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# Influence of Length on the Electromigration of Aluminum through Molybdenum disilicide Thin films

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**Summary:**
The effect of the length of the test structure on the electromigration of aluminum in encapsulated molybdenum disilicide layers has been investigated. Using the same measurement conditions an increase of the electromigrated volume of aluminum through the test structure with an increase of the length of the test structure could be observed.

**Keywords:** electromigration, molybdenum disilicide, thin film

### Background and Motivation

Because of its high melting point molybdenum disilicide ($MoSi_2$) [1] is often used in heating devices such as MEMS micro heaters [2, 3]. Electromigration and diffusion of contact pad materials into $MoSi_2$ and electromigration within the $MoSi_2$ layer can cause device failure [3]. Electromigration in $MoSi_2$ has not been thoroughly been investigated. Some findings show the electromigration of aluminum through $MoSi_2$ [4 - 7] without mentioning influences of the length on the observed electromigrated volume. The length of lines under test influencing the electromigration is well known [8, 9] e.g in the Blech length or short-stripe effect [10] includes a decrease of the electromigration drift velocity with a decrease of the stripe length. During the electromigration the force onto an ion is:

$$\vec{F} = Z^* \cdot e\vec{E} - \Omega \frac{\partial \sigma_{xx}}{\partial x} \qquad (1)$$

wherein $Z^*$ is the effective charge which includes the direction of the exchange of the momentum of the ions, e is the electron charge, Ω is the atomic volume $\sigma_{xx}$ is the normal stress along the sample and x being the coordinate along the sample axis. For F=0 and therefore the mass transport $J_{EM}$=0 the critical product can be derived

$$(lj)_c = \frac{\Omega \, \Delta\sigma_{xx}}{eZ^* \rho} \qquad (2)$$

If the product of length and current density is bigger than $(lj)_c$ electromigration can occur.

The electromigrated volume V and the mass transport $J_{EM}$ are related:

$$V = \Omega J_{EM} At \qquad (3)$$

With A being the cross section of the electro migrating line and t being the time of the electromigration.

### Experiments

P-doped silicon wafers with <100> orientation were used as substrates. A thin silicon oxide layer was grown, followed by the deposition of a silicon nitride layer (500 nm) and a high temperature silicon oxide layer as adhesion layer. On top of this a $MoSi_2$ layer (175 nm) was magnetron sputtered using a stochiometric target. Followed by an annealing process at 1000°C for 30 min in nitrogen atmosphere. This causes the $MoSi_2$ to be predominantly in the tetragonal phase. Different encapsulating layers were deposited using different wafers. All the $MoSi_2$ layers were contacted through an opening of the encapsulating layer with aluminum contact pads.

*Tab. 1: Encapsulating layers*

| Thickness nm | material |
|---|---|
| 20 | High temperature silicon oxide (HTO) |
| 60 | High temperature silicon oxide (HTO) |
| 25 | Plasma enhanced silicon nitride (SixNy) |
| 75 | Plasma enhanced silicon nitride (SixNy) |

A laser scanning microscope (Keyence VK-X200 series, objective lens CF Plan Apo 150X/ 0,95, wavelength 408nm). was used to measure the surface of the contact region of aluminum and $MoSi_2$ before and after current stressing for 7 min under ambient conditions to determine the volume of hillocks grown during the experiment.

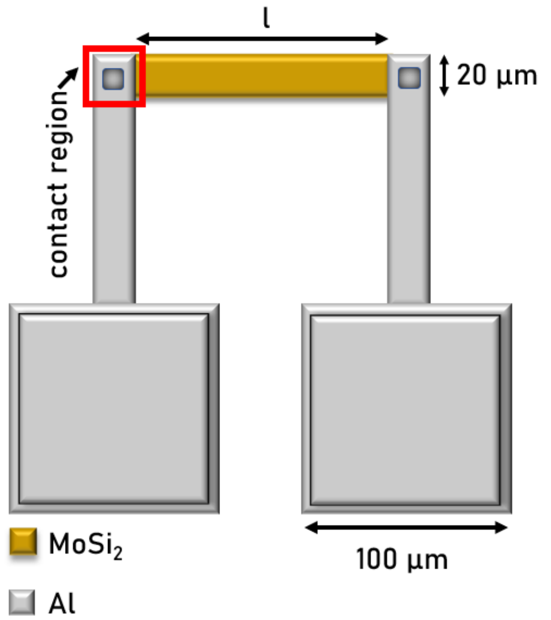


*Fig. 1. Schematic of a line under test.*

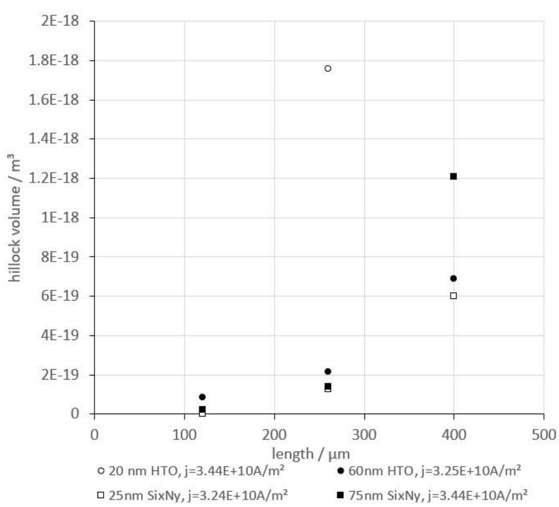


*Fig. 2. Hillock volume dependent on the length of the line under test.*

Similar to historic findings in other metals we observed a decrease of the electromigration with reducing the length of the line under test.

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