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Superlattices and Microstructures 40 (2006) 161–165
Superlattices and Microstructures
www.elsevier.com/locate/superlattices

Optimal conditions for controllable one-dimensional nanomold by selective etching of multilayer film

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Received 27 March 2006; received in revised form 19 July 2006; accepted 20 July 2006
Available online 17 August 2006

Abstract

Nanomold is the most important part for the nanoimprint technique which determines the obtained feature size. We prepared relievo nanomolds by selectively etching of the a-Si/SiN_x multilayer thin-film deposited by a PECVD system. SEM results showed that the mold feature sizes were controllable on the nanometer scale and the structures depended on the conditions of the film preparation and the following etching process. Ultrasonic processing and short etching time are necessary to get the desired patterns of good quality by the chemically selective etching process, especially for strips thinner than 20 nm. The substrate surface morphology also affects the mold structures greatly.

Keywords: Nanomold; Multilayer deposition technique; Selective etching

Nanoimprint is a promising technique for the fabrication of ordered patterns with resolutions beyond conventional photolithography [1,2]. In the nanoimprint technique the central step is to prepare a high-quality mold with the desired feature size, which usually is fabricated by photolithography or electron beam lithography [3,4]. In practice these procedures still involve a lift-off step, which will cause defects in the structure especially when the feature size is under 50 nm. Melosh et al. used a superlattice to prepare the mold, and ultrahigh-density structures were obtained [5]. But the deposition system is complex and expensive, which limits applications. Fabrication of a-Si/SiN_x multilayer film in a PECVD system is a simple process and the thickness

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0749-6036/$ - see front matter
doi:10.1016/j.spmi.2006.07.011

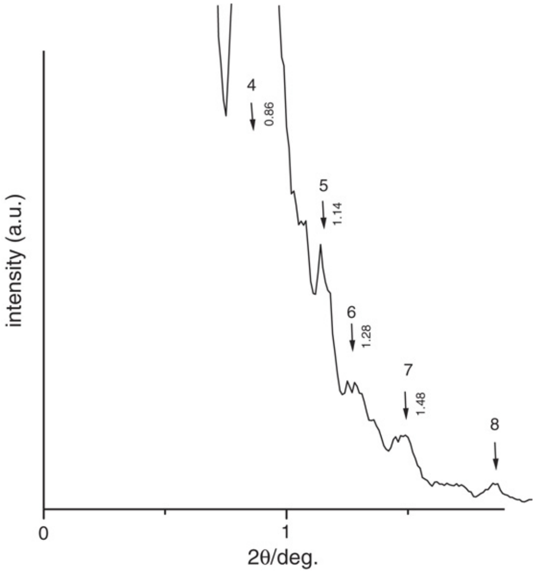

Fig. 1. SAXRD measurement for the multilayer a-Si/SiN_x (20 nm/20 nm).

of sublayers can be controlled easily. Moreover, the mechanical strength of SiN_x promises suitable applications [6]. In this paper we prepared nanomolds based on a multilayer thin-film deposition technique, in which the relievo one-dimensional mold was obtained by selective etching of the cleaved cross-section of a-Si/SiN_x multilayer film. By changing the experimental parameters the optimal etching condition was obtained. The a-Si/SiN_x multilayer thin film is deposited in a PECVD system. The a-Si:H sublayers are deposited with a reactive gas of pure silane (SiH_4) and the SiN_x sublayers with mixing gases of SiH_4 and NH_3.

The film is deposited on the Si substrate at 250 °C. The deposition rate is 0.1 nm/s under a total reaction pressure of 16 Pa and r.f. power 30 W. Four sets of samples are grown for this study, sample a, b, c and d. The structures of sample a and b are 20 nm/20 nm (a-Si/SiN_x) and 100 nm/50 nm (a-Si/SiN_x), and the periodicities are 20 and 6 respectively. Sample c has three kinds of periodicities and structures, from the substrate to the surface: a-Si/SiN_x(10 nm/20 nm, 5 periods; 20 nm/20 nm, 5 periods and 100 nm/50 nm, 10 periods). Sample d is a single SiN_x layer. The etching solution is a mixture of HNO_3, HF and H_2O with a volume ratio 3:100:100. The etching time is 10–100 s. Small angle X-ray diffraction (SAXRD) is performed on a D/Max-RA X-Ray Diffractometer (Rotating Anode, 12 kW, Cu Kα radiation, RIGAKU). Raman scattering spectroscopy with a microprobe of 1 μm diameter is performed on a T6400 system. SEM measurements are performed on a LEO1530VP.

Fig. 1 shows the SAXRD measurement for sample a. Calculations based on the Bragg formula, $2d \sin\theta = \lambda$, show the periodicity is around 45 nm, close to the experimental setting of 40 nm. So we can control sublayer thickness on the nanometer scale by setting the deposition time.

The sample b was cleaved and dipped into the etching solution, and tiny bubbles escaped from the sample indicating the etching process happened. Fig. 2 shows the SEM image of the sample etched for 10 s. All the strips are straight and no defects are visible over stretches greater than hundreds of micrometers. And the strips have distinct sidewalls, sharp edges, and uniform