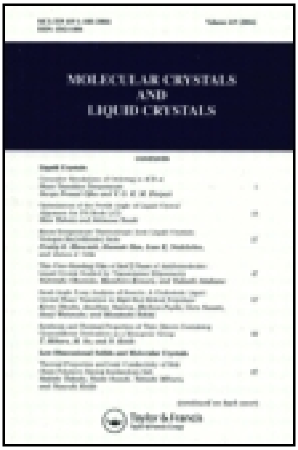

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Silver Coating by Low-Temperature Sintering of Nanoparticles

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Silver coating by low-temperature sintering of nanoparticles

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ABSTRACT Silver coating was examined on metal, glass and heatproof resins by using silver metallo-organic nanoparticles. An excellent silver-coated film was obtained by the low-temperature sintering at 300 ℃ or below. Utilization of the nanoparticle pastes for patterning in microelectronics is proposed.

Keywords: Silver coating; Low-temperature sintering; Silver metallo-organic nanoparticles; Thermal decomposition method

INTRODUCTION

Sputtering, chemical vapor deposition (CVD) techniques and the paste printing methods are popular coating procedures in the field of microelectronics. Those techniques are effective for preparing pure and dense coating films; however, they need cost for production facilities and equipments[1].

The printing technique is, on the other hand, simple and inexpensive to prepare coating films, where pastes composed of metal particles or metallo-organic compounds (MOC) are used as precursors of metallic films. Unfortunately, the paste made of metal particles is not appropriate for drawing highly accurate patterns. MOC is available for preparing dense metallic films in good accuracy, but the metal content of common MOC pastes is only 10-15 wt. %[1].

Concerning the applicable temperature for patterning, little is known as the pastes at the range of 200 to 500 ℃. For example, the upper limit of the pastes composed of metal particles and thermosetting resin is 200 ℃, and the lower limit of the glass-frit added type is about 500 ℃. Thus, we have tried to prepare a new coating method of silver in the field of microelectronics.

In this study, silver metallo-organic nanoparticles were examined for silver coating on metal, glass and heatproof resins. Low-temperature sintering of the nanoparticles took place at 300 ℃ or below to result in excellent silver-coated films. We report here the thermal properties of the silver metallo-organic nanoparticles.

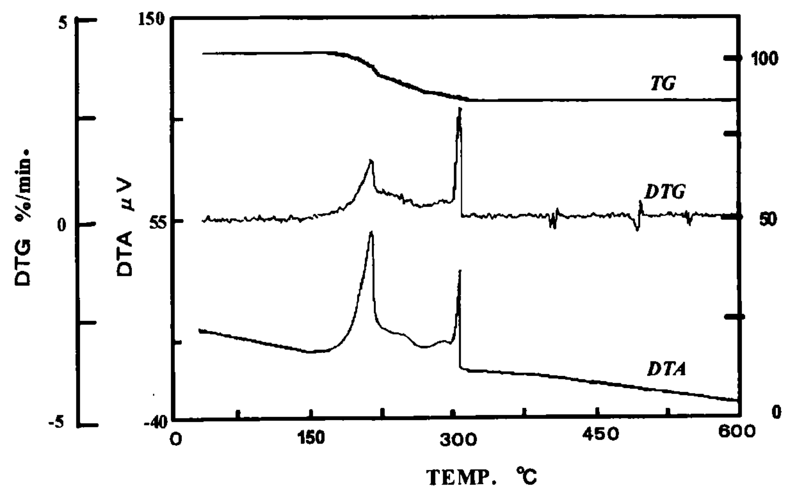

FIGURE 1 Thermogravimetry (TG) and differential thermal analysis (DTA) of the silver metallo-organic nanoparticles.

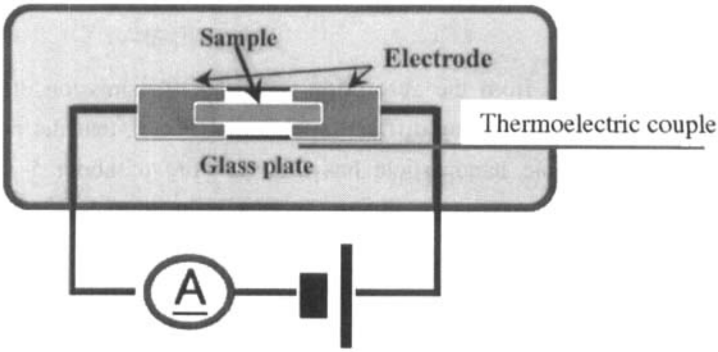

FIGURE 2 An experimental setup for the measurement of electric conducitivity.

EXPERIMENTAL

The thermochemical properties of the silver metallo-organic nanoparticles prepared from silver complexes were analyzed by thermogravimetry (TG) and differential thermal analysis (DTA) (Fig. 1). The electric conductivity as a function of temperature was also measured (Fig. 2); the nanoparticles were loaded like a belt (5 mm in width) on a glass plate equipped with two electrodes (10 mm in distance), and the conductance was measured at rising rate of 5 ℃/min.

