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Resonant Bending Fatigue Tests on Thin Films

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The fatigue properties of thin-film materials are extremely important in the design of durable and reliable micro-electromechanical systems (MEMS). However, it is rather difficult to apply the conventional fatigue testing method for bulk materials to thin films as the specimen size is extremely small. Therefore, a fatigue testing method suitable for thin-film materials is required. We have developed a fatigue testing method that uses the resonance of a cantilever-type specimen prepared from thin films. Cantilever beam specimens with dimensions of $3(L) \times 1(W) \times 0.01(t)$ mm^3 were prepared from Ni-P amorphous alloy thin films and gold foils. In addition, cantilever beam specimens with dimensions of $3(L) \times 0.3(W) \times 0.005(t)$ mm^3 were prepared from single-crystal silicon thin films. These specimens were fixed to a holder that was connected to an audio speaker (actuator) and were resonated in the bending mode. The Young's moduli measured from the resonant frequencies of Ni-P and gold foil were 116 and 72 GPa, respectively. These values were comparable to those measured by other techniques, indicating that the specimens resonated in a theoretically predictable manner and that our method is valid. Resonant fatigue tests were carried out for these specimens by changing the amplitude range of resonance, and S-N curves were successfully obtained for Ni-P amorphous alloy thin films, gold foils, and single-crystal silicon thin films.

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