On the evolution of surface morphology of polysilicon MEMS structures during fatigue

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Received 1 June 2002; received in revised form 4 September 2002

Abstract

This paper presents the results of a combined experimental and computational study of surface topology evolution preceding fatigue crack nucleation in polysilicon MEMS structures. The evolution in surface topology observed during the crack nucleation stage is related to the underlying notch-tip stress distributions calculated using the finite element method. Measured changes in surface topography due to the stress-assisted dissolution of silica are shown to be predicted by a linear stability analysis. The implications of the results are discussed for modeling of fatigue in polysilicon MEMS structures.

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Keywords: Polysilicon MEMS; Fatigue; Surface reaction; Stress-assisted dissolution; Surface topology evolution; Linear stability analysis

1. Introduction

Micro-electro-mechanical systems (MEMS) fabricated from polysilicon are extensively used in a wide range of applications in which fatigue failure is possible. These include applications ranging from accelerometers, actuators and pressure sensors (Wise and Najafi, 1991; Madou, 1997; Togawa, 1997), in which cyclic loads can ultimately lead to the nucleation and propagation of cracks. However, unfortunately there are no existing mechanism-based models for the prediction of fatigue in polysilicon.

The initial work on the fatigue of silicon MEMS structures was done by Brown and co-workers (1992, 1993, 1993, 1997). 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. (1999), Muhlstein et al. (2001), Sharpe et al. (1997), Sharpe and Turner (1999) and Allameh et al. (2000) have also reported the result of experimental studies of fatigue in polysilicon. However, the underlying mechanisms of fatigue crack nucleation and growth in polysilicon MEMS structures are yet to be established.

The paper presents a combined experimental and analytical/computational study of surface topology evolution preceding fatigue crack nucleation in polysilicon MEMS structures. Following a brief description of the material and experimental

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