

### **Ag Nanoparticle Films for Color Applications.**

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## Ag Nanoparticle Films for Color Applications

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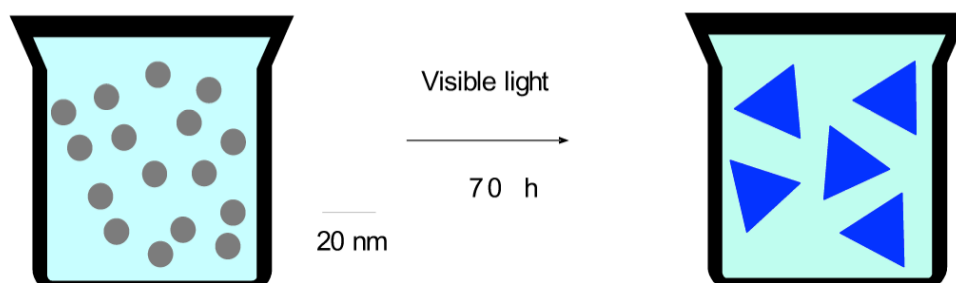
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### ABSTRACT

The focus of this present work is concerned with a novel and facile method for obtaining colored Ag nanoparticle films using a sulfide as a coloring agent. The Ag nanoparticle films change their colors depending on the dipping time in a solution of a sulfide and the dipping time is at most on the second time scale. The color of the films, initially silver (shiny white), changes to shiny yellow, red, and blue. Our scanning electron microscopy studies indicate that the color of the Ag nanoparticle films depend on the particle size of the Ag nanoparticle films.

### INTRODUCTION

It is well known that Ag nanoparticles absorb visible light of various wavelengths due to surface plasmon resonance and the wavelength depends on particle size, particle shape, and local refractive index [1]. It is also known that colloidal Ag nanoparticles which have spherical morphology can be converted into larger ones which have prismatic morphology by photoinduced method as shown in figure 1 [2]. The light-irradiation process results in Ag nanoparticle colloids which have a variety of colors depending on the irradiation time. However, this irradiation process in the colloid system requires many hours for the conversion of Ag nanoparticles.



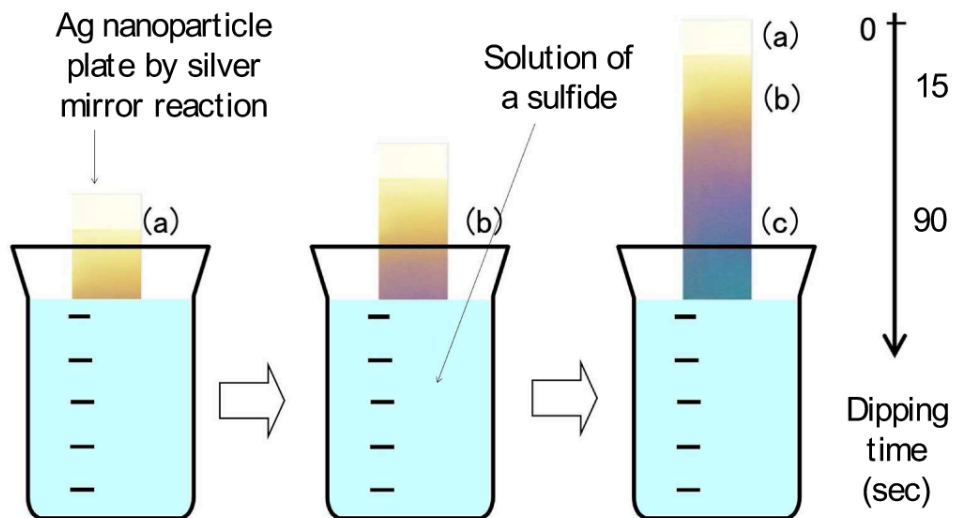
**Figure 1** Schematic diagram of showing the conversion from small spherical Ag nanoparticles to large prismatic ones by photoinduced method in a colloid system.

Recently, we have discovered a novel and facile method for preparing colored Ag nanoparticle films. In our method, the target for color change is not Ag nanoparticle colloids but Ag nanoparticle films. Specifically Ag nanoparticle films made by silver mirror reaction are colored by dipping them in a solution of a sulfide. To the best of our knowledge, this is the first time to control the colors of Ag nanoparticle films by using chemicals.

It is of great scientific interest to elucidate the mechanism of the color change of our Ag nanoparticle films. Therefore, in this paper, these Ag nanoparticle films have been characterized in terms of their particle size, surface chemical compositions and optical properties by experimental techniques, including scanning electron microscopy, X-ray photoelectron spectroscopy, and visible reflection spectra.

## EXPERIMENT

Ag nanoparticle films before coloration were made by silver mirror reaction. Synthetic procedure has been described in detail elsewhere [3]. The coloration of the Ag nanoparticle films was carried out as follows: A ca. 5 x 15 cm plate of Ag nanoparticle film was dipped in a 100 ml of 5 wt. % solution of a sulfide at room temperature. The plate was gradually escalated after the dipping as shown in figure 2. Surface parts of the plate turned their colors depending on the dipping time.

