

# Residual Strain Measurement of Thin Films Using Microfabricated Vernier Gauges

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The design and application of microfabricated vernier gauges for *in-situ* measurements of the average residual strain in thin-film materials are described. The vernier gauges are used to measure the extension or contraction of cantilevers made from the material of interest. Knowledge of residual strain in thin films is especially important for characterizing structural layers in microelectromechanical systems (MEMS). The available precision of microfabricated vernier gauges is considered, and error sources including the effects of film warpage are discussed. Measurements with the vernier gauges, which are mounted on double-cantilever microstructures, are described using examples of phosphorus-doped polycrystalline- and boron-doped monocrystalline-silicon films. Practical examples show that measurements for strain in the  $10^{-4}$  range are feasible.

## 1. Introduction

The design of mechanical structures depends upon characterizing the stress/strain state in these structures under the combined influence of both loading and residual stresses. The values for residual stress/strain are vital, in many cases, for making accurate predictions of the maximum load, the resonant frequencies of