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Tuning the shape and curvature of micromachined cantilevers using multiple plasma treatments

Wang-Shen Su [a], Sheng-Ta Lee [b], Cheng-Yu Lin [b], Ming-Shih Tsai [c], Ming-Chuen Yip [b], Weileun Fang [a,b,*]

[a] MEMS Institute, National Tsing-Hua University, Hsinchu, Taiwan
[b] Power Mechanical Engineering, National Tsing-Hua University, Hsinchu, Taiwan
[c] National Nano Device Laboratory, Hsinchu, Taiwan

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Abstract

This study reports a novel method for tuning the deflection profile of micromachined cantilever by means of multiple plasma surface modification. In short, the shape and curvature of the cantilever can be tuned using the combination of plasma treatments along the beam length and the beam width, respectively. To demonstrate the feasibility of this approach, various NH_3 plasma treatments were employed to tune the deflection profile of cantilevers made of SiO_2 film. The deflection profiles predicted by the simulation and analysis agree with that determined from measurement.

Keywords: Plasma; Cantilever beam; Shape; Curvature

1. Introduction

The mechanical properties of thin film are very critical for the performance of microelectromechanical systems (MEMS). In general, thin films have different mechanical properties from their bulk counterparts. In this regard, the mechanical properties of thin films have attracted lots of attentions [1]. The micromachined devices are generally made from a film that has an internal stress due to its fabrication process. Consequently, when the device is released from its substrate, the internal stress will relax and the device will be deformed [2]. The deflection of micromachined structures resulted from the thin film residual stresses need to be considered for MEMS.

The micromachined cantilever has various applications, for instance, flow sensors [3], microvalves [4], microswitchs [5], and AFM tips [6]. The cantilevers will be bent after the relief of gradient residual stress [7]. On the other hand, it is possible to tune the profile of micromachined cantilever using the thin film residual stresses [8]. Presently, many techniques have been developed to control the thin film residual stresses [9–11]. The most straightforward approach to tune the thin film residual stress by changing the deposition (or growing) conditions. For example, the residual stress of a sputtered film can be altered from tension to compression by varying the film thickness [12]. Another possible approach is to reduce the net residual stresses by depositing compensatory film [13,14].

Plasma treatment for surface cleaning and modifications are widely implemented in semiconductor manufacturing [15]. Plasma treatment techniques for modification on thin films have been extensively studied in [16–22]. It is feasible to exploit the effects of plasma treatments and the changes of surface bonding to tune the mechanical properties of thin film. In this study, the plasma treatment technique has been employed to modulate the residual stress of thin film, so as to tune the shape and curvature of the micromachined cantilever. In application, the variation of the shape and curvature of SiO_2 cantilever for various NH_3 plasma treatments was investigated. The changes of chemical bonding and mechanical properties of SiO_2 after plasma treatment were also characterized by X-ray photoelectron spectroscopy (XPS), secondary ion mass spectrometer (SIMS), scanning electron microscope (SEM), and optical interferometer.

* Corresponding author. Tel.: +886 3 574 2923; fax: +886 3 573 9372.
E-mail address: fang@pme.nthu.edu.tw (W. Fang).

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2. Concept and experiment

The thin film residual stresses can be regarded as the combination of a uniform residual stress σ_0 (either in compression or in tension) and a gradient residual stress σ_1 [12]. For MEMS applications, most of the thin film structures are not bonded to the substrate. Thus, the thin film residual stresses can be relieved through the deformation of these micromechanical structures [12]. The micromachined cantilever will experience a bending moment *M* after release the gradient residual stress σ_1. In [23], the equivalent gradient residual stress is modified using the plasma treatment, so that the radius of curvature of the structure is changed. This characteristic has been employed in this study to tune the shape and curvature of micromachined cantilever.

