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Fabrication of Mechanical Durable Glass Nanopillar with Bridged Structure

Hiroyuki Kuwae[1], Takenari Sudo[1], Kousuke Takayama[2], Shuichi Shoji[1], and Jun Mizuno[3]

[1] Department of Nanoscience and Nanoengineering, Waseda University
3-4-1 Okubo, Shinjuku, Tokyo 169-8555, Japan.
Phone: +81-3-5286-3384 E-mail: kuwae@shoji.comm.waseda.ac.jp
[2] Research Center, Asahi Glass Co., Ltd.
1150 Hazawa-cho,Yokohama, Kanagawa 221-8755, Japan.
[3] Research Organization for Nano & Life Innovation, Waseda University,
513 Wasedatsurumakicho, Shinjuku, Tokyo 162-0041, Japan.

Abstract

We proposed highly mechanical-durable glass nanopillar structure for highly functionalized glass. The glass nanopillar was connected each other with bridge structures to disperse stress concentration. The bridged nanopillar was fabricated by Talbot photolithography and dry etching. The bridged nanopillar shows higher scratch resistance than the nanopillars without bridged structures. Moreover, self-cleaning effect of the bridged nanopillars were confirmed. We expect that the proposed bridged glass nanopillar structures will be a highly promising technology for optical applications.

1. Introduction

Glass substrates have been widely used in many applications, such as MEMS devices and solar cells [1, 2], because of their favorable mechanical and optical properties [3]. In particular, optical transmittance of glass substrates is one of the important key factors for practical uses. In order to maintain its high transparency, there has been considerable interest in a self-cleaning glass, which allows rain to wash away particulate contaminations on the glass surface without wiping. There have been a number of report on a self-cleaning glass which has a fine protrusion structure on its surface [4]. Since wettability on a glass surface is dramatically improved by surface topology as indicated by Wenzel's equation [5], the surface shows superhydrophilicity excellent in self-cleaning function. In addition, periodical nanopillar structure, which act as a graded refractive index medium, can eliminates reflections at the surface by moth-eye effects [6].

Previous studies have been made of glass nanopillar fabrication by reactive ion etching (RIE) system, and they showed self-cleaning or moth-eye effects [6]. However, high plasma power is required to fabricate the glass nanopillars, although it cause a trench at the edge of the nanopillar resulting from specular reflection of high energy ions [7]. The trench reduces the toughness of nanopillar, and the nanopillar is easily fracture when it is scratched.

In this study, we proposed a bridged glass nanopillar structure with high mechanical-durability. The glass nanopillar was connected each other with bridge structure to disperse stress concentration. Mechanical property of bridged nanopillar was evaluated by both analytically and experimentally. Additionally, self-cleaning effect of glass with the bridged glass nanopillar was demonstrated.

2. Experiments

Fig.1 show a design of the bridged glass nanopillar. The nanopillar was 400 nm in bottom diameter, 600 nm in pitch, and 400 nm in height. The bridge structure was 200 nm in height. The stress distribution of glass nanopillars when they scratched was examined by finite element analysis (FEA) using COMSOL Multiphysics software.

The resin mask for bridged glass nanopillar was fabricated using anisotropic Talbot photolithography. Subsequently, the mask pattern was transfer into the substrate by inductive coupled plasma (ICP)-RIE. In addition, a glass nanopillar without bridged nanostructure was also prepared as a reference.

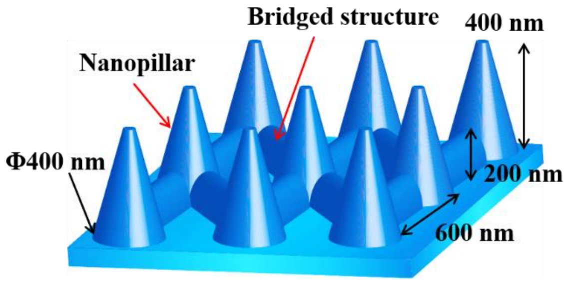

Fig. 1 Design of bridged glass nanopillar.

3. Results and discussion

The FEA results of stress distribution with and without bridged structure were shown in Fig. 2. Stress of the nanopillars without bridged structure was strongly concentrated at the bottom edge of the nanopillar. On the other hand, with bridged structure, the stress concentration was dispersed.

