Importance of Annealing Temperature on the Electrical Conductivity of Screen Printed Graphite Organic Paste

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***Abstract*—The effects of annealing temperature on the electrical conductivity of graphite paste printed on alumina substrate were studied via two points probe I-V machine. The characteristics of the annealed material were studied using Raman spectroscopy. The results show that by increasing the annealing temperature the electrical conductivity increases. Raman results indicate that crystallization of the graphitic paste has direct relation with temperature of annealing process.**

***Keywords*— Graphite, Annealing Temperature, Raman, Electrical Conductivity**

I. INTRODUCTION

Graphite is well known as one of the oldest forms of pure carbon. Due to the unique physical properties of these materials, they are essential to our modern life style and fast growing societies. With regard to electronic application, graphite is a promising ultra-conductor due to high thermal conductivity, high breakdown voltage and other exceptional characteristics that result from narrow C-C bonding and sp2 hybridization. However, the mechanical strength of graphite is low and will reduce drastically after annealing. So development of durable graphitic material with high conductivity is necessary.

Organic binders are carbon forming and include materials such as tar, pitch, high temperature modified pitches, phenol formaldehyde resins and alternative bonding system like Thermocarbon. The binders may suffer from limitations like high cost, handling problems, smell and health hazards. Organic binder are used in refractory products with high graphite contents >5%. The graphite content inhibits the sintering, therefore an organic bonding is needed to achieve the strength of the refractory product. Linseed stand oil is one of organic binder that easy to handle. It reduces the consistency oil colors and enhances flow. It is viscous and dries slowly to a tough elastic film. Faster drying than pure linseed oil.

Thin film is favorable due to its thinness and portability; however crystalline graphite is favorable due to its thermal stability and electrical conductivity. Hence there is a need in enhancing the crystalline carbon technology. In other researches, it was shown that surface texturing can be considered as a good candidate to solve the efficiency problem of graphite (Abdullah et al., 2009).

II. EXPERIMENTAL DETAILS

A. Material

Synthetic graphite powder (Gr) with particle size of <20 μm as graphitic material; linseed stand oil, α-terpineol and m-xylene act as binder agents in this experiment.

B. Paste Composition

The preparation of thin film includes the preparation of binder, the preparation of graphite paste, screen printing the graphite paste onto substrate, and heat process after printing.

The particle size of Graphite powder (Gr) was modified into nano size using high energy ball milling machine for 3 hours. The graphite pastes were fabricated by mixing graphite powder (Gr) with binder. The binder was prepared by mixing 2.5wt% α-terpineol and 12.5wt% m-xylene in 85wt% linseed stand oil, which took place through magnetic stirring for 3 hours with 250 rpm at 40°C. Binder was homogenized in magnetic stirrer to obtaining homogenous consistency. Binder and graphite powder (Gr) were mixed in magnetic stirrer for 24 hours with 500-700 rpm at 40°C.*Units.*

C. Characterization

In this experiment we studied the I-V characteristics via two point probe machine. The crystallization was studied using Raman spectroscopy. Electrical resistance is taken from the gradient of the graph.

Electrical resistivity and electrical conductivity can be calculated via formula:-

$$\rho = \frac{RA}{l} \quad (1)$$

Where: ρ is resistivity
R is Resistance
A is Cross sectional area of graphite paste
l is length of the graphite paste

Conductivity, σ is defined as the reciprocal of resistivity. The reason resistivity is defined this way is that it makes resistivity an intrinsic property, unlike resistance. Graphite organic paste, irrespective of their shape and size, have approximately the same resistivity but can be change due to the changing of temperature. Every material has its own characteristic resistivity.

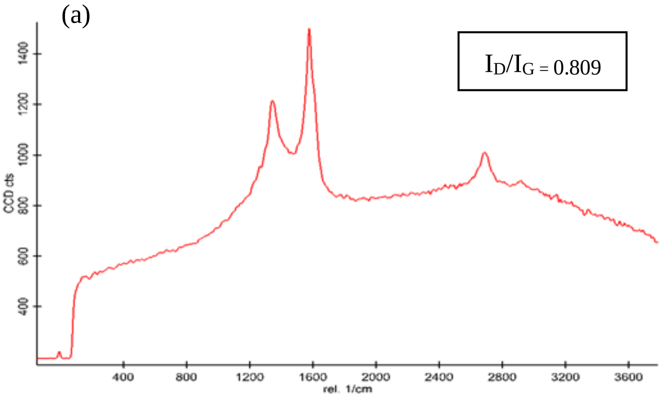
III. Result and Discusion

A. Influence structure of annealing temperature

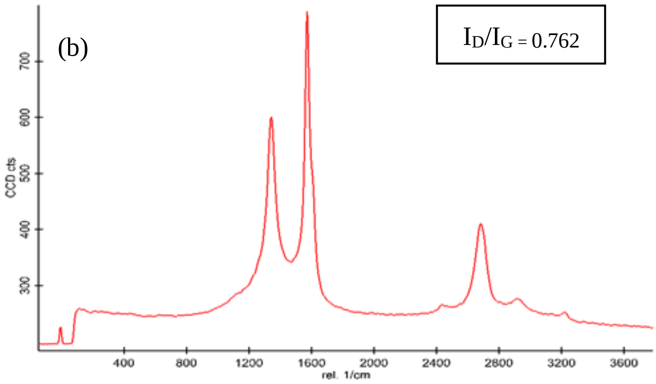
Since all graphitic materials are black in color with a similar density, the characterization of graphitic samples to distinguish one from another is important. Before mechanical tests, conductivity or other electrical measurements, it is common to carry out standard characterization measurements on sp2 graphitic materials which best can be done using Raman spectroscopy.