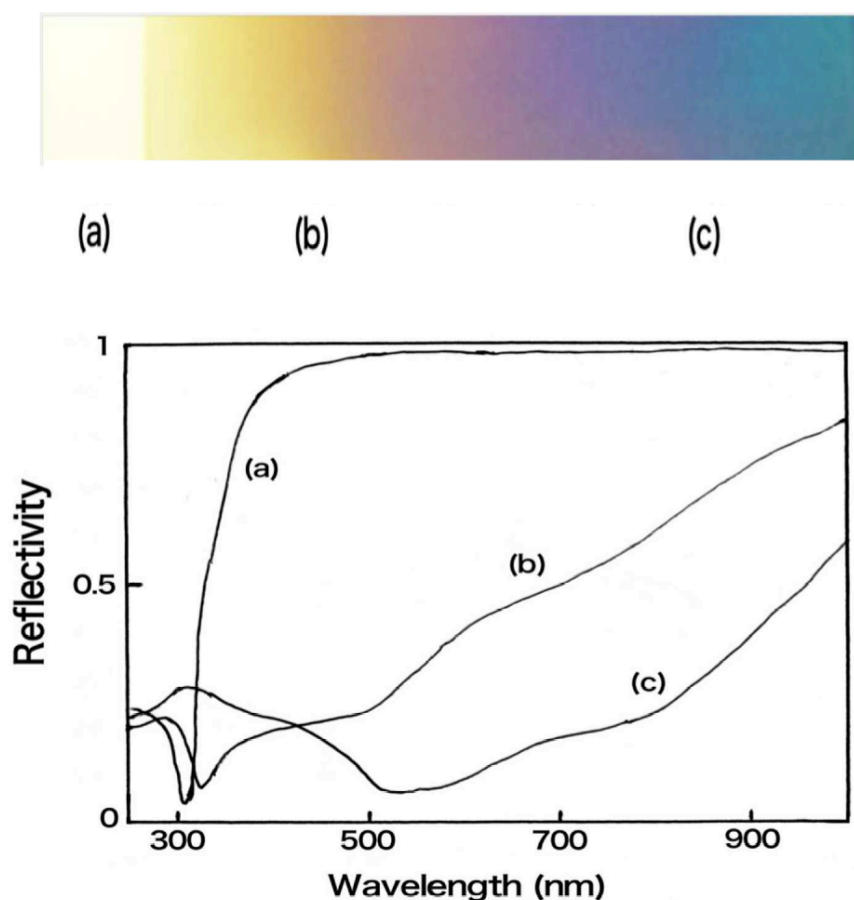


**Figure 2** Schematic diagrams showing the coloration of a Ag nanoparticle film using a solution of a sulfide.

Scanning electron microscopy (SEM) studies in order to observe the surface morphology of the Ag nanoparticle films were made using a Hitachi S-4800 instrument at an operating voltage of 3.0 kV. X-ray photoelectron spectroscopy (XPS) studies in order to characterize the surface chemical composition of the Ag nanoparticle films were carried out using a Ulvac 2000 instrument. The procedure for the characterization of the reflection spectra of Ag nanoparticle films has been described in detail elsewhere [4].

## DISCUSSION

Reflection spectra yield useful, albeit qualitative, information on the color change of the Ag nanoparticle films. Reflection spectra of the non-dipped Ag nanoparticle film (a) and the dipped films of the dipping time of 15 sec (b) and 90 sec (c) are shown in figure 3. Spectrum (a) is very similar to that of a Ag nanoparticle film reported by Sato [5] which has no absorbance in the visible light range. On the other hand, both spectra (b) and (c) have absorbance bands in the visible light range and these absorbance bands yield the shiny yellow and blue respectively.



