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Electrical behaviour of nanosilver doped gallium flexible conductor for biomedical application

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Abstract: In the biomedical field, continuous researches have been expanding on doping of metals to acquire new materials for flexible conductors. Flexible conductors have been rapidly sought in several biomedical applications such as biosensors, implants, prostheses, etc. For example, prostheses are to mimic the movement of the human body which enables flexible and repetitive movement. However, these alloys functions hampered due to fatigue or loss of conductivity when subjected to bending. To address such issue, gallium is a potential solution as it has high ductility. However, gallium has relatively low electrical conductivity. In order to enhance the conductivity, nanosilver was used to doped as silver has the highest electrical conductivity. Moroever, nanosilver enables better diffusibility into the gallium matrix. In this research, for doping process, gallium and nanosilver were mixed at six different ratios, which were Ga:Ag of 1:1, 2:1, 3:1, 4:1, 5:1 and 6:1. It is revealed that higher concentration of gallium to nanosilver provides better diffusion, and better electrical behaviour. It is also revealed that the Ga:Ag of 3:1 is the most effective concentration in terms of better homogeneity and lower electrical resistance. Such findings are crucial for proper doping process and considered as the founding parameters for better alloy formation. Nevertheless, these findings would also contribute to biomedical research industry especially for artificial organ through developing new alloy materials.

1. Introduction

Human may encounter loss of body parts due to few reasons, including accidents, health problems or being born without particular part. In biomedical field, several approaches are developed. Installing prosthetic is a common technique to place an artificial body parts for substitution. The installed prosthetic part is known as a prosthesis. Conventional prostheses for example wooden legs are easy to produce. However, they are heavy and less functionality. A more advanced prosthesis with improved functionality will help to improve the living quality of the user [1-5]. For instance, a prosthesis with bending fingers will enable the user to perform his daily routine more effectively than a conventional prosthesis. For this improvement to be achieved, flexible conductors are required. The development of flexible conductors has been advancing throughout the decades. In general, the benefits of flexible conductors include flexible connection of moving or vibrating parts, reduce assembly or maintenance time, and are able to pass through complicated geometry [2,6-10]. It can be seen that the development of flexible conductors will not only be beneficial towards biomedical field, but also other fields such as automotive applications or electrical field.

When it comes to selection of good electrical conductor, metals will always be the first choice. The non-localized valence electrons of metals allow massive electron flow rate. The examples of good electrical conductors are copper, silver and aluminium. However, materials tend to lose conductivity when bent [3,11-14]. This makes the selection of material difficult. Recently, various flexible conductors have been invented. As an example, one of the invention consists of two silicone rubber films and a gel electrolyte injected between the silicone spacer. It can withstand 300% tensile strain with its special shape while conducting electric [4,15-18]. Nevertheless, it is found that the device leaks gel electrolyte and this denotes that it is not suitable for implantation. In this study, gallium is selected due to its high ductility, but the electrical conductivity of gallium is relatively low compared to other metals. Silver has the highest conductivity among all elements. By doping gallium and silver, it is believed that a conductor that is flexible while maintaining high electric conductivity can be achieved. Researches have been done regarding the doping of gallium with other metals [12-20]. There are limited researches done on mixing gallium and silver. However, research regarding the doping of nanosilver into gallium in order to enhance the electrical conductivity is yet to be estalished. The effective mixing concentration of doping gallium and nanosilver has not been established yet. Therefore, the aim of this research is to identify effecting mixing concentration of doping gallium and nanosilver for electrical conductivity. It is believed that effective mixing concentration is crucial in order to achieve proper doping of gallium and nanosilver.

2. Experimental

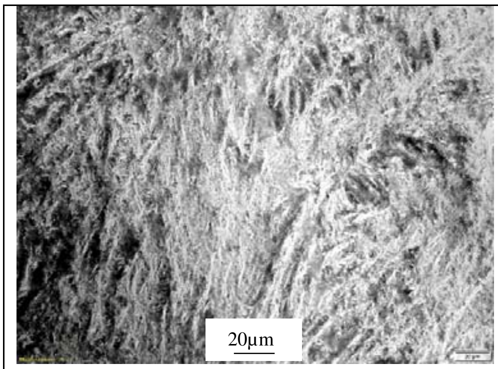
2.1 Materials and preparation

The material used are gallium and silver. The mixing process was under temperature of 50°C. At first samples were prepared for 6 different mixing ratio where the ratio of Ga:Ag are 1:1, 2:1, 3:1, 4:1, 5:1 and 6:1 which were represented as samples K01, K02, K03, K04, K05, K06 respectively. After that the solid solution were heat treated and allow to cool down in room temperature. All the specimens were undergone through material characterization. Finally, electrical testing was performed to determine the resistance of the doped specimen using Fluke high voltage multimeter.

