Size-effects in time-dependent mechanics of Al-Cu MEMS

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Size-effects in time-dependent mechanics of Al-Cu MEMS

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Abstract

Creep is a time-dependent deformation mechanism that affects the reliability of metallic MEMS [1]. Examples of metallic MEMS are RF-MEMS capacitors/switches, found in wireless/RF applications. The role of size-effects on creep in MEMS is not well understood. This precludes modeling for reliability of MEMS. To have a better understanding, first a novel micro-beam bending methodology is set up to study time-dependent deflection in Al-Cu alloy thin film micro-cantilever beams that are micro-fabricated in the same MEMS fabrication process as actual RF-MEMS devices. Second, measurements are performed where the effect of variations in size on the deflection behavior is studied.

Mechanical characterization of this behavior at the micro-scale is not trivial. Recently a suitable methodology has been developed to measure time-dependent deflections of µm-sized cantilevers [2,3] . A fully mechanical deflection-controlling mechanism is designed, a so-called micro-clamp. Combined with in-situ confocal profilometry, cantilever deflection is precisely controlled and measured. Following a period of prolonged constant deflection, time-dependent deflection recovery is measured once deflected cantilevers are released. Applying digital image correlation and kinematics-based averaging algorithms to the measured surface profiles corrects for various errors and yields a precision of < 7% of the surface roughness. Assuming a visco-elastic model, further analysis is then applied to extract basic quantities describing the deflection recovery behavior. This successful methodology will be briefly discussed.

With this methodology the effect of intrinsic, e.g. grain size, alloy structure, and extrinsic, e.g. structure size, on the deflection recovery behavior is measured. Alloy structure variations are achieved by aging Al-(1wt%)Cu thin metal films at elevated temperatures, whilst grain size variations are revealed using EBSD. First results show a remarkable yet clear trend that micro-cantilevers of aged alloys show more deflection recovery. These will be presented, alongside the effect of grain size. Finally, these insights will be discussed in light of the underlying dislocation and diffusion mechanisms.

[1] Van Spengen, Microelectron. Reliab, 2003

[2] Bergers, etal. Proc. 11th EurosimE, 2010

[3] Bergers, etal. Microelectron.Reliab. (accepted), 2011