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Deformation and fatigue behavior measurement of thin films undergoing thermo-mechanical loading at high strain rates – A novel test setup

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The deformation and fatigue behavior of thin films on substrates undergoing either single or repetitive thermo-mechanical loading has been investigated extensively in the last years due to the high relevance for industrial applications, ranging from cutting tools to microelectronic devices.
A popular method to evaluate the stresses occurring in the thin film during temperature cycling is to measure the change in the curvature of the thin film on the substrate during heating and cooling. From the change in curvature, knowing the elastic constants of the substrate and the film and substrate thickness, the stresses in the film can be calculated using Stoney's formula. Such wafer-curvature measurements are generally conducted at slow heating rates lower than several 10 K/s. This is mainly due to experimental constraints, but also originates in the fact that Stoney's formula is only valid if substrate and thin film have a homogeneous temperature, which will not be the case for high heating rates.
In power semiconductors, short high power pulses cause material heating with rates in the range of 10e5 - 10e6 K/s. It is questionable if the material response at low and high heating rates is comparable, which necessitates the development of methods to monitor the material behavior at heating rates comparable to the ones occurring during usage. Therefore, a new wafer curvature measurement setup has been developed, where the curvature is measured from the reflection of incident parallel laser beams using a high speed camera, allowing much faster data acquisition rates than with conventional cameras. Thin metallization films deposited onto polysilicon and single crystalline Si are heated by Joule heating using a pulse generator allowing to vary pulse shape, length, repetition rate and power. This can be used to vary the heating rate between 10e2 and 10e5 K/s and can be utilized to study the effect of cyclic heating with various temperature amplitudes and frequencies on the metallization behavior. Besides the description of the test setup, an overview on the stress evaluation procedure, necessitating the use of finite element modeling is presented.
Changes in material response are deduced from changes in the stress-temperature behavior of the thin films after either one temperature cycle, or after thermo-mechanical fatiguing. Microstructural and morphological changes in the coatings are investigated using SEM, FIB cross-sections and surface roughness measurements.