Facile wide-scale defect detection of UV-nanoimprinted resist patterns by fluorescent microscopy

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Introduction

UV nanoimprint lithography (UV-NIL) attracts a lot of attention recently as a promising nanofabrication tool to make high resolution nanopatterns at high throughput and low cost. Surface crenellated nanopatterns of optically transparent SiO_2 or polymer resin molds are pressed to a thin film of UV-curable resin on a substrate and transcribed to a surface of UV-cured resin by exposure to ultraviolet light. In some cases, defects of UV-nanoimprinted resist patterns arising from unleveled residual layer thickness, bubble trap, unfilled resin, dewetting, capillary bridge and particle contamination were induced by changing slightly fabrication condition. Therefore, a facile method for detecting resist pattern defects is very important in nanofabrication by UV-NIL. At present, microscopic defect detection is carried out by scanning electron microscopy (SEM) and atomic force microscopy (AFM), while macroscopic defect detection is performed by optical methods based on angular-dependent reflection, light scattering, and interference. We consider that a more sophisticated defect detection method to cover a size range as wide as possible should be developed. We have recently developed fluorescent UV-curable resists for UV-NIL to measure a residual layer thickness in convex parts of resist patterns [1, 2]. In this article, we revealed detectable sizes of lateral pattern resolution for residual layer thickness and pattern pitch. We also demonstrate other advantages of our detection method by fluorescent microscopy with a fluorescent UV-curable resist.

Experimental

A fluorescent UV-curable resist that our developed is now commercially available as PAK-01F from Toyo Gosei Co., Ltd in Japan and used as recieved. A thin film of 0.1 μm thick was formed by spincoating PAK-01F on a silicon wafer, pre-baked, and subjected to UV nanoimprint with a Mesyo-kiko NM-0801 nanoimprinter at room temperature under a pressure of 1.0 MPa. A SiO_2 mold (NTT-ATN) modified with Optool-DSX (Daikin Chemicals Sales) was used. The mold after UV nanoimprint and cured resist patterns on a silicon wafer were observed with an Olympus fluorescent microscope. Fluorescent microscope (FM) images were taken with an Olympus DP-70 CCD camera and analyzed with a Mitani Win-Roof analysis software.

Summary

FM images of imprinted PAK-01F resist patterns and a used SiO_2 mold were shown in Fig. 1. Slight adhesion of UV-cured resin fractures on a mold surface could be visualized as brighten parts (Fig. 1a). Unfilled resist patterns on a silicon wafer as darken lines due to bubble trap by UV nanoimprint under an air atmosphere could be detected (Fig. 1b). Resist line patterns of 500 nm width (line : space (L:S) = 1:10) were clearly observed (Fig. 1c) and resist line patterns of 80 nm width (L:S = 1:10) could be recognized (Fig. 1d). Fig. 2 indicated line profiles of fluorescent intensity observed for fluorescent resist line patterns made from PAK-01F, with results for Fig. 1b (150 – 500 nm line width at L:S = 1:2) and Fig. 1d indicated in Fig. 2a and 2b, respectively. In the case of L:S = 1:2, pattern pitches of >600 nm were detectable from the line profile of fluorescent intensity owing to fluorescence emission around 570 nm from a dye. Therefore, line patterns of 80 nm width at L:S = 1:10 could be visualized. Residual layer thicknesses in patterned regions could be measured by avoiding overlap of fluorescent emission from neighboring patterns. We demonstrated that fluorescent microscopy will be a powerful tool for facile wide-scale defect detection in UV nanoimprint lithography.

[1] K. Kobayashi et al., MNC2009 (Sapporo, Japan), 18D-7-111. [2] K. Kobayashi, et al. submitted.

