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Measurement of Young's Modulus, Residual Stress, and Air Damping Effect Using Silicon Microstructures

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A novel method of measuring mechanical properties of thin films is presented, where Young's modulus and residual stress are obtained precisely. The method uses two kinds of microbeams, a cantilever structure and a bridge (doubly supported) structure, whose mechanical resonant frequencies are electrically measured. From the cantilever resonant frequency, Young's modulus is derived. Combining Young's modulus and the bridge resonant frequency, residual stress is determined. By applying this technique to heavily boron-doped silicon microbeams, a 1.47×10^{11} Pa Young's modulus and a 3.49×10^7 Pa residual stress are obtained. These values agree well with those obtained using other methods. From the micromechanical beam vibration characteristics, the air damping effect is also evaluated. For the current bridge beam arrangement, the damping coefficient of 0.06 is obtained at 50 Torr.

1. Introduction

Various thin films, such as those of polysilicon, Si, SiO_2, Si_3N_4, and polyimide, have been widely used in a variety of microsensors and microactuators, whose microstructures were fabricated using various microfabrication techniques such as polysilicon surface micromachining, silicon anisotropic etching, and silicon wafer