Fig. 1 shows the Raman spectrum of graphite paste on substrate with different annealing temperature for 3 hour. The most prominent features in the Raman spectra of graphitic material are the so-called G band appearing 1582 cm-1 (graphite), D band at about 1350 cm-1, and G´ band (2D band) about 2700 cm-1. All kind of graphitic materials exhibit strong Raman band which appear in 2700 cm-1 and this feature corresponds to the overtone of the D band.

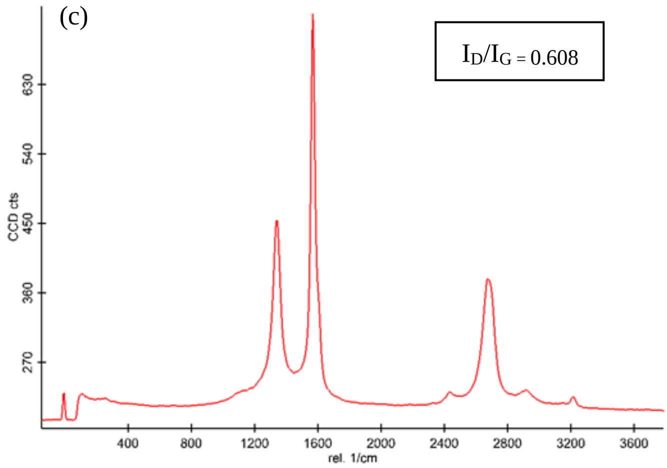
In graphitic sample, there are different in-plane crystalline size La, and concluded that the ratio of the D and G band intensities (ID/IG) is inversely proportional to the in-plane crystalline size La.



Annealed for 3 hr at 300 °C



Annealed for 3 hr at 400 °C



Annealed for 3 hr at 500 °C

Fig. 1 Effect of annealing temperature on structure of Screen Printed Graphite Organic Paste

B. Influence electrical conductivity of annealing temperature

The graphite paste printed on substrate were separately annealed at 300 °C, 400 °C and 500 °C for 3 hours. Then the resistance was measured by the gradient of i-v graph. The resistivity and conductivity were calculated as explained above. The results are shown in Fig.2 and Fig.3. Electrical resistivity is an intrinsic property that quantifies how strongly a given material opposes the flow of electric current. A low resistivity indicates a material that readily allows the flow of electric current. Electrical conductivity is the reciprocal of electrical resistivity and measure a material's ability to conduct an electric current.

It can be seen from Fig. 2 and Fig. 3 that the electrical conductivity increase, while the resistivity decrease after annealing at different temperature. When the annealing temperature is higher, the recrystallization, grain grow up, following the rising of electrical conductivity. With the decline of resistivity, the electrical conductivity incline but it become brittle that show the tensile strength decreases.

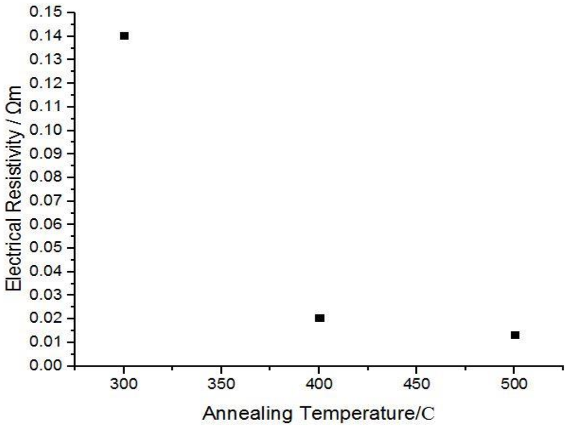


Fig. 2 Effect of annealing temperature on electrical conductivity of screen printed graphite organic paste

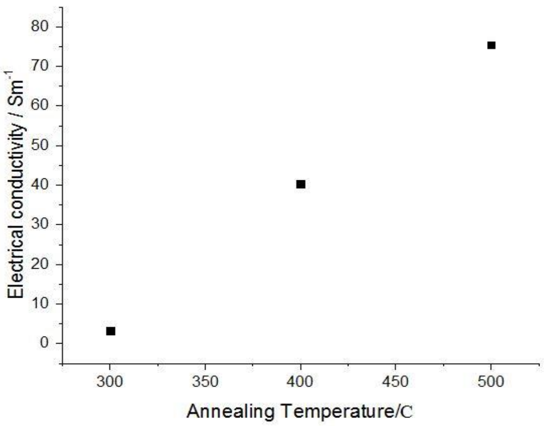


Fig. 3 Effect of annealing temperature on electrical conductivity of screen printed graphite organic paste

IV. CONCLUSION

A review of the Raman spectra of graphite was presented. The D and 2D Raman peaks change in temperature. This reflects the evolution of the electronic structure. Doping upshifts and sharpens the G peak. Disorder can be monitor via the D peak. Thus Raman Spectroscopy can be efficiently used to monitor a number of layers, quality of layers, doping level and confinement in graphite nanosturctures. The investigation of the decrease of Raman I_D/I_G ratio has been used to interpret the annealing process.

The results show the electrical conductivity increase while the resistivity decrease when annealing temperature become higher because of the recrystallization occurs during the annealing process. Graphite is an electrical conductor. It can conduct electricity due to the vast electron delocalization within the carbon layers. These valence electron are free to move, so are able to become conductivity due to changing of temperature.

ACKNOWLEDGMENT

We thank Dr. Ismayadi for many helpful discussion about Raman scattering in graphite and also for help with Raman measurement used in Fig. 1. In addition we thank Intan for useful suggestion of screen printing and two point probe I-V machine. The work was supported by the Department of Higher Education, Ministry of Higher education under Nanomite.

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