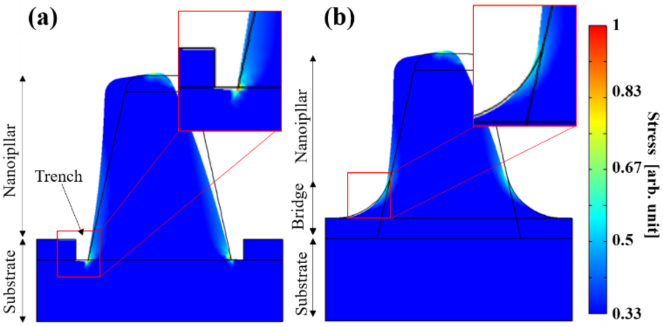

Fig. 2 FEA results of stress distribution in glass nanopillar (a) without bridged structure and (b) with bridged structure.

Fig. 3 shows scanning electron microscope (SEM) images of the fabricated bridged nanopillars. The nanopillars with and without bridged structure were successfully fabricated all over the area. The nanopillar without bridged structure has a trench at the edge of the nanopillar caused by specular reflected ions [7]. Fig. 3 (b) shows that the bridged structure was fabricated in adjacent cross structure in bridged nanopillar. In addition, bridged nanopillar reduced the trench formation.

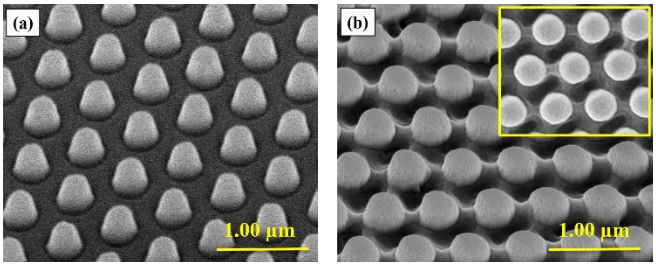

Fig. 3 Tilted view SEM images of glass nanopillar (a) without and (b) with bridged structure. The inset shows top view image.

SEM images after friction test using flannel cloth with 750 g weight were shows in Fig. 4. Obvious defects were not observed in the bridged nanopillar (white particles were remained flannel cloth), while many defects were found in the nanopillar without bridged structure. Furthermore, bridged glass nanopillars were not collapsed through high stress friction test using a steel wool. This result was well agreed with FEA results. In addition, self-cleaning effect was successfully observed in the bridged nanopillar (Fig. 5). Surface contamination was washed away by simply spraying water droplets, because the bridged nanopillars shows super-hydrophilicity (contact angle < 5°).

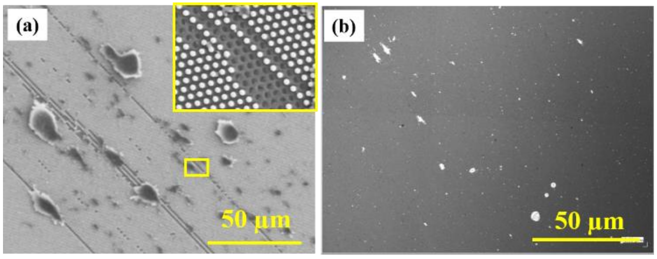

Fig. 4 SEM images of glass nanopillar after friction test. (a) Without bridged structure and (b) with bridged structure. The inset shows magnified image.

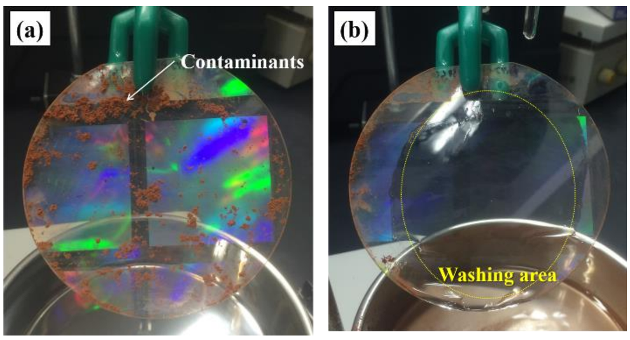

Fig. 5 Self-cleaning demonstration of bridged glass nanopillar. (a) Before washing and (b) after washing.

3. Conclusions

In this study, we proposed bridged glass nanopillar with high mechanical-durability. The bridged nanopillar were successfully fabricated by Talbot photolithography and dry etching. The improvement of scratch resistance by bridged nanopillar were confirmed by FEA and friction test. Additionally, self-cleaning effect of the bridged nanopillars was successfully demonstrated. We expect that the proposed bridged glass nanopillar will be a highly promising technology for high functionalized glass.

Acknowledgements

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