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ENVIRONMENTAL EFFECTS ON THE MECHANICAL BEHAVIOR OF COVETIC ALUMINUM MEMS COMPONENTS

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ABSTRACT

Covetic aluminum has been researched for its mechanical properties. It has been credited with higher strength in tensile and fatigue loading [1,2]. Modest changes in temperature during tensile testing of covetic aluminum causes significant changes in the ductility and tensile strength. Increasing the temperature from 15 °C to 44 °C causes a decrease in the tensile strength down to 63.8% but an increase in the ductility up to 117% [3]. To further study the environmental effects, microtensile testing was carried out in an environmentally-controlled chamber using a hybrid microtester at high and low relative humidity. MEMS-scale dog-bone shaped specimens with a cross section of 200x250 microns were machined from bulk covetic aluminum using a CNC for milling their contours and a ram-type EDM for detaching them from the work piece. The chamber was purged with gases low or high in moisture maintaining a positive pressure. An Omega sensor-controller unit was used to regulate the temperature and relative humidity of the chamber. The results of the tests show a reduction of ductility at high relative humidity. The implications of the results are discussed in relation to the reliability of MEMS structures.

INTRODUCTION

The maturity of MEMS industry, exhibited by the application of hundreds of MEMS devices in one single modern car, emphasizes the significance of reliability of MEMS components. This is most important when microdevices are used in applications such as biomedical devices, weaponry triggering systems, and monitoring units where lives are at stake [4]. While bulk materials such as silicon may not suffer from cyclic loadings on macroscale, however, this is not true at microscale, and in the presence of water vapor [5-10]. Nickel, on the other hand, is known to resist oxidation at macroscale. This does not hold valid when scale goes down to micro level in fatigue applications [11-14].

PRIOR WORK

Mechanical tests conducted on MEMS and other small structures have clearly established properties of microscale specimens including size effect [15-17]. The leading cause of failure of MEMS-scale specimens has been determined to be stress corrosion cracking (SCC) [5-8], nevertheless, other factors may play a role in the fracture of small components made from materials other than those already tested. At small scale, materials appear to be stronger [15,16]. This enhanced strength have been attributed to several factors among which are microstructure, surface phenomena, density and concentration of natural and geometrically necessary dislocations to mention a few [11-17].

Except for micro- and nano-indentation most mechanical tests conducted so far have included microtensile microfatigue, and microbending in various loading configurations. [1-17]. Metallic MEMS have been tested in tensile and fatigue loading configurations by Shrotriya et al. [15], Lou et al.[17] and Sharpe et al.[18] to mention a few. Non-metallic small structures have been studied by Allameh et al. [7] and Shrotriya et al.[8] among many others. While the role of environment has been explored for

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