Resist Pattern Peel due to Resonance Effect of Micro Tip

Akira Kawai

Department of Electrical Engineering, Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata, 940-2188 Japan
kawai@nagaokaut.ac.jp

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1. Introduction

Recently, the development the micro devices such as integration density of memory and micro machine requires an improvement of adhesion strength of micro resist pattern. The micro pattern adhesion has been recognized as one of important problem because the contacting area between resist and substrate decreases considerably.[1] A great deal of effort has been made on monitoring the adhesion property. What seems to be lacking, however, is quantitative and direct analysis in microscale. In this regard, the present author has already proposed the novel principle of direct analysis method for resist pattern adhesion and collapse, that is, direct peeling with AFM tip (DPAT).[2] By this method, the dependency of the load required for peel the ArF excimer resist pattern on the diameter has been determined. The purpose of this paper is to analyze the pattern peel of KrF resist by using the resonance method [3] between tip-pattern system experimentally.

2. Resonance effect of tip-pattern system

Figure 1 shows a schematic explanation of the resonance system accompanying with the detection amplitude due to the cantilever displacement. (i): Prior to the pattern peel investigation, the dot resist pattern was imaged by the AFM in the non-contact mode by which no pattern peel occurs. (ii): In the initial stage of the tip vibration operation, the tip apex is already set apart from the Si(100) substrate slightly in order to prevent the friction of tip apex and the substrate. (iii): Subsequently, the tip apex contacts to the dot pattern top by moving the piezo stage. (iv): By contacting the tip to the top of the dot pattern, the cantilever vibration was modulated gradually. (Fig.1a) (v): Then, by directly monitoring the amplitude of tip vibration, the resonance of tip-pattern system can be detected. (Fig.1b) Consequently, the dot pattern adhering on the substrate can be peeled by the resonance effect. (vi): Finally, the pattern peel and residue formation on the substrate can be reconfirmed by imaging the sample surface in the non-contact mode with the AFM.

Fig. 1 Resonance model of tip-pattern system.
Neither the tip apex nor the dot resist pattern appeared to be damaged as a result of the surface scanning procedure by the cantilever tip. All investigations were carried out in a dry atmosphere (23 °C, 4 %RH), because water vapor is known to coat surfaces with several monolayers. Details of the instrumentation are described elsewhere.[2]

Generally, the resonance property of tip-sample system can be analyzed quantitatively as follows.[4]

\[ \omega'_0 = \omega_0 \sqrt{1 - \frac{F'}{k_z}} \]  

(1)

where the symbols, \( \omega_0 \) and \( \omega'_0 \), represent the angular resonance frequency of cantilever and the modulated angular resonance frequency, respectively. The symbols \( k_z \) and \( F' \) represent the spring constant of cantilever and external load, respectively. In this study, the frequency change due to eq.(1).

3. Experiment

A KrF chemically amplified positive resist consisting of polyhydroxystylene with acid labile blocking groups and photoacid generators was used. The blocking group was tert-butoxy carbonyl (t-BOC). The photoacid generator was trifluoro-methanesulfonic acid. The dot patterns of KrF resist were fabricated on the poly-Si substrate. The silane-coupling treatment with hexamethyl-disilazane (HMDS) as an adhesion promoter was performed at 90 °C for 60 s. The dot shapes 300 nm in diameter were imaged to the resist film by using a KrF excimer laser stepper with an irradiation energy of 30.5 mJ/cm². Post exposure baking was performed at 130 °C for 90s. Then, the resist patterns were developed by dipping into tetramethylammoniumhydroxide (TMAH) 2.38 % aqueous solution for 60 s. Subsequently, the resist patterns were rinsed in deionized water, and dried by the spin method.

A commercially available AFM, integrated with a micro cantilever tip was used for the pattern collapse investigation. The length, width and thickness of the cantilever made of silicon nitride thin film was 240, 30 and 4 \( \mu \)m, respectively. The tip was made of Si single crystal by photolithography technique. The radius of curvature of the tip apex is approximately 8 nm. The apex angle of the tetrahedral tip was approximately 15 degree. The torsion and deflection spring constants of the cantilever were 2200 and 7.2 N/m, respectively. The cantilever torsion, brought out by contacting a resist pattern, was detected using a laser reflection system.

4. Results and Discussion

Figure 2 shows the resonance curve of the tip-pattern system after making a contact. It is clearly observed that the resonance frequency decreases by making a contact with tip to pattern. The frequency shift occurs due to increase of external load as shown in eq.(1). Figure 3 shows the AFM images before and after the resonance investigation. The peeled area can be clearly observed. Therefore, the resonance of tip-pattern system has an effect to peel the micro pattern from the substrate.

5. Conclusion

It is shown that the resonance of tip-pattern effect has an effect to characterize the micro pattern adhesion.

References