Application of Layer-by-layer Assembled Nanoparticles to Anti-reflection Film

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1 Summary

Anti-reflection film in flat panel displays is indispensable for reducing the reflection of incident light and eliminating the ghost and flare phenomena that occur in a camera lens. In this report, an alternate layer-by-layer assembly of silica nanoparticles with polycations was investigated to create a super-low refractive index material for single-layer anti-reflection film. Materials with a refractive index lower than 1.32 can be fabricated by controlling the zeta-potential on silica nanoparticles.

2 Features of Technology

- We discovered a method for producing an anti-reflection (AR) film with ultralow refractive index – lower than 1.32 – by using layer-by-layer assembly.
- The method can reduce the refractive index by controlling the zeta potential of silica nanoparticles.
- The thin AR film produced is transparent, has low wavelength dependence, and possesses anti-reflection property.

3 History of Development

For optical lens component, coating with AR film is necessary to prevent flares and ghosts due to sensitivity, resolution, and diffuse reflections and to prevent errors in operation. In recent years, however, lenses have become thinner and lighter, optical component has become single-lens, and low cost is being demanded. Thus the materials have changed from glass to plastic, and the lens shape has become more complex, from being spherical to being aspherical and having high curvature. Under those conditions, problems with conventional methods of coating AR films have arisen. These problems include insufficient precision in film thickness with dry processes such as sputter coating or evaporation coating and the increase of production cost of AR film.

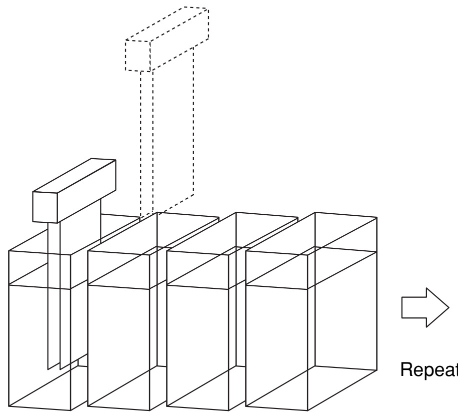

Figure 1 Layer-by-layer assembly process (schematic)

Meanwhile the layer-by-layer assembly process has been proposed as a method of coating thin film of nanometer thickness from solution (see **Figure 1**). This process produces a composite film in which cations and anions are layered. A substrate is dipped alternately in electrolyte solutions with positive and negatively charges to absorb cations and anions to the substrate through electrostatic attraction.[1), 2)] While this method is a wet process, it offers superior conformance to the shape of the base material. It can also form a uniform film on a variety of base materials. Here, we then sought to develop a method of coating AR film by using layer-by-layer assembly.

4 Content of Technology

(1) Research Method

A film with low refractive index can be achieved by forming a porous structure that includes air (refractive index = 1) in the silica bulk.[3), 4)] Here, we could form a layer-by-layer assembled film using silica nanoparticles and polycations. To stabilize the dispersibility of the silica nanoparticle in the slurry, conditions were adjusted to raise the absolute value of the zeta potential. In actuality, adding alkali or acid maintains a high zeta potential. As shown in **Figure 2**, if the pH of the dispersed slurry could be lowered to the acidic side, the zeta potential decreases and the refractive index of the thin film also decreases.

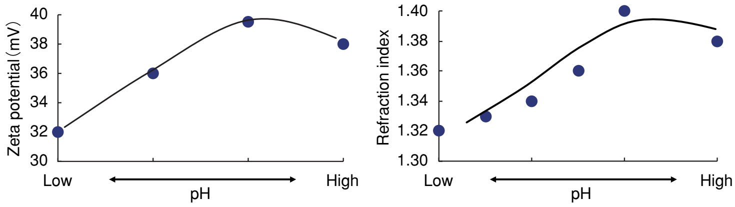

Figure 2 Dependence of refractive index on pH

(2) Discussion

As the zeta potential decreases, electrostatic repulsion among nanoparticles decreases, and aggregation of nanoparticles in the slurry occurs. Under this condition, the ultra low refractive index film is obtained. We estimated that its reason is mutual steric hindrance made by the irregularly shaped aggregation formed on the substrate. (see **Figure 3**).

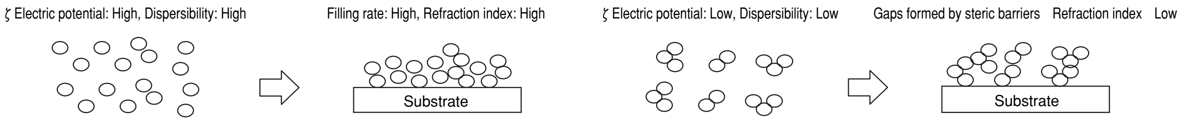

Figure 3 Dispersion condition and film structure

(3) Application to AR Film

The thin film produced by the method we developed has the feature of being a single layer and having no color. Its lowest surface reflection rate is below 0.1%, and in the visible spectrum (400 nm – 700 nm) it has an AR function of less than 1% (see **Figure 4**). Compared to AR film formed with magnesium fluoride (MgF_2), which uses the conventional vacuum process, the reflection rate is sufficiently low.

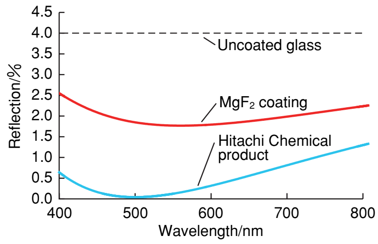

Figure 4 Comparison of reflection spectra

Also, as shown in **Figure 5**, the AR film formed on micro-lens shows excellent conformance to the shape of the lens. The obtained film has a porous structure. Because it has a low durability and does not prevent fingerprint, we believe it can be applied to optical lenses loaded in the inside of devices.

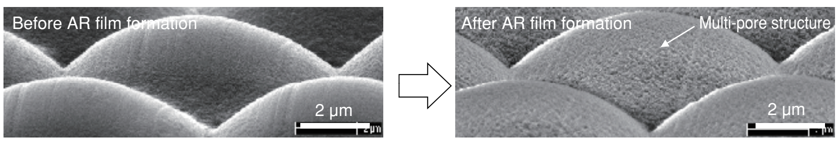

Figure 5 AR-coated micro-lens (SEM image)

5 Future Developments

- Improve mechanical strength (hardness) of nanoparticle thin film.
- Search for applicable products for layer-by-layer assembled functional thin film.
- Apply to mass processes.

【References】

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2) International publication No. W003/082481 A1 (2003)
3) Y. Lvov et al., " Langmuir, " 13, (1997) 6195
4) Bravo J, Zhai L, Wu ZZ, et al., " Langmuir, " 23, (2007) 7293