Electrical performances of Graphene with different filler loading as conductive ink

M. Mokhlis[1, 2,*], M.A.Salim[1, 2*], N.A.Masripan[1, 2]

[1)] Faculty of Mechanical Engineering, 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 e-mail: azli@utem.edu.my

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ABSTRACT – Recent years have witnessed many breakthroughs in research on graphene for conductive ink application**.** This study focusing on the electrical performances of graphene as conductive ink at 10wt. %, 20wt. %, 30wt. % and 40wt. % of filler loading using a four-point probe. From the result obtained, low percentage of filler loading has no presence of conductivity while for a higher percentage of filler loading has lower resistivity and presence of conductivity. The outcome from this work would provide a convenient way to fabricate conductive ink for various printed electronics fields.

1. INTRODUCTION

Conductive inks, ink that developed in a printed object that can conduct electricity with widespread uses such as wearable electronics and healthcare devices, are regarded as the next generation of electronic devices [1]. In this project, graphene is a conductive material that contains superior electrical properties that draw the attention of many researchers. An effective conductive ink comprises three main components; conductive material, a polymer binder, and solvent. This study will be focusing on optimizing graphene filler loading percentage to produce a high conductive ink. The process to fabricate conductive ink includes printing procedure, ink-substrate interaction and curing process [2]. The mixing ratio of filler, binder, and hardener was a critical step to produce an ink with high conductivity, a preliminary study on the mixture of the three components was conducted. The purpose of the experiment is to identify the optimum percentage of filler loading with lower resistivity. The result obtained will bring opportunities to produce the new generation of high conductive inks. In this project, five different filler loading were prepared by manual mixing

2. RESEARCH METHODOLOGY

2.1 Formulation of graphene ink

The ink formulation of graphene, reinforced epoxy resin and hardener were achieved by a simple method involving mixing, printing and curing process. The materials were weighed using digital analytical balance (ME204E from Mettler Toledo) and the same process was repeated for each case using a different weight of the mixture. The process was continued with mixing process which took about 10 minutes at room temperature. A well-dissolved mixture was obtained with a correct stirring technique; stir in one direction at a constant speed. The printing process was then carried out using the doctor-blading technique [3]. In this technique, the thickness of exposure ink can be controlled manually. A sharp blade was used to move the ink across the substrate at a constant speed to ensure the ink is fully exposed at the constructed gap. In the final step, curing process takes place in order to improve the bonding between the particles of filler, binder, and hardener. Curing was also applied to melt and harden the mixture with the help of the hardener so that the adhesion between ink and substrate could be improved.

Table 1 The composition of filler loading.

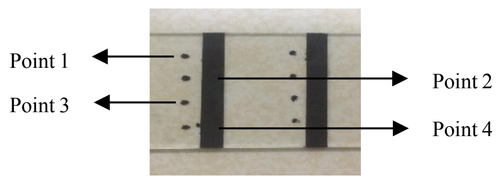
Sample	Filler		Binder		Hardener	Total
	(wt. %)	(g)	(wt. %)	(g)	(g)	(g)
1	10	0.2	90	1.8	0.54	2
2	20	0.4	80	1.6	0.48	2
3	30	0.6	70	1.4	0.42	2
4	40	0.8	60	1.2	0.36	2
5	50	1.0	50	1.0	0.30	2

2.2 Samples characterization

The sheet resistance values of the samples were characterized in ohms-per-square was carried out using a four-point probe (RM3000 from Jandel). Four-point probe works by forcing a constant current along two outer probes and next, the voltage is read out from the two inner probes.

3. RESULTS AND DISCUSSION

The resistivity the ink will be discussed to find out the best ink formulation. Four points were marked and measure to determine the average of the sheet resistance.



From the results Table 1, the presence of resistivity can only be observed at 30wt. % and 40wt. %. At 10wt. % and 20wt. %, there is no resistivity present due to the insufficient amount of filler loading as a small amount of filler loading lead to agglomeration effect. Agglomeration effect can cause uneven dispersion [4]. Therefore, no electrical conductivity can be produced due to agglomeration effect.

Table 2 Result of sheet resistance

Method	**Manual mixing**	Four point probe
Sample	Filler (%)	(Ω/sq)
1	10	-
2	20	-
3	30	4862.12
4	40	7997.84
5	50	-

The conductive ink fabricated were characterized based on the electrical properties and microstructure behavior to determine the optimum ratio of filler loading. It was pointed out that the filler loading of 10wt. %, and 20wt. % did not have any presence of conductivity, while 30wt. % and 40wt. % show the existence of the conductivity, hence the decision to choose the filler loading merely based on the filler loading 30wt. % and 40wt. %.

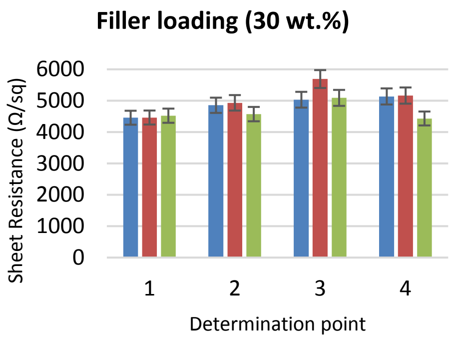


Figure 1 Graph of 30 wt. % filler loading

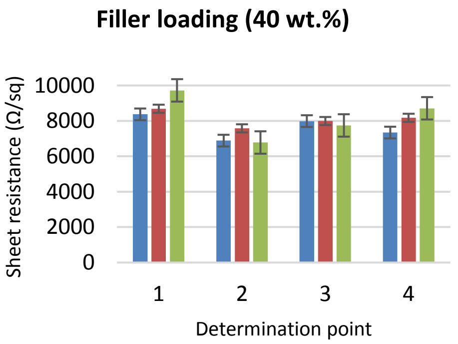


Figure 2 Graph of 40 wt. % filler loading.

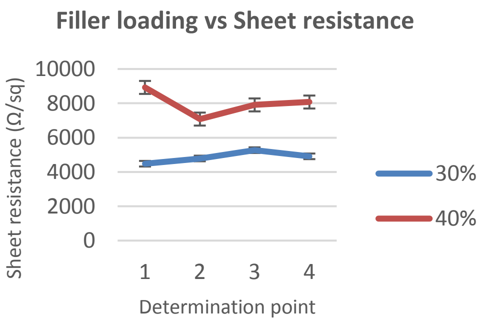


Figure 3 Graph of filler loading vs. sheet resistance

Various composition between filler, binder, and hardener was able to produce different results based on resistivity and the microstructure behavior. As for now, filler at 30% will be chosen as the base formulation to produce high conductive ink. Moreover, the process to formulate the 30 wt. % ink was easier as compared to ink that a high percentage of filler loading.

4. SUMMARY

In conclusion, fabrication of conductive ink can be carried out through several processes; mixing, printing and curing process on the substrate. The conductive ink fabricated were characterized based on the electrical properties to determine the optimum ratio of filler loading. Filler loading at 30wt. % was pointed as the optimum ratio of ink mixture as its show lower resistivity and better ink dispersion.

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