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Fabrication of Functional Devices Based on Highly Ordered Nanohole Arrays in Anodic Porous Alumina

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Highly ordered nanohole-array architecture with high aspect ratios was fabricated based on the anodization of Al. In the report, two types of fabrication processes for highly ordered nanohole arrays, and their application to several kinds of fabrication for functional devices are described.
Key words: Anodic Porous Alumina, Functional Devices, Photonic Crystals, Self-ordering

1. INTRODUCTION

Fabrication of highly ordered hole-array architectures with uniform-sized holes ranging from the submicron to nanometer range has recently attracted increasing interest because of demands for the development of various types of functional devices. Anodic porous alumina, which is formed by anodization of Al in appropriate acidic solutions, is a typical self-ordered nanohole-array material[1]. This material is one of promising candidates for the starting structure of nanofabrication due to its unique fine geometrical structures (Fig. 1).

Here, we show the some results concerning the fabrication of highly ordered anodic porous alumina and its application to functional devices.

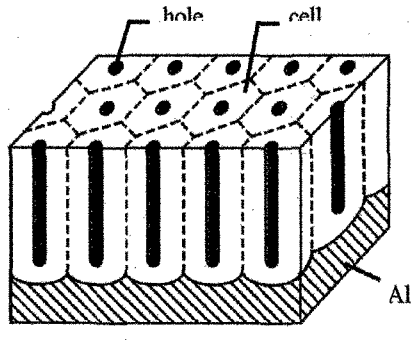

Fig. 1. Schematic drawing of anodic porous alumina.

2.FABRICATION OF HIGHLY ORDERED ANODIC POROUS ALUMINA

We have been studying the two types of fabrication processes of highly ordered hole arrays of anodic porous alumina: (1) the fabrication process of highly ordered hole arrays based on naturally occurring long-range ordering under appropriate anodizing conditions, and (2) the fabrication process of an ideally ordered hole configuration using pretexturing of Al with a mold.

In the case of naturally occurring ordering of hole configuration, conditions for the long-range ordering of the hole configuration of anodic porous alumina are characterized by long anodization under the constant anodizing voltage condition at the appropriate voltage specific for the anodizing solution[2-5]. The long-range ordering takes place at 28 V in sulfuric acid, at 40 V in oxalic acid, and at 195 V in phosphoric acid corresponding to cell sizes of 63nm, 100nm, and 500nm, respectively. In Fig. 2, the SEM micrographs of the hole configuration with naturally occurring long-range ordering obtained in these three anodizing solutions are shown.

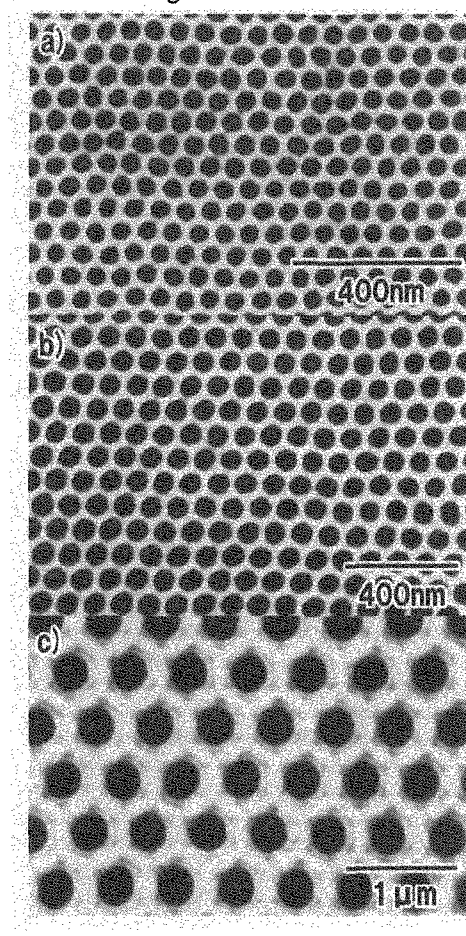

Fig. 2. Nanohole configurations with naturally occurring long-range ordering obtained in three anodizing solutions: (a) sulfuric acid, (b) oxalic acid, and (c) phosphoric acid.

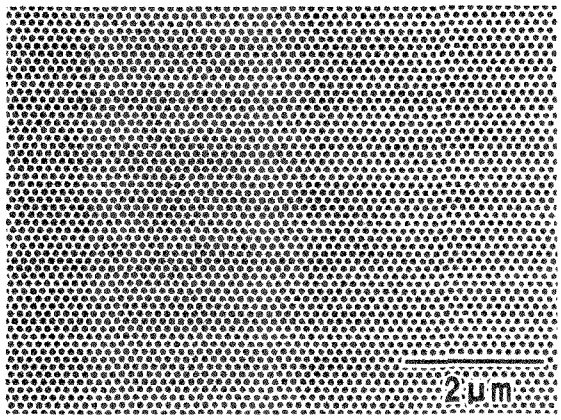

Fig. 3. Ideally ordered nanohole array in anodic porous alumina.

