

Date of Submission:

平成 28 年 7 月 15 日

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## Abstract

## 論文内容の要旨 (博士)

Title of Thesis 博士学位論文名	Wettability/surface potential control on different interfaces and their applications on optical and electrochemical devices (異種界面における濡れ性と表面エネルギーの制御と光学および電気化学素子への応用)
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(Approx. 800 words)

(要旨 1,200 字程度)

Being an attractive topic, surface wettability/potential has been well studied in the last two decades. Controlling of the wettability and surface potential has many areas of applications such as bio-fouling, liquid lens fabrication and the electrophoretic deposition (EPD). Controllability of the surface wettability/potential by physical and chemical methods has been studied in this work. By analyzing and using different principles, the application of surface wettability/potential control were expanded to make optical and electrical devices with higher performances.

In the first study, the wettability of Nafion film was found to have a time dependent: contact angle (CA) of a water droplet on the Nafion film reduced from 149° to 134° within one minute. The change in CA could be explained from the molecular structure of Nafion, which is a polymer material containing long branches with sulfonic group endings. When the interface changed from air/Nafion into water/Nafion, according to the surface potential, these branches became upright or bend over. This causes a “flip-flop” wettability change phenomenon. To study the effect of the applied voltage on this phenomenon, we used multilayered thin films of 67 nm Nafion / 150 nm TiO<sub>2</sub> / 110 nm Pt coated on silicon wafer. The results showed that when a water droplet was loaded by positive DC voltage higher than 2V, owing to the strong attraction force towards the sulfonic top groups, the unwinding of the branched chains in the polymer film becomes enhanced. A decrease in CA to a minimum of 20° can be obtained in two minutes. Conversely, a negative DC voltage inhibits the “flip-flop” property by giving repulsive force towards the sulfonic groups.

In the second study, electrowetting property on dielectric multilayered thin films was investigated. Similar to “flip-flop” wetting, electrowetting is a modification of the wetting properties on a solid surface by using an applied voltage. Teflon was used as the hydrophobic top layer in this study, owing to its remarkable CA reversibility. Multilayered thin films of 50 nm Teflon / 160 nm TiO<sub>2</sub> / 80 nm Al<sub>2</sub>O<sub>3</sub> / on ITO glass were used as the solid phase. The TiO<sub>2</sub> layer was added to increase dielectric constant for a larger CA changing range. Meanwhile, the Al<sub>2</sub>O<sub>3</sub> layer was used to give high dielectric strength to prevent breakdown. Sol-gel and chemical solution dip coating processes were used to prepare each layer. By measuring the CAs with different applied voltages, we found that negative DC is more stable than positive DC. In addition, by testing the

leakage current during the electrowetting, the most suitable working voltage was obtained to be to -10 V DC. In dodecane atmosphere, the CA of a water droplet on Teflon surface was controlled from 155° to 67° by loading with -10 V DC without any electric breakdown. Furthermore, when the same multilayers were coated on the inside of a glass tube, the curvature of the water-oil interface could be adjusted by the applied voltage and due to the different refractive indices of water and oil, light passing through the interface can be converged or diverged depending on the curvature. By this principle we designed and assembled a liquid focusing lens driven by electrowetting. The performance of the liquid lens was tested based on its range of focusing lengths, response time, and life time. The results showed that by increasing the voltage from 0 V to -10 V, the focal length changed from -2 mm to infinity then to +10 mm. The lens had a quick response time of less than 100 ms and it was still stable after 1800 loading periods.

In the final study, on dye-sensitized solar cells (DSSCs), we prepared silver nanoparticles (Ag NPs) with high Zeta-potential and improved a method of making Ag NPs / TiO<sub>2</sub> nanotubes (TNTs) composite, by electrophoretic deposition (EPD). Ag NPs with an average size of 25 nm were modified by carboxy methylcellulose on their surfaces to obtain a high Zeta-potential of -43.3 mV. TNT arrays with a thickness of 13 μm were grown by anodizing Ti foils. EPD was employed to fill the TNT arrays with Ag NPs. A combination of +2 V DC and square waved 4 V AC with a frequency of 1 Hz proved to be the most effective applied voltage for EPD according to the results obtained by quantitative analysis of deposited Ag NPs. Also, an acetone vapor pretreatment was invented to replace the air in the TNTs before the EPD process. Back illuminated DSSCs were fabricated with the TNT arrays with different EPD time. After the TNT arrays was filled by Ag NPs using 30 min EPD time, the efficiency of DSSCs increased from 3.70% to 5.01% due to the surface plasmon resonance effect. However, the efficiency decreased to 4.62% with excess Ag NPs deposition when the EPD time was increased to 60 min.