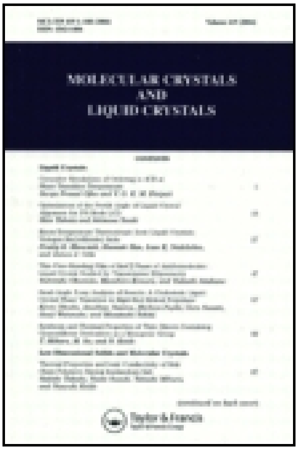

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Microporous Aluminum Oxide Membrane-Based Optical Interferometric Sensor

Hao-Li Zhang [a], Shan-Lin Pan [a], Ya-Fei Zhang [a] & Hu-Lin Li [a]

[a] Department of Chemistry, Lanzhou University, Lanzhou, 730000, China

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 1999, Vol. 337, pp. 489-492
Reprints available directly from the publisher
Photocopying permitted by license only

Microporous Aluminum Oxide Membrane-Based Optical Interferometric Sensor

HAO-LI ZHANG, SHAN-LIN PAN, YA-FEI ZHANG and HU-LIN LI

Department of Chemistry, Lanzhou University, Lanzhou 730000, China

The aluminum oxide membrane containing uniform micro-pores displays well-resolved interference pattern in the reflectance spectrum. Adsorption of molecules onto the surface of the porous layer leads to pronounced shifts of the interference pattern. Basing on the changes of pattern, the microporous aluminum oxide membrane could be used for fabricating a new class of sensor. Our experiments demonstrate that the detective limit of stearic acid in chloroform is 10^{-10} mol/L.

Keywords: sensor; microporous aluminum oxide; interference spectra

INTRODUCTION

Optical interferometric detector is an important component for a variety of highly sensitive analytical equipment [1]. Combined with certain recognition element, such kinds of sensors are proved to be highly effective for detecting either small molecules or multiple layers of biomolecular interactions. Here we describe a new optical interferometric transducer scheme based on porous aluminum oxide (PAO) membranes which is readily available and cheap optically flat thin film.

Anodization of aluminum in certain aqueous solution to produce porous aluminum oxide film has been extensively studied. The film was proved to contain paralleled micro-pores with their principal axis perpendicular with the aluminum substrate[2]. The depths and diameters of the pores are almost uniform and well controlled by the applied voltage as well as the composition of the solution. In our recent researches, reflectance spectra on PAO films having optical flat surface were found to show well-resolved interference pattern in ultraviolet-visible region. Adsorption of few molecules on the surface of PAO films could alter the pattern remarkably, that can be considered a new kind of sensor.

The spontaneous adsorption of alkanoic acid onto aluminum oxide surface from solution has been extensively studied[3]. Herein, we adopt stearic acid as a simple probe to test the feasibility of PAO based sensor.

EXPERIMENTAL SECTION

Optically flat PAO films prepared in sulfuric acid under proper condition usually contain uniform pores having average diameter around 20 nm depth about 2 μm. Freshly prepared PAO films were washed with pure water and then kept in vacuum. Stearic acid was dissolved in chloroform to a series of concentrations. The volume of the solution used for adsorption is maintained to 40ml. Adsorption was performed by immersing freshly prepared PAO film into chloroform solution of stearic acid overnight. Afterwards, the film was washed with chloroform and dried in N_2 prior to the characterization.

RESULTS AND DISCUSSION

Figure 1 shows the changes between the interference spectra of the PAO film before and after treated with 10^{-8} mol/L stearic acid in chloroform. Clearly, a monolayer adsorption of molecules on the PAO layer results obvious change of the spectra and the difference spectrum demonstrates a pronounced wave shift of the pattern.

The reflected monochromic UV-vis light at the top and bottom of the PAO film results the interference spectrum in which the reflectance was determine by[4]:

$$m\lambda = 2nd\cos\theta \quad (1)$$

The product of n and d in Eq. (1) is also termed effective optical thickness (EOT). The principle of our optical sensor is that the adsorption of special analyte into the porous layer leads to a change of the refractive index and is detected as a corresponding shift of the pattern in interference spectrum. It is known that very little change in the refractive index could result a detectable shift of the interference pattern. Therefore, the PAO film based sensor is expected (in principle) to be highly sensitive.

