Application of Color-changeable Ag Films Using Inkjet Technology

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Abstract

We have recently discovered a novel and easy method for preparing colored Ag films using an aqueous solution of sulfide as a coloring agent. In the presence of specific sulfide, the color of Ag films, initially sliver, changes to yellow, red, and blue depending on the preparation conditions. The focus of this present work is to explore the possibility of these Ag films as inkjet imaging media. We have succeeded to write lines on Ag nanoparticle films using an electrostatic inkjet device. In this imaging system, an aqueous solution of sulfide acts as an ink for changing the color of Ag films.

Introduction

It is well-known that Ag films are easily sulfurized in the presence of sulfide and turn their silver surfaces to undesirable spotted black ones. On the other hand, we have recently reported a novel and easy method for preparing colored Ag films [1]. In this method, Ag films made by sliver mirror reaction are colored by dipping them in an aqueous solution of a specific sulfide as shown in Figure 1. The color of the films, initially silver changes to pale yellow, deep yellow, red, and blue. To the best of our knowledge, this is the first time to control the colors of Ag films by using chemicals.

These color-changeable Ag 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. One of interesting applications is for use in nail arts as shown in Figure 2. Another interesting candidate is the application as imaging materials. Considering the industrial application, it is preferable to give an ink receiving nature to Ag films, assuming the imaging by inkjet devices. Therefore, in the present work, we explore the potential for the Ag films as inkjet imaging media.

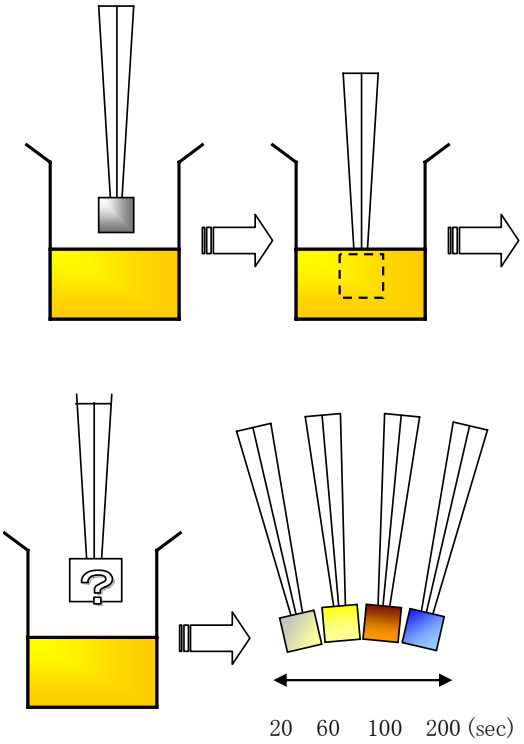

Figure 1. Schematic diagrams showing the coloration of Ag films dipped in an aqueous solution of sulfide

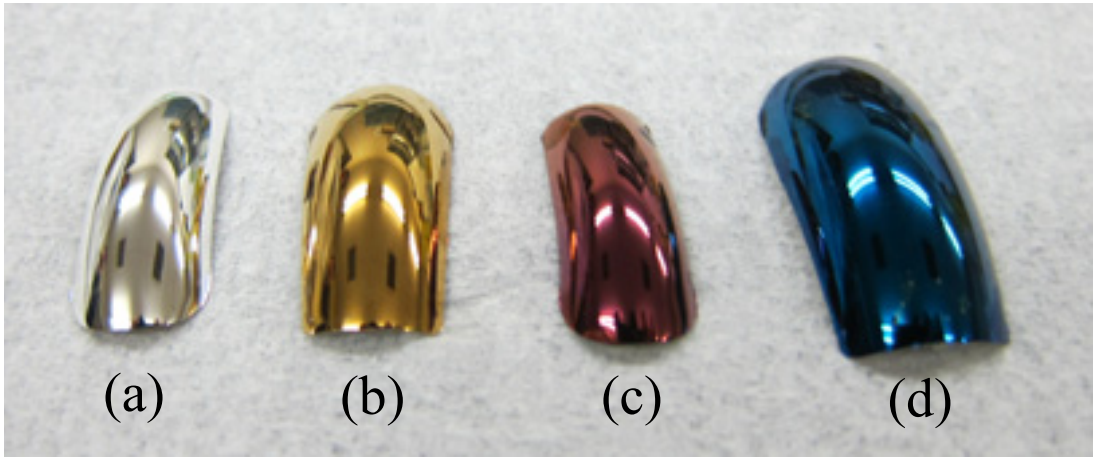

Figure 2. Application to nail art (a) the nail with silver by silver mirror reaction, and the colored nails with a sulfide dipped in (b) 5 sec, (c) 10sec, (d) 20sec

Mechanism for coloration of Ag films

In order to address the question why Ag films change their colors in the presence of sulfide, the surfaces of the Ag films were characterized in terms of their morphology and chemical composition using SEM, XPS and EDX, respectively. As the result, although it is still unclear at present, we found that the color changes of Ag films are mainly due to the surface plasmon resonance and/or thin film interference. We have already reported the mechanism based on the surface plasmon resonance [2].