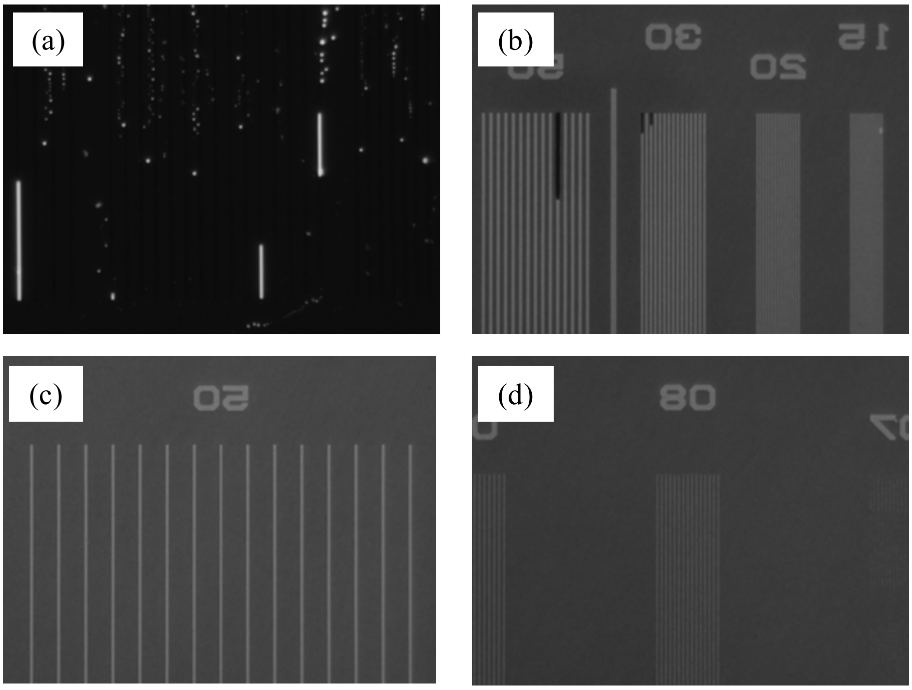

Fig. 1 Fluorescent microscope (FM) images of (a) a SiO_2 mold surface after UV nanoimprint and (b-d) line (L) & space (S) resist patterns on a silicon wafer: The pattern sizes at L:S are (b) 150, 200, 300, and 500 nm at 1:2, (c) 500 nm at 1:10, and (d) 80 nm at 1:10.

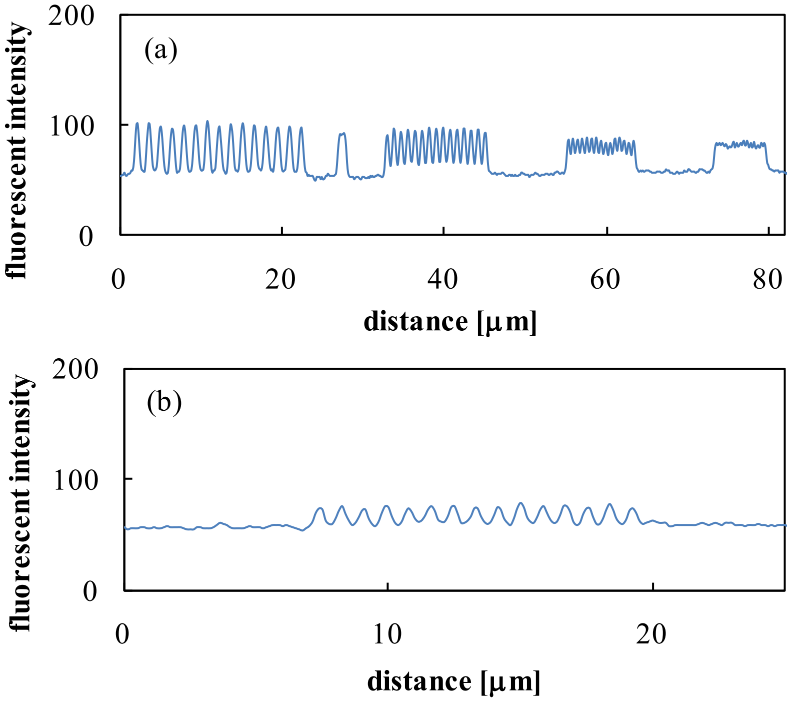

Fig. 2 Line profiles of fluorescent intensity analyzing line resist patterns of Fig. 1b and 1d. The pattern sizes at L:S are (a) 150, 200, 300, and 500 nm at 1:2 and (b) 80 nm at 1:10.