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Integrated tunneling device for high sensitive sensor applications

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Abstract

This paper describes an integrated tunneling sensor for applications of an electronic nose and a scanning probe microscope. Ultra-thin silicon dioxide having a thickness of ~2 nm is used as a material of the tunneling sensor. It provides much higher sensitivity in comparison with others sensing methods. The tunneling sensor is placed on a fixed edge where the maximum strain arises. As additional masses or forces are added to the surface of the cantilever, the thickness of the thin silicon dioxide layer is slightly decreased. By using exponential nature of electron tunneling dominated by the thickness of the silicon dioxide it can be used as an ultra-high sensitive sensor. The thin dioxide is fabricated by dry oxidation using a vertical furnace. The cantilever structures are defined by conventional MEMS technologies. Current density of the tunneling sensor is evaluated as a function of voltage and is compared with numerical analysis based on direct tunneling phenomena.

Introduction

Micromachined cantilevers are of great practical interest in measuring the force, pressure and temperature etc, because the resonant frequency or the vibration amplitude of the cantilever is related to these measurands. Several techniques such as optical lever deflection, interferometery and piezoresistive sensing are used for precise measurement of the mechanical properties of the cantilevers in commercial systems[1-8]. Among them, the optical method using a semiconductor laser is the most popular technique because the technique can detect the cantilever deflection in the sub-angstrom regime. However, all techniques discussed in previous reports have several disadvantages to be used in arrays of cantilevers working in parallel. For example, optical techniques can not be integrated within devices to form a sensor system alone.

In this paper, we have proposed a new concept of a cantilever sensor using a tunneling current which is dominated by a thickness of ultra-thin insulator. It is integrated onto each cantilever arm to measure the deflection of the cantilever beam. An ultra-thin silicon dioxide layer is used as the sensor material which is fabricated by a dry oxidation using a vertical furnace. It offers much higher sensitivity in comparison with other conventional techniques and is very useful for the use of microsensors working in parallel. Important application of an array of the cantilever sensors is an electronic nose that requires a number of detection at a time.

Design and microfabrication of the integrated tunneling device

The use of our proposed tunneling sensor is fundamentally different to the tunneling adopted in general scanning tunneling microscope or in some high resolution tunneling accelerometers. Figure 1 shows the concept of a novel sensor based on tunneling effect proposed in this paper. Generally in