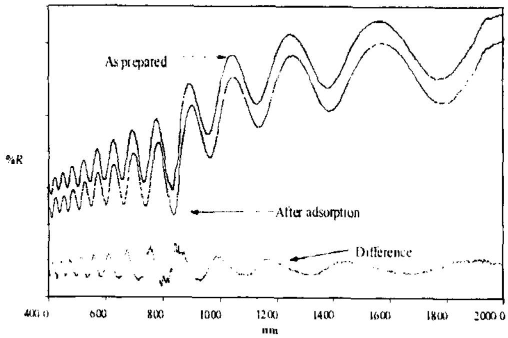

FIGURE 1 The interference spectra of PAO film before and after dipping into the 10^{-8} mol/L stearic acid in chloroform solution.

The EOT of porous layer of the PAO films can be evaluated from the positions of two neighboring peaks in the interference patterns as Eq. (2).

$$nd = \frac{\lambda_1\lambda_2}{2(\lambda_1 - \lambda_2)\cos\theta} \qquad (2)$$

We studied the dependence of the variation of EOT on the concentration of analyte (Figure 2). As the concentration of stearic acid in chloroform is higher than 10^{-9} mol/L, the changes of EOT do not show obvious dependence on the concentration. However, the change of EOT is hardly detected while the concentration lower than 10^{-10} mol/L. The correlation between EOT and concentration is agreed with the kinetics of stearic acid self-assembly onto the PAO film. Previous researches have suggested that the n-alkanoic acids usually form monolayer on oxidized aluminum substrate in few hours if enough acid in the solution [5]. Therefore, the plateau in Figure 2 reveal that full monolayers were formed on PAO while the concentrations higher than 10^{-9} mol/L. While the concentration lower than 10^{-10} mol/L, there is insufficient acid in solution to form a full monolayer, consequently, the change of EOT become smaller as the concentration is lowered. In summary, the stearic acid in the solutions more

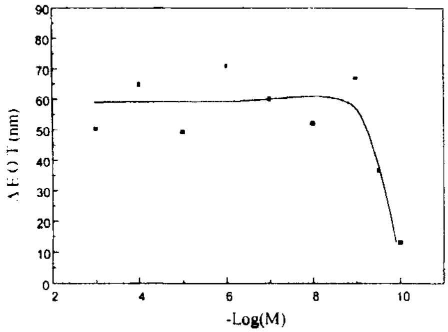

FIGURE 2 Relationship between the changes of effective optical thickness and concentration of stearic acid in solution.

concentrate than 10^{-10} mol/L could be detected by our PAO sensor. However, it seems that the PAO sensor is more suitable for qualitative, rather than quantitative analysis in our procedure. To obtain a highly selective sensor, it may be necessary to immobilize highly specific recognition elements (eg. antibody, enzyme receptor) into the PAO film. Related works are under investigation in our research group.

Acknowledgments

This work is supported National Natural Science Foundation of China.

References

[1] V. S.-Y. Lin, K. motesharei, K. S. Dancil, M. J. Sailor and M. R. Ghadiri *Science* **278,** 840–843 (1997).
[2] G. Paolini, M. Masero, F. Sacchi, and M. Paganelli, *J. Electrochem. Soc.* **112**(1), 32–39 (1965).
[3] D. L. Allara and R. G. Nuzzo *Langmuir* **1,** 52–66 (1985).
[4] B. Rossi, Optics (Addison-Wesley, Reading, MA, 1957).
[5] D. L. Allara and R. G. Nuzzo *Langmuir* **1,** 45–51 (1985).
[6] D. Routkevitch, A. A. Tager, J. Haruyama, D. Almawlawi, M. Moskovits and J M. Xu *IEEE TRANSACTION ON ELECTRON DEVICE* **43,** 1646–1658 (1996).
[7] C. K. Preston, M. Moskovits *J. Phys. Chem.* **97,** 8495–8503 (1993).