For the ideally ordered hole configuration, the combined process of a pretexturing treatment of Al and appropriate anodization generates the ideally arranged hole configuration[6]. Figure 3 shows a typical example of the obtained ideally ordered nanohole array in anodic alumina. The hole interval can be typically controlled from 40 nm to 500 nm by changing the interval of the pretextured pattern and the applied voltage.

3. 2D PHOTONIC CRYSTALS USING ANODIC POROUS ALUMINA[7]

Optical properties of ordered structures with a two-dimensionally (2D) periodic index of refraction have attracted growing interests because of potential applications for the design of novel optoelectronic devices. Anodic porous alumina with highly ordered hole arrays is a promising candidate for two-dimensional (2D) photonic band gap materials. Figure 4 shows the typical result of the optical properties of the ideally ordered anodic porous alumina. The observed gap in the transmission spectra of the anodic porous alumina showed good accordance with the calculated value.

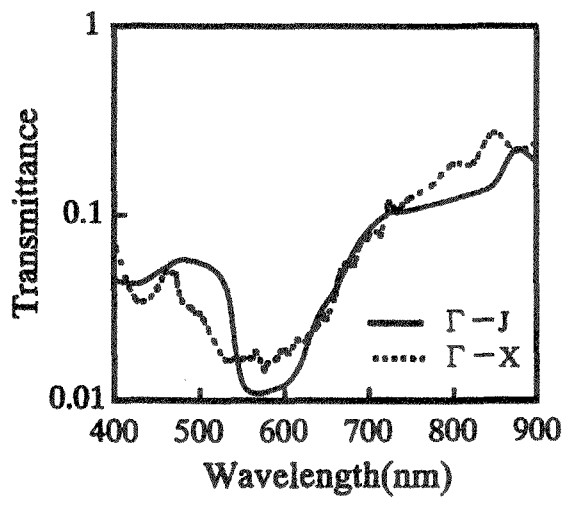

Fig. 4. Typical result of the optical properties of the ideally ordered anodic porous alumina. The lattice constant and filling factor were 250 nm and 0.3, respectively.

Fabrication of 2D photonic crystals was prepared using the pretexturing process. The sample was cut at the specific directions in the air cylinder array, (Γ-X and Γ-J directions). Measurements of the optical properties were carried out with a spectrophotometer equipped with micro-focusing optical arrangement using two distinct polarization light, E and H polarizations.

3. NANOFABRICATION USING HIGHLY ORDERED ANODIC POROUS ALUMINA

Anodic porous alumina with highly ordered hole-array architectures can also be used as a starting material for nanofabrication. We have applied anodic porous alumina to several replication processes. A two-step replication process using ordered anodic porous alumina as a starting structure generates a hole array structure composed of metals and semiconductors. In this process, the fabrication of negative-type anodic porous alumina and the subsequent formation of the positive type generates hole arrays of metals[2,8,9] and semiconductors[10] with a geometrical structure identical to that of the starting anodic porous alumina.

Another application of the highly ordered anodic alumina in the fabrication processes is usage of through-hole alumina as a mask in vacuum evaporation, or dry-etching processes[3,11]. A membrane with ordered through-holes could be used for the fabrication of a nanodot array on several kinds of substrates.

4. CONCLUSION

In conclusion, highly ordered nanohole array structures using anodic porous alumina could be prepared based on two kinds of fabricating processes. The obtained ordered hole array structures of anodic porous alumina will be promising for the fabrication of wide variety of functional nanodevices.

REFERENCES

[1] F. Keller, M. Hunter, and D. L. Robinson, J. Electrochem. Soc., **100**, 411 (1953).
[2] H. Masuda and K. Fukuda, Science, **268**, 1466 (1995).
[3] H. Masuda and M. Satoh, Jpn. J. Appl. Phys., **35**,L126 (1996).
[4]H. Masuda, K. Yada, and A. Osaka, Jpn. J. Appl. Phys., **37**, L1340 (1998).
[5]H. Masuda, F. Hasegawa, and S. Ono, J. Elecrochem. Soc., **144**, L127 (1997).
[6] H. Masuda, H. Yamada, M. Satoh, H. Asoh, M. Nakao, and T. Tamamura, Appl. Phys. Lett., **71**, 2770 (1997).
[7] H. Masuda, M. Ohya, H. Asoh, M. Nakao, M. Nohtomi and T. Tamamura, Jpn. J. Appl. Phys., **38**, L1403 (1999).
[8]H. Masuda, K. Nishio, and N. Baba, Jpn. J. Appl. Phys., **31**, L1775 (1992).
[9]K. Nishio, M. Nakao, A. Yokoo, and H. Masuda, Jpn. J. Appl. Phys., **42**, L83 (2003).
[10]K. Nishio, K. Iwata, and H. Masuda, Electrochem. Solid-State Lett., **6**, H21 (2003).
[11] H. Masuda, K. Yasui, Y. Sakamoto, M. Nakao, T. Tamamura, and K. Nishio, Jpn. J. Appl. Phys., **40**, L1267 (2001).

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