INVESTIGATION ON ELASTICITY RATE OF SILVER NANO-PARTICLES-FILLED EPOXY CONDUCTIVE INK

N.A.A. Rahim[1], M. Mokhlis[1], M.A. Salim[1,2], A. Md. Saad[2] and G. Omar[1,2]

[1]Fakulti Kejuruteraan Mekanikal,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[2]Centre for Advanced Research on Energy,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

Corresponding Author's Email: [1]azli@utem.edu.my

ABSTRACT: This paper investigates the elasticity rate of silver nanoparticles-filled conductive ink with nano indentation tester. The nano indentation tester is used to measure the hardness value of the silver nanoparticle-filled epoxy conductive ink. Based on the results, silver nanoparticles with 90 %wt have the highest Young's modulus as compare to the others. Thus, this nanoparticles have higher opportunity to retain its original shape. In addition, silver nanoparticles with 90 %wt also have the highest hardness, which is 3.07 Hv.

KEYWORDS: *Silver Nanoparticles; Conductive Ink, Hardness*

1.0 INTRODUCTION

Conductive ink is an ink that can conduct electricity when applied on a printed object. Conductive ink have been widely investigated and researched in the recent years. It is due to its popularity and consist of specific and unique application, which belongs to the next level of future technology. Conductive ink is a great invention that can be used to replace wire, small circuit, ink in a printer, and a creative t-shirt marketing. However, this technology still in research and not widely used in the industry. Silver nanoparticle based inks represent the most widely used in studies worldwide and applied in commercial nanotechnology-derive products [1]. This study uses silver nanoparticles as a filler with the binder (epoxy) and solvent (hardener) to produce the conductive ink.

Silver is the most expensive conductive material but it still preferred by end-users because of its high conductivity, even during oxidization. Some advantages of the silver are that it is easily formulated into inks and its adhesion to substrates is better than copper. The conductivity of a printed silver layer depend on the shape and size of the silver particles. The amount of temperature and time required to sinter is depended upon how easy the bond breaks and the particles size. The smaller of the particle size requires lower temperature to sinter the particles [2-3].

2.0 RESEARCH METHODOLOGY

2.1 Samples Preparation

The process started with the fabrication of all samples of silver nanoparticles-filled epoxy. The conductive ink composition consisted of filler loading, which was silver nanoparticles binder (epoxy) and hardener. The loading of hardener was 30% of amount of the epoxy loading. Then, the loading of silver nanoparticles, epoxy and hardener were weighed based on the Table 1 and the total values of mass only included the sum of filler and binder loading. The total mass was set at the beginning of experiment.

Table 1: Composition of Ink Loading

Sample	Filler		Binder		Hardener (g)	Total (g)
	(%)	(g)	(%)	(g)		
1	10	0.2	90	1.8	0.54	2
2	20	0.4	80	1.6	0.48	2
3	30	0.6	70	1.4	0.42	2
4	40	0.8	60	1.2	0.36	2
5	50	1.0	50	1.0	0.30	2
6	60	1.2	40	0.8	0.24	2
7	70	1.4	30	0.6	0.18	2
8	80	1.6	20	0.4	0.12	2
9	90	1.8	10	0.2	0.06	2

After they were weighed, the materials were mixed inside the beaker. Then, the mixture was stirred slowly in one direction either clockwise or anticlockwise for 10 minutes with consistent speed by using a glass rod until all three materials were mixed. Next, the ink were printed by using a blade coating method with 0.5 cm of width gap. The final step was the curing of conductive ink. The sample was placed in an oven with the temperature of 160 °C for 60 minutes in order to preserve the adhesion between ink and the substrate. Then, the ink was dried at the room temperature until it fully dried.

2.2 Hardness Measurement

The measurement of hardness was carried on by using nano indentation. The sample was pressed with the pre-force to the penetration depth of "h" by 0.7mN force at three different locations at one point. For the purpose of this study, three readings of hardness were taken at each constructed point of the ink track. Next, additional force was applied for dwell period of 5 seconds. Then, the test force was calculate based on the pre-test and the additional test forces. The average values of hardness were recorded.

3.0 RESULTS AND DISCUSSION

3.1 Results of Elasticity

The nano indentation tester was been used to evaluate the effect of elasticity and hardness of the silver nanoparticles-filled epoxy conductive ink.

Figure 1 was used to determine the elastic modulus of these silver nanoparticles by nanoindenter. This process is very effective to study the mechanical properties of induced localized mechanical deformation. Displacement was measured with high resolution measuring load. Elastic modulus, E and hardness, H that proportional to the yield strength, which can represent the typical properties can be concluded from the results.

The results reveal that silver nanoparticle with 90 wt% silver has larger load when approaching 0.6 um. According to that, this silver nanoparticle has higher Young's modulus as compared to others.

Therefore, silver nanoparticles with 90wt% silver have a higher opportunity to retain its original shape.

On the other hand, silver nanoparticle printed with 30 wt% silver can withstand small force and higher depth as compared to 20% and 10%. It is because, silver nanoparticle with 30 wt% silver has the lowest elastic modulus. The type and thickness of substrate have low influence on Young's modulus and hardness of ink-jet printed silver layer.