To demonstrate the present concept, thermal oxide cantilevers were fabricated and then treated with various NH_3 plasmas. The process flow is schematically shown in Fig. 1. In Fig. 1, AA′ and BB′ represent the cross sections along the beam length and beam width, respectively. The 0.8 μm thick SiO_2 film was thermally grown at 1050 °C on the (1 0 0) silicon wafer. The SiO_2 thin film was patterned by photolithography and reactive ion etching (RIE) as shown in Fig. 1(a). The aluminum film was deposited and patterned using the lift-off process in Fig. 1(b). This aluminum film acted as the mask to define the region for

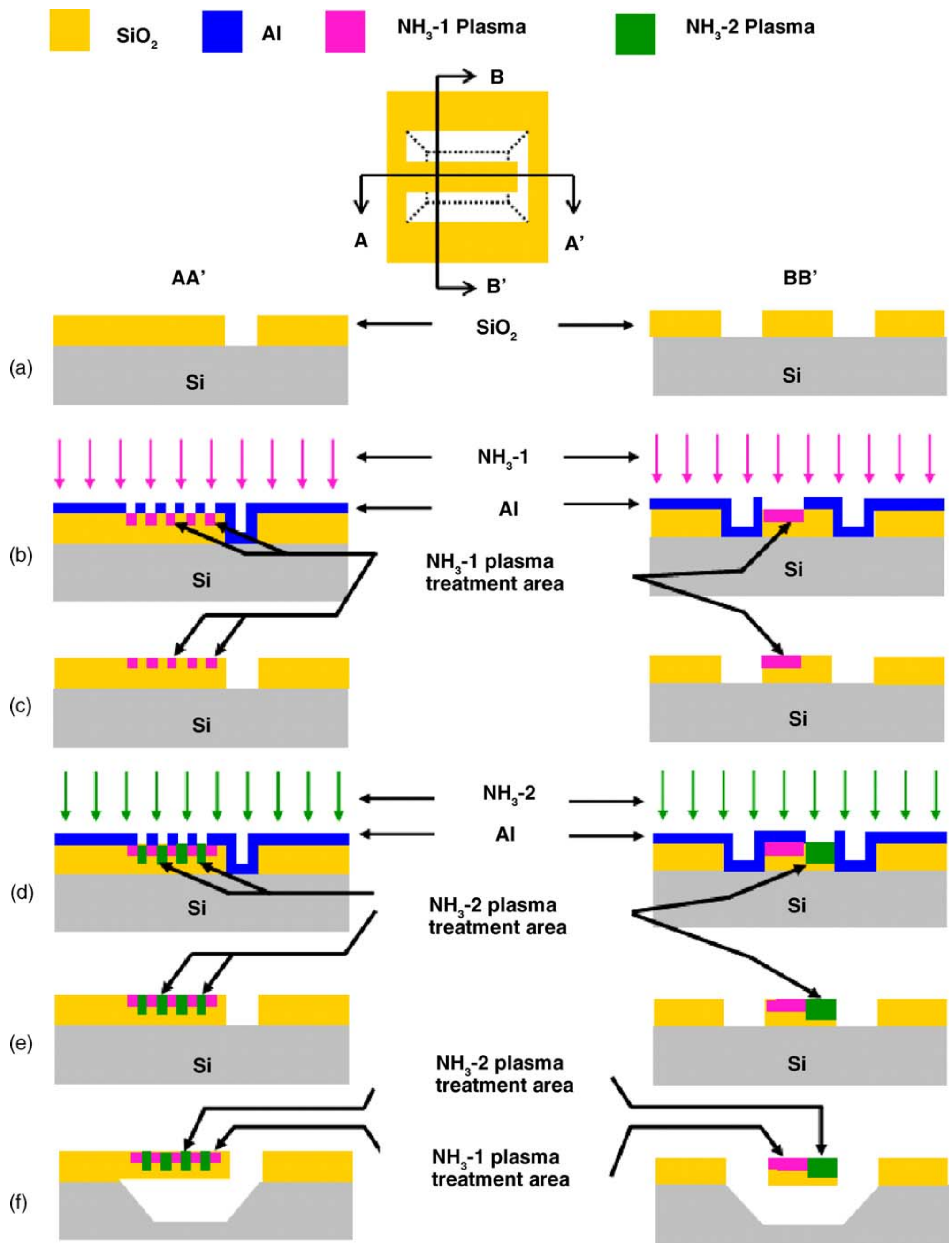

Fig. 1. The present fabrication process steps.