration depth of Al in the $MoSi_2$ is increased while its signal intensity at the surface itself remains unchanged, hinting to an accumulation of Al in the $MoSi_2$ layer during stress due to electromigration from the Al contact pads.

Possible falsifications of the SIMS profiles could be caused by inhomogeneities in the chemical composition of the $MoSi_2$ layers that could arise during their production process or by the small diameter (20 µm) of the lines that could lead to SIMS measurements including areas outside of the line of interest. The chosen raster size, apertures as well as egating for the SIMS measurements make the occurance of the later mentioned error source unlikely.

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