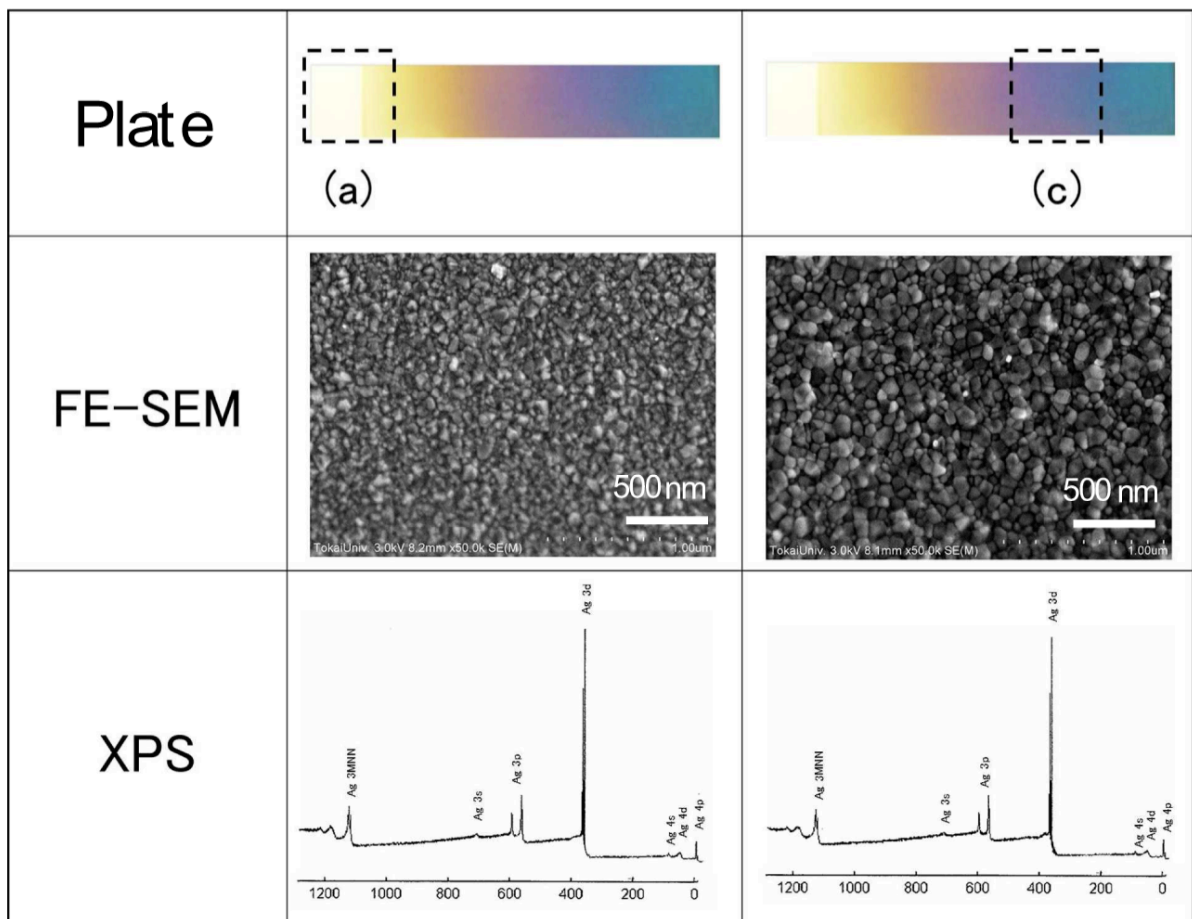
**Figure 3** Reflection spectra of the non-dipped Ag nanoparticle film (a) and the dipped films of the dipping time of 15 sec (b) and 90 sec (c).

A summary of the typical experimental data on the surface observation and surface chemical composition of the non-dipped part (a) and 90 sec dipped part (c) of the Ag nanoparticle films is presented in figure 4. The scanning electron micrographs depicted in figure 4 show the difference of the particle size between the non-dipped (a) and dipped (c) parts of the Ag nanoparticle film. The particle size of the non-dipped part (a) has a globular morphology with particulate dimensions in the range of 10-100 nm. Clearly the particle size of the dipped part (c)

is somewhat larger than the dimensions of the non-dipped part (a) and the range is in 20-200 nm. Thus the particle size may play an important role in the coloration of the Ag nanoparticle films.

In this present work, XPS is used to determine the surface composition of the Ag nanoparticle films. Since XPS is highly surface-specific (the typical sampling depth is 1-5 nm), this technique has proved particularly useful in assessing the surface chemical composition of the Ag nanoparticle films. According to XPS survey spectra depicted in figure 4, essentially the same surface chemical compositions were obtained regardless of the treatment of the sulfide. Thus there is a possibility that the surface chemical composition has nothing to do with the coloration of the Ag nanoparticle. However, we are going to carry out the analysis for obtaining XPS core line signals in order to confirm the relation between the color change and the surface chemical composition of Ag nanoparticle films.

As mentioned above, it is still unclear at present whether the color change with these two parts of the Ag nanoparticle films is primarily due to the physical or chemical difference on their surface. However, it can be said that the coloration of the films is at least in part due to the change of the particle size of the surface Ag nanoparticles.



**Figure 4** Typical experimental data on the surface observation and chemical composition of the non-dipped part (a) and 90 sec dipped part (c) of the Ag nanoparticle films.

## **Application areas of the Ag nanoparticle films**

Our color-changeable Ag nanoparticle films have a number of potential applications including coating materials, imaging materials and optical memories, since the film is easy to prepare, low cost, and applicable to a large area. Promising candidates are the applications as imaging materials. And one of interesting candidates as imaging materials is for use in nail arts (see figure 5). In this potential application, a solution of a sulfide acts as a color agent for coloring nails covered with Ag films made by silver mirror reaction.



**Figure 5** Nails covered with Ag films made by silver mirror reaction [5].

Finally we note that our Ag nanoparticle films have not only unique colors but also properties of metal, such as catalytic effect and superior electrical conductivity. Therefore, there may be lots more applications in the other fields. For example, given well-documented antibacterial activity of Ag, the Ag nanoparticle films could have biological applications.

## **CONCLUSIONS**

We described the preparation and characterization of a novel Ag nanoparticle films for color application. Our SEM studies indicate that the color change of the Ag nanoparticle films may come from the particle size change of the Ag nanoparticle films by dipping in the solution of the sulfide.

## **ACKNOWLEDGMENTS**

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