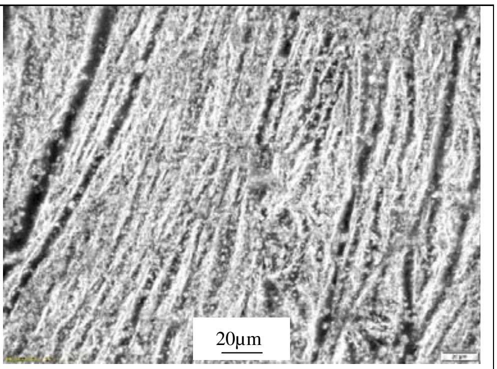
3. Result and Discussion

The micrographs of all six of the samples are shown in the Figure 1a, 1b, 1c, 1d, 1e and 1f for samples K01, K02, K03, K04, K05, K06 respectively with magnifications of 500X respectively. In Figure 1 (a), it is revealed that there are numerous dark spots are presented on the surface of the sample K01. This indicates that there is coagulation of nanosilver in many regions of the surface. Figure 1b showed the micrographs of K02. It can be seen that there are large dark spots and folds on the surface. It is also revealed that the dark spots which indicate that there are clusters of coagulated nanosilver. The micrographs of K03 were shown in Figure 1c. It is shown that some dark spots appeared at the surface. It is also shown that some of the dark spots are the smooth surface that reflected light away. This behavior is similar to pure gallium. Therefore, in K03, there are very little coagulation of nanosilver. In Figure 1d, again, it is revealed that there are very little small dark spots in sample K04. Therefore, it can be shown that there is very little coagulation of nanosilver in K04. Figure 1e showed the micrographs of K05. Again,very little small dark spots were found on the surface of the sample. However, the dark spots are found also to be the smooth surface reflecting light away which was similar behavior occurred as before. This indicates again that very little coagulations of nanosilver was present. Finally, the micrographs of K06 is shown in Figure 1f. Only a few small dark spots can be seen in and those the dark spots appeared to be the reflection of light, similar to before again.

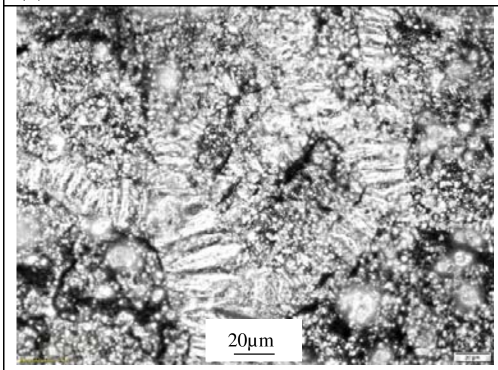
Therefore, very little coagulations of nanosilver were formed in K06. By considering all six micropgrapphs, it is revealed that K01 and K02 showed similar large dark spots on the surface, which indicates that there are coagulations of nanosilver. On the other hand, K03, K04, K05 and K06 showed similar behavior, and no large dark spots are observed. This indicated that the nanosilver is evenly distributed and no coagulation of nanosilver occurred. Therefore, the concentration of gallium is said to be insufficient for the nanosilver to be fully diffused in K01 and K02. It can be seen that K03 is the effective concentration among all six samples. Hence, it is revealed that in this experiment, Ga:Ag of 3:1 is the most effective concentration between 1:1 to 6:1 in terms of characterization.