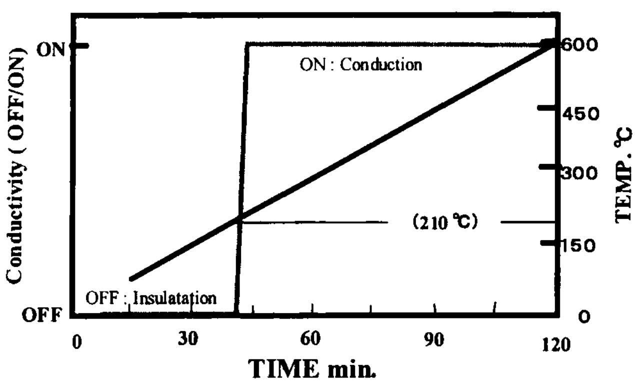

FIGURE 3 The electric conductivity as a function of temperature

RESULTS AND DISCUSSION

It is already known from the absorption spectrum, transmission electron micrograph (TEM) and X-ray diffraction patterns (XRD), that the present silver metallo-organic nanoparticle has a silver core of about 5 nm in diameter, and there exists an organic layer on the surface[2,3]. In the TG/DTA measurements, the nanoparticles started to decompose at ca. 200 ℃, exhibited a heat peak at 240 ℃, then decomposed completely at ca. 400 ℃. This result indicates the low-temperature pyrolysis of the silver metallo-organic nanoparticles. When spread on a glass substrate, the nanoparticle film became electrically conductive at 210 ℃ or above (Fig. 3). In addition, it was found that the silver coating film adhered tightly to several materials, i.e., glass and heatproof resins such as polyimide film and polyether-ether-ketone (PEEK) resin.

We have tried to prepare new silver-pastes by use of this silver metallo-organic nanoparticles. Newly prepared Ag-pastes are characterized as follows:

1) Chemical Stability: Good,

2) Homogeneity: Highly dispersible (no solid components found),

3) Viscosity: Suitable for screen-printing.

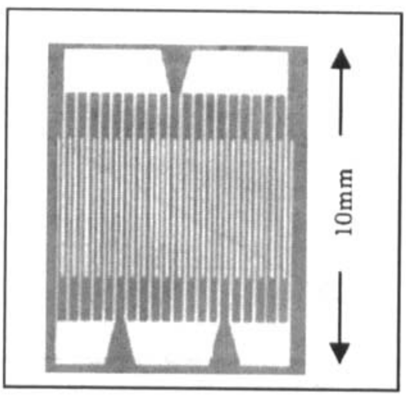

FIGURE 4 Ag-films on the polyimide film that is a representative example of the substrate for electronic circuits.

The low temperature sintering of new Ag-pastes was tested on soda-lime glass and polyimide film. The Ag-pastes were printed on these substrates by screen printing technique. Other coating methods such as dipping, spray, and spin coating methods are also available, because the viscosity of the paste is controllable.

The coated pastes on the substrates were dried at 100 ℃ for 10 min. The stepwise exothermic reactions of the Ag-pastes occurred in the range of 200 to 400 ℃. The metallic Ag-films were produced on the soda-lime glass and polyimide film by keeping the Ag-pastes at 300 ℃, which was the temperature corresponding to the first exothermic peak of the Ag-metallo-organic nanoparticles in TG/DTA curves (Fig. 1). Therefore, the first exothermic reaction of the metallo-organic nanoparticles should be their decomposition, most probably of their organic surfaces.

Figure 4 shows the appearance of sintered Ag-films on the polyimide film that is a representative example of the substrate for electronic circuits. These Ag-films tightly bound onto the polyimide films. Their mechanical features are shown in Table 1, where the hardness test was examined by the simple method of pencil hardness and the peeling test by use of adhesive tapes. These results suggest that the Ag-pastes were heated under appropriate conditions to produce tightly bound metallic films on polyimide films. By analogy with polyimide films, conductive metallic films are expected to be formed on soda-lime glass, too. Further details will be described elsewhere.

CONCLUSION

New silver metallo-organic nanoparticles showed thermal decomposition at low temperature between 210 and 300℃. By use of these Ag-nanoparticle pastes, thin Ag-films could be prepared on substrates such as soda-lime glass and engineering plastics. These new Ag-nanoparticle pastes are available for low temperature sintering, and applicable to the preparation of electrical circuits, sensors, and electrodes for analytical instruments.

TABLE 1 Estimation of the Ag-film

Substrate	Hardness Test*	Tape Pull Test**
Polyimide	2H	◎
Soda-lime glass	H	○

* by Pencil Hardness

** ◎,Very Good; ○,Good; △,Local Peel Off
×, Peel Off

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