On the other hands, both XPS and EDX analyses suggest that thin film interference between silver sulfide and silver layer may cause the color change. Thin film interference is the phenomenon that occurs when incident light waves reflected by the upper and lower boundaries of a thin film interfere with one another to form a new wave.

Experiment

Imaging on Ag films using masks

At first, we investigated the potential of Ag films as imaging materials. Ag films prior to the color treatment were made by sliver mirror reaction. Synthetic procedure of the Ag films was described in the literature [3]. Typical procedures in order to obtain Ag films were carried out as follows: Surface of ca. 10x 10mm Ag film was practically masked with adhesive tapes in order to make a latent image of ”F” letter. This Ag film was bonded to tips of chopsticks and was then dipped in a 50 ml of a 5w/w%, 90℃ aqueous solution of lime sulfur as shown in Figure 3. The dipping was allowed to 5 sec. The surface of the film turned yellow apart from the masked “F” letter. The film was then picked up, rinsed by de-ionized water, dried in air and the adhesive tapes were removed.

Imaging on Ag Films using inkjet

Typical procedures in order to use Ag films as inkjet media were carried out as follows: A ca. 10 x 10mm Ag film was set on the stage of inkjet device described in Figure 4. An aqueous solution of lime sulfur was then dropped onto the Ag film via the inkjet nozzle. Several blue colored lines were observed on the Ag film after this treatment. The Ag film was picked up, rinsed by distilled water, and dried in air. Surfaces of line and background area of the Ag film were observed in terms of their morphologies using a Hitachi S-4800 instrument at an operating voltage of 5.0kv.

Results and discussion

Trial samples to examine the potential as imaging materials are shown in Figure 5. We observed that silver parts of samples were clearly different from the colored parts as the background. Therefore we confirmed that these Ag films can be utilized as imaging materials.

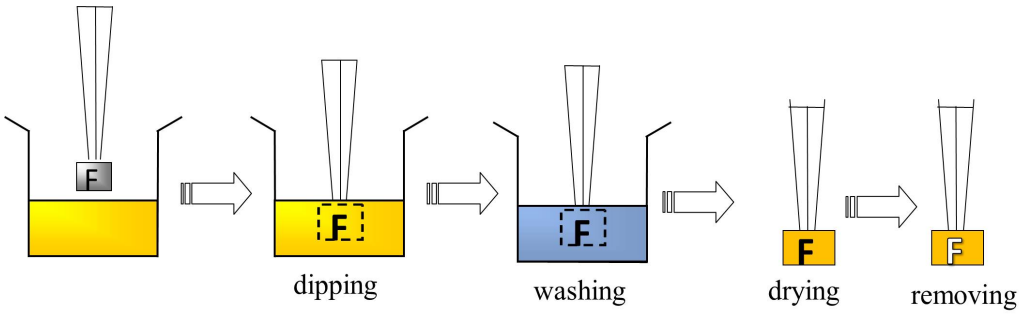

Figure 3. *Schematic diagram showing the coloration of Ag films*

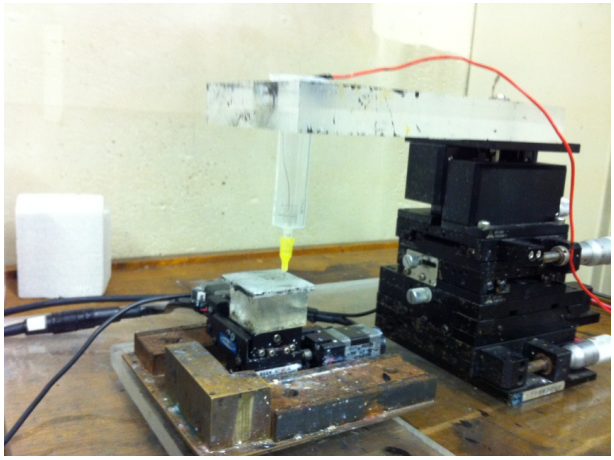

Figure 4. *Electrostatic inkjet device*

(a) yellow background

(b) red background

(c) blue background

Figure 5. *Trial samples to examine the potential as imaging materials. These colored Ag films samples were dipped in (a) 20 sec, (b) 100 sec, and (c) 200 sec in a 1 w/w%, 40 ℃ aqueous solution of lime sulfur. Silver parts of the samples were masked when dipped in the lime sulfur solution and then removed*

Turning our attention to the inkjet samples we have observed several lines after dropping sulfide solution on the Ag Films using the inkjet device as shown in Figure 6. Therefore, it can be said that we have succeeded to utilize our Ag films as inkjet media.