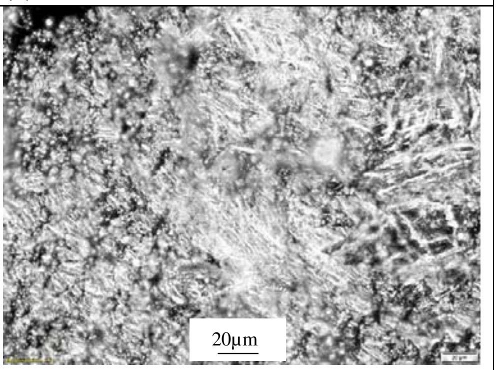
(a) K01



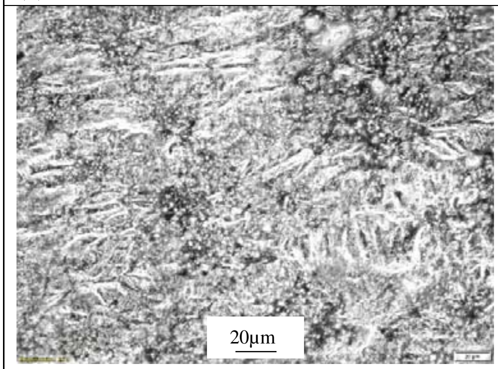
(b)K02



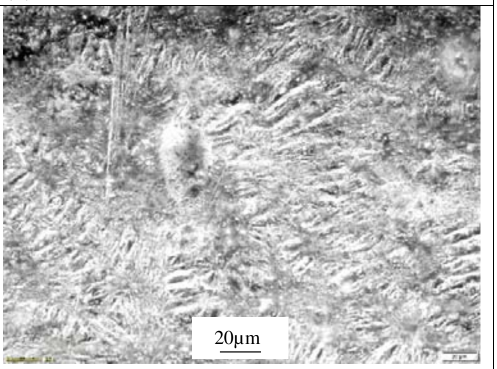
(c)K03



(d)K04



(e)K05



(f)K06

Figure 1(a) - (f): Micrographs of samples K01-K06 with magnification 500X.

Based Figure 2, it is revealed that all samples have lower resistance than pure gallium which is 83.46Ω. The resistance decreases from K01 to K06. It can be seen that K01 and K02 have relatively high resistance. There is a significant drop from K02 to K03, and resistance of sample K03, K04, K05 and K06 are almost similar.

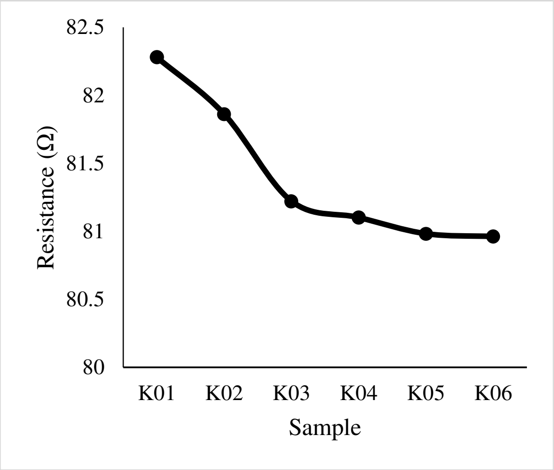


Figure 2: Electrical resistance of samples K01, K02, K03, K04, K05 and K06.

Based on the results obtained, It is understood that the generally decreasing resistance across six samples is due to the increasing amount of nanosilver, which results in better electron flow. It is believed that the drastic drop of resistance from K02 to K03 indicates that K03 is the threshold concentration. The diffusion of nanosilver in K03, K04, K05 and K06 are almost the same, it is said that K03 is the minimum concentration for effective diffusion. Therefore, it is revealed that in this experiment, Ga:Ag of 3:1 is the effective concentration in terms of electrical behavior. As a summary, based on both characterization and electrical test of all samples, Ga:Ag of 3:1 is found to be the effective concentration among 1:1, 2:1, 3:1, 4:1, 5:1 and 6:1.

4. Conclusions

In this research, the mixing process of gallium and nanosilver with Ga:Ag concentration of 1:1, 2:1, 3:1, 4:1, 5:1, and 6:1 has been achieved. The most effective concentration for mixing gallium and nanosilver has been identified. It is revealed that higher concentration of gallium to nanosilver provides better diffusion of nanosilver. It is also revealed that the effective concentration of Ga:Ag that provides better homogeneity is 3:1. Interestingly, it was notices that higher concentration of gallium to nanosilver provides better electrical behavior. Finally, it is concluded that the threshold concentration of Ga:Ag that provides the lowest resistance (80.96 Ω) is 3:1 among all six mixing ratios.

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