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Surface Topology and Fatigue in Si MEMS Structures


ABSTRACT: This paper presents the results of an experimental study of surface topology evolution that leads to crack nucleation and propagation in silicon MEMS structures. Following an initial description of the un-actuated surface topology and nano-scale microstructure of polysilicon, the micromechanisms of crack nucleation and propagation are elucidated via in-situ atomic force microscopy examination of cyclically actuated comb-drive structures fabricated from polysilicon. It is found that surface of the polycrystalline silicon MEMS undergoes topological changes that lead to elongation of surface features at the highest tensile point on the surface. A smoothing trend is also observed after a critical stress level is reached.

KEYWORDS: Surface, topology, fatigue, Si MEMS, AFM, morphology

Introduction

In recent years, there has been an explosion in the application of Micro Electro Mechanical Systems (MEMS) [1-3]. These include applications in gears, steam engines, accelerometers, hydrostats, linear racks, optical encoders/shutters, and biological sensors in the human body [1-3]. The projected market for MEMS products is estimated to be about $8 billion by the year 2002, and the prognosis for future growth appears to be very strong [3]. Most of the MEMS structures in service have been fabricated from polycrystalline silicon (polysilicon) or single crystal silicon. The reliability of these devices is a strong function of type of loading and environment. Due to the small size of the devices most of the useful life of MEMS devices corresponds with the crack initiation stage. Once a crack is initiated, it rapidly propagates through the device causing failure.

Our current understanding of the micromechanisms of fatigue crack initiation and propagation in silicon MEMS structures is still limited, in spite of the recent rush to apply MEMS structures in a wide range of applications [1-3]. This has stimulated some research activity, especially on single crystal silicon and polycrystalline (polysilicon) [4-13]. The early work on the fatigue of MEMS structures was done by Brown and co-workers [4-7], who developed micro-testers [5, 7] for conducting static/fatigue tests on MEMS structures. Their work demonstrated that stable crack growth can occur in MEMS structures fabricated from polysilicon and single crystal silicon, even though reversed plasticity [16] would not normally be expected to occur in such materials at

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