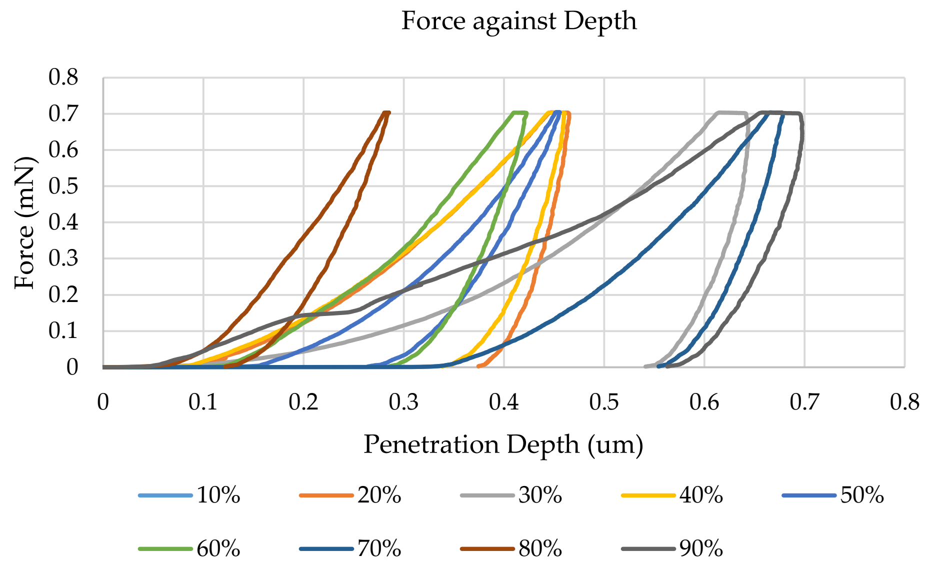

Figure 1: Graph of Force and Penetration Depth for Conductive Ink

3.2 Results of Hardness

The data of hardness was obtained from the nano indenter tester. Each sample had three points and each point recorded three readings of hardness.

Hardness is a measure of material's resistance to deformation by that is obtained by surface indentation. The plastic deformation is caused by the motion of dislocations in the atomic structure of a material. The yield strength of a material can be changed by inhibiting dislocation motion through imperfections, alloys or grain boundaries. The depth of nano indentation is one of the key consideration to obtain the true mechanical properties of a film on a substrate system. Figure 2 shows the graph of hardness against percentage of filler loading.

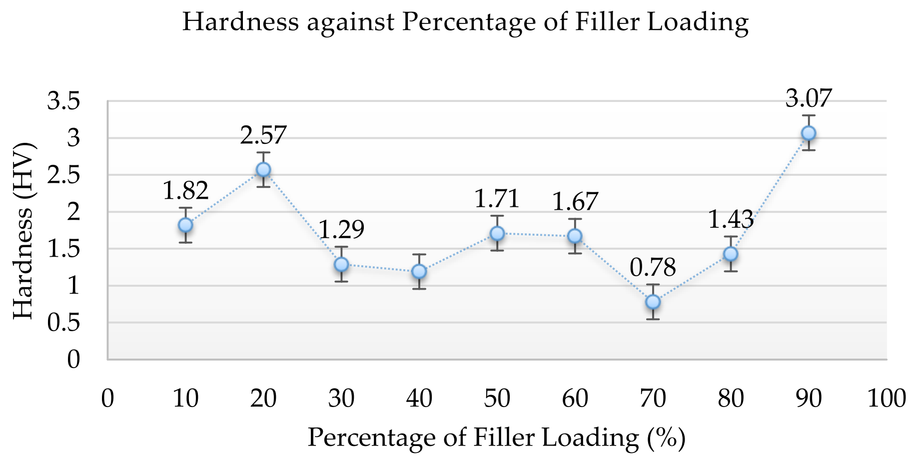

Figure 2: Graph of Hardness against Percentage of Filler Loading

Silver nanoparticle with 90 wt% silver has the highest hardness, which is 3.07 Hv as compared to other filler loadings. It can see from the morphology of silver nanoparticle with 90 wt% that the grain boundaries between silver (black dot) and epoxy (white) have wider gap. When the grain boundary increases, hardness is also increases. The lower values of both elastic modulus and hardness can be explained by the incomplete sintering. Figure 3 shows the morphology image of 90% of filler loading.

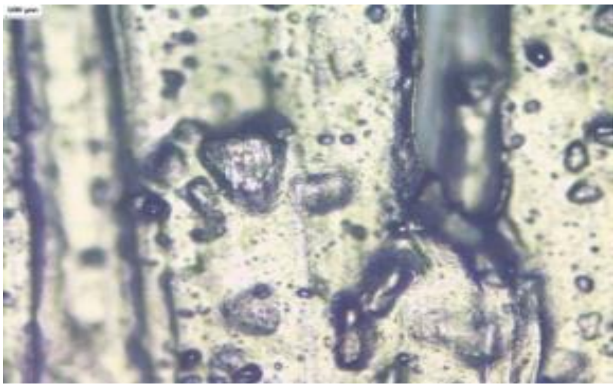

Figure 3: Morphology Image for 90% of Filler Loading

4.0 CONCLUSION

This study investigated the elasticity of silver nanoparticles filled epoxy conductive ink. From the testing of hardness by using a nano indenter tester, silver nanoparticle with 90 wt% had the highest Young's modulus as compared to the others. Thus, this silver nanoparticles had higher opportunity to retain its original shape. In addition, this nanoparticles also had the highest hardness which was 3.07 Hv. This was because the grain boundaries between silver (black dot) and epoxy (white) had wider gap. Therefore, if the grain boundary increased, the hardness will also increase.

REFERENCES

[1] Rajan, K., Roppolo, I., Chiappone, A., Bocchini, S., Perrone, D., & Chiolerio, A. (2016). Silver nanoparticle ink technology: state of the art. Nanotechnology, science and applications, 9,

[2] Bhore, S. S. (2013). Formulation and Evaluation of Resistive Inks for Applications in Printed Electronics

[3] Rahim, N. A., & Salim, M. A. (2018, April). Investigation of silver nanoparticles ink resistivity on polyethylene terephthalate. In 1st Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER'18) (Vol. 1, p. 10). Penerbit Universiti, Universiti Teknikal Malaysia Melaka.