Size-effects in time-dependent mechanics in metallic MEMS

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Extended Abstract

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Authors

Name	Company	Author Order	Role	Copyright Received
Dr. Johan P.M. Hoefnagels	Eindhoven University of Technology	1	Contact Presentation and Lead Author	
Lambert I.J.C. Bergers	Eindhoven University of Technology	2	Co-Author	
Norman K.R. Delhey	Eindhoven University of Technology	3	Co-Author	
Marc G.D. Geers	Eindhoven University of Technology	4	Co-Author	

Track: Mechanics of Materials and Structures

Name	Company	Phone & Fax	Role
Prof. Charles Bakis	ESM Department	P:814-865-3178	Track Chair

Topic: 4-3 Multi-Physics of Nanoscale Materials and Interfaces

Name	Company	Phone & Fax	Role
Aman Haque	Penn State University	P:814 865 4248	Topic Chair

Abstract

Reliability of microelectromechanical systems (MEMS) depends a.o. on time-dependent deformation such as creep and fatigue. It is known from literature that this behavior is affected by size-effects: the interaction between microstructural length scales and dimensional length scales. Not much research has focused on characterizing size-effects in time-dependent material behavior, specifically for free-standing thin films. Therefore, this study investigates size-effects caused by grain size and grain statistics in time-dependent deformation in micrometer-sized free-standing aluminum cantilever beams. A numeric-experimental method is employed to determine material parameters. In the experiment, a constant deflection is applied to the micro-beams for a prolonged period. The applied deflection can be controlled with <50 nm resolution via a home-built micro-clamp that allows for in-situ microscopic visualization. The beams are then released. Immediately after, the deformation evolution is recorded by acquiring surface height profiles with a confocal optical profiler. Image correlation of the full-field beam profiles is applied to correct for specimen drift and tilt. The experiment yields the tip deflection as function of time with <3 nm precision. In the numerical part, this data is combined with a finite element model based on a standard-solid material model to extract the material parameters describing the time-dependent behavior. The time constants describing the deflection evolution are determined within 20%, as verified by predicting the time-dependent behavior of micro-beams of different geometry. To investigate the size-effects of grain statistics, orientation imaging microscopy (i.e. EBSD) is employed directly on the free-standing cantilevers. This work correlates the obtained time-dependent material parameters to the actual grain sizes, grain boundary length and texture orientation per specimen. Insights into the interplay between micro-mechanisms and grain characteristics and the effect on the time-dependent material behavior are presented.

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