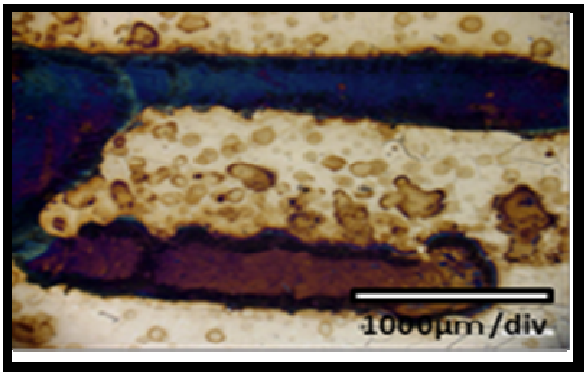

Figure 6. *Inkjet imaging on Ag film*

Some of representative scanning electron micrographs of the surface of Ag film are shown in Figure 7 and 8.

The observation point of Figure 7 and 8 was located on the colored line area, non-colored area, respectively. The small white points on the optical micrographs of upper right correspond to the actual observation area scanning micrographs. The particle size of non-colored area in Figure 8 is around 40 nm. Clearly the particle size of colored line area in Figure 7 is larger than that of non-colored one and the size is around 80 nm. The mechanism for the coloration of Ag films by this inkjet system can be considered to be the same to that of the colored Ag films which we have already reported [2].

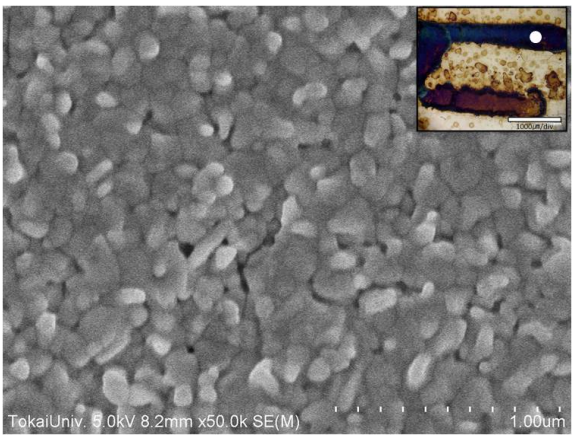

Figure 7. *Surface observation of colored Ag film*

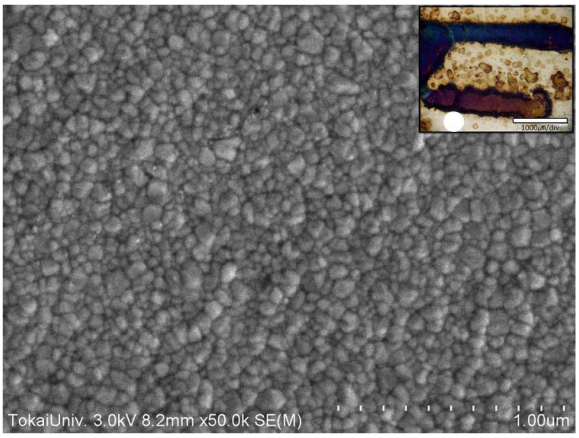

Figure 8. *Surface observation of none-colored Ag film*

Conclusion

1) We have succeeded to write lines on Ag films using the electrostatic inkjet device with the lime sulfur solution as the ink.

2) The mechanism for the coloration using this inkjet system may be the same to that of the colored Ag films previously reported.

3) We think that the Ag films have potential as inkjet imaging media.

Acknowledgement

We would like to express our sincere gratitude to Dr. Umezu and Mr. Akiyama of Department of Mechanical Engineering at Tokai University for their useful discussion and kind assistance of Ink jet studies. Mr. Miyamoto and Mr. Haraki of the Technical Service Coordination Office Tokai University are thanked for their kind assistance with the SEM studies on the Ag nanoparticle films.

Reference

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Author Biography

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Takayasu Suzuki was born in 1988. He received his B.E. degree in 2011 from Tokai University. He is expected to receive his M.E. degree from the graduate school of Tokai University in 2013. He is now engaged in a study of novel method for coloration of Ag films.

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