MECHANISMS OF FATIGUE IN POLYSILICON MEMS STRUCTURES

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ABSTRACT
Fatigue crack initiation is shown to be associated with the stress-assisted dissolution of a surface silica layer that forms during the normal exposure of unpassivated polysilicon surfaces to lab air. In-situ atomic force microscopy (AFM) techniques are used to reveal the evolution of overall surface topology during incremental cyclic deformation to failure. Linear perturbation analysis of stress-assisted dissolution is then utilized to predict the evolution of the surface morphology. The predictions from the perturbation analysis are shown to be consistent with measured surface morphologies obtained using AFM techniques.

KEYWORDS
Polysilicon MEMS, fatigue, surface reaction, stress-assisted dissolution, surface topology evolution, linear stability analysis

INTRODUCTION
Micro-Electro-Mechanical Systems (MEMS) fabricated from polysilicon are extensively used in a wide range of applications in which fatigue failure is possible [1-9]. These include applications ranging from accelerometers, actuators and pressure sensors [1,2], in which cyclic loads can ultimately lead to the nucleation and propagation of cracks. Unfortunately, however, the current understanding of fatigue in polysilicon is still limited.

The initial work on the fatigue of silicon MEMS structures was done by Brown and co-workers [3-5]. They obtained stress-life and fatigue crack growth rate data that suggested a strong influence of water vapor on the fatigue of polysilicon. More recently, Kahn et al. [6], Muhlstein et al. [7], Sharpe et al. [8] and Allameh et al. [9] have also reported the result of experimental studies of fatigue in polysilicon. Most of these studies have suggested that the overall fatigue life in polysilicon MEMS is dominated by the crack nucleation stage [3-9].

The paper presents the results of a combined experimental and computational/analytical study of the possible role of surface topology evolution in the nucleation of fatigue cracks in notched polysilicon MEMS structures. Evidence of surface topology evolution obtained from atomic force microscopy is analyzed using Fourier analysis techniques. Evidence of surface topology evolution is presented along with finite element analysis of the notch-tip stress distributions that suggest a strong influence of stress state on the topology evolution. The measured surface