

On the Micromechanical Characterization of Metallic MEMS by a Hybrid Microtester

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Abstract:

Micromechanical characterization of microelectromechanical systems (MEMS) components allows testing on scales comparable to those of the corresponding applications. The results help investigate the reliability of MEMS devices especially those that are used in vital applications such as life supporting, medical, aerospace or automotive technologies. Size effect clearly influences mechanical properties such as fatigue where surface phenomena play an important role. This is especially true for MEMS reliability exposed to aggressive environments such as humid air or oxygen-bearing atmospheres at ambient and high temperatures. It is known that bulk silicon does not undergo fatigue on macroscale, however, micromechanical tests on small specimens of silicon have clearly shown that moist environment leads to stress-corrosion cracking of silicon caused by moisture in the air. Similar results on nickel MEMS specimens show microcrack initiation and propagation accelerated by oxygen being introduced in the bulk due to the transport phenomena occurring within the slip planes. A newly-developed hybrid micromechanical system combines the advantages of a macroscale slow-action motion mechanism producing large displacements with a small scale fast piezo-driven motion. The main advantage is to study small structures such as thick and thin film developing cracks that travel on millimeter scale during fatigue. The combination of piezo position monitoring with image-recognition-based local deformation

determination allows specification of the beginning of phenomena such as micro-void-induced softening with relative accuracy. Such studies are most useful for investigation of the onset of nucleation of microcracks from fatigue-induced surface flaws. The significance of finding the onset of crack propagation lies in the fact that crack initiation constitutes the major portion of fatigue life for small structures (occasionally up to 99.3%). New advances in materials processing, 3D printing, and new lightweight designs lead to new manufacturing practices that allow the use of thinner-walled structures for load-bearing applications. From metallic foams made of aluminum and copper to 3-D printed thin-walled steel engine blocks micromechanical properties may play an important role. Covetic metallic materials with superior mechanical properties are good candidates for thin walled-3D printed structures and benefit from microtesting in various environments. This paper investigates the use of a hybrid micromechanical testing system in the characterization of mechanical properties of micro-specimens from aluminum and steel at different temperatures and humidity levels in both monotonic and cyclic loading conditions. The results will show the effects of such variables on the initiation and propagation of microcracks that lead to the failure of corresponding MEMS components in fatigue.

Introduction:

Extensive work has been conducted on the mechanical properties of MEMS [1-13]. A comprehensive early work in this field has shown size effect for small samples. Stress