Thermal behaviour of nanosilver doped gallium flexible conductor for biomedical application

Sheena J. Yong¹, Mahmood Anwar¹*, Sumaiya Islam¹, Sujan Debnath¹

¹Department of Mechanical Engineering, Curtin University, Malaysia, CDT 250, Miri 98009, Sarawak, Malaysia

*Email: mahmood.a@curtin.edu.my

Abstract: Gallium has been of interest in the medical community in the past decades due to its flexibility, non-toxic and anti-microbial property. In addition to its ductility, gallium makes a reasonable choice for the approach of a flexible conductor but it has a relatively low electrical conductivity as compared with other common metals which restricts usage in bio-sensors as well as other biomedical applications. In order to address such issue, a novel method was investigated using nanosilver doped gallium for enhancing charge transfer ability in the gallium metal matrix. Nanosilver has been ideal dopant due to its characteristics of highest electrical conductivity where nanoscale enables better diffusibility into the gallium matrix. The experiments were carried out to identify the effective thermal parameters which were temperature and heating duration for nanosilver doped gallium at three different temperatures, 250°C, 500°C, and 1000°C. Nevertheless, each heating duration were also in three different level, 6 hours, 12 hours, and 24 hours. All samples were tested in terms of surface morphology using an optical microscope. It was revealed that among the three temperatures, 1000°C showed better homogeneous surface morphology. It was also revealed that longer heating time promotes higher diffusion of nanosilver particles into gallium. The effective heating duration was observed to be 24 hours in terms of better homogeneity of surface morphology. Nevertheless, such findings had laid the foundation of better doping process of nanosilver into gallium to achieve a flexible conductor that can widely benefit in biomedical application.

1. Introduction

Conductive Technology advances in the medical field has helped to save many lives and improved the quality of life [1-4]. Extensive researches have been done for the development of better health-care that can save lives and prolong the human lifespan [5-11]. Recent advances include flexible and stretchable implants or devices that monitor body functions such as cardiac pacemaker that helps to control abnormal heart beats, or prosthesis that replace lost body parts. Albeit the significant advances that has progressed in the past decades, it is still a challenge to achieve a conductor that has flexibility and conductivity. A flexible conductor would open up the potential to further innovation that can contribute to the biomedical applications, such as in prosthetic skin, cochlear prosthesis, or implantable medical sensors can be used to monitor the human-activity and health-care [12-17]. Various metal alloys have taken part in contribution in the biomedical applications due to their properties including mechanical properties, biocompatibility properties, wear resistance, and low friction coefficient. Metal alloying typically aims to achieve in a novel alloy that incorporates the properties of the two distinguish metals.

In the past decades, gallium has been of interest in the medical community as it has an anti-microbial property and is non-toxic [17-22]. Gallium’s ductility is suitable for the approach of producing a flexible conductor in the biomedical application. However, it has a relatively low electrical
conductivity. On the other hand, silver also has an anti-microbial property and is known for having the highest electrical conductivity among all metals. Therefore, it is likely that doping gallium and silver will enable a flexible conductor. Hence, objective of this research is to identify effective thermal conditions that enables effective doping process. This will be useful in applications such as prosthetic arms, cardiac pacemakers and neural implants for paralysis.

2. Experimental

2.1 Materials and preparation

All materials used in this study were supplied by Sigma-Aldrich, which are gallium (99.99%) and nanosilver powders (99.5% trace metal basis). 120 mg of nanosilver was placed into a crucible boat. Then, 120 mg of gallium was extracted using a micropipette and added to the nanosilver powder. The gallium and nanosilver powders were gently mixed using the micropipette tip that was used to extract the liquid gallium. Then, the crucible boat was placed into the tube furnace to heat the sample to the desired temperature and heating durations.

2.2 Experiment Plan

Five Nine different samples were prepared. The temperature and heating durations are displayed in Table 1. in the Table 1 Experiment design for effect of concentration of iodothiophene below.

| Sample | Ratio of gallium to nanosilver | Temperature (°C) | Heating Duration (Hours) |
|--------|--------------------------------|------------------|--------------------------|
| SX6    | 1:1                            | 250              | 6                        |
| SX12   | 1:1                            | 250              | 12                       |
| SX24   | 1:1                            | 250              | 24                       |
| SY6    | 1:1                            | 500              | 6                        |
| SY12   | 1:1                            | 500              | 12                       |
| SY24   | 1:1                            | 500              | 24                       |
| SZ6    | 1:1                            | 1000             | 6                        |
| SZ12   | 1:1                            | 1000             | 12                       |
| SZ24   | 1:1                            | 1000             | 24                       |
3. Result and Discussion

The micrographs of all nine of the samples are shown in the Figure 1, 2, 3, 4, 5, 6, 7, 8 and 9 with magnifications of 100X and 200X respectively.

**Figure 1(a) and (b):** Micrography of sample SX6 with magnification (a) 100X and (b) 200X

**Figure 2(a) and (b):** Micrography of sample SX12 with magnification (a) 100X and (b) 200X
Figure 3(a) and (b): Micrography of sample SX24 with magnification (a) 100X and (b) 200X.

Figure 4(a) and (b): Micrography of sample SY6 with magnification (a) 100X and (b) 200X.

Figure 5(a) and (b): Micrography of sample SY12 with magnification (a) 100X and (b) 200X.
Figure 6(a) and (b): Micrography of sample SY24 with magnification (a) 100X and (b) 200X.

Figure 7(a) and (b): Micrography of sample SZ6 with magnification (a) 100X and (b) 200X.

Figure 8(a) and (b): Micrography of sample SZ12 with magnification (a) 100X and (b) 200X.
Based on the results obtained, it was noticed that there is a pattern in relation to the temperature. SX samples did not show any obvious inception of nucleation instead resembles similar morphology to pure gallium. However, SY samples showed through clusters of black spots which indicate coagulation of nanosilver particles. The clusters signify that the nanosilver particles had not diffuse into the gallium. On the other hand, well-formed nucleation instead of visible coagulation of nanosilver particles in SZ samples. It was observed that higher temperature produces improvement of homogeneity of the samples. Aside from that, the results also showed the effect of heating duration on the homogeneity where the grain size was observed to grow towards complete size. It was interesting to note that trends of homogenous morphology were revealed at longer heating duration.

4. Conclusions

In this research, nanosilver was doped with gallium. The effect of temperature on the homogeneity, effect of heating time, and effective heating duration for nanosilver doped gallium were studied. It is revealed by surface morphology that nanosilver diffusion had been influenced by the temperature and that the temperature that provides a better growth in grain size and more homogeneity surface morphology is 1000°C. It is also discovered that the effective heating duration is 24 hours as longer heating time allows higher energy that promotes higher diffusion of nanosilver particles into gallium. The 24 hours heating time provides more homogenous sample based on the microscopy analysis. In conclusion, there is an effect of temperature as well as heating duration on the homogeneity of nanosilver doped gallium.

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