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Analysis of Hexagonal Boron Nitride Based Film for Thermally Conductive Printed Circuit Boards

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ABSTRACT: Power electronic devices are usually heavy in size due to the thermal management systems in them. The size reduction of the device is not possible with large heat sinks. Here, a model of thermally conductive printed circuit board (PCB) structure that can also act as a heat sink is discussed. This method will help to reduce device size by eliminating large heat sinks. In this work, a thermally conductive base is needed for making thermally conductive PCB. Hexagonal boron nitride(h-BN) is an electrically insulating material which is thin filmed on a copper plate using RF sputtering. Then determined the band gap of h-BN film is determined by using UV-Vis spectroscopy and also determined the resistance of the films using source meter. From the results, it is found that the RF sputtering not affects the band gap of h-BN film and it possess very large resistance. So, the h-BN coated copper sheet possesses a good thermally conductive and electrically nonconductive.

KEYWORDS: Hexagonal boron nitride thin films, RF sputtering, printed circuit board, UV- Vis spectroscopy of h-BN films, electrical analysis, thermally conductive PCB.

I. INTRODUCTION

Power electronics devices are capable of handling high current and voltage. Such devices are used in many applications like electric vehicles and heavy industrial machines, etc. Today, the electronic devices are becoming very small thus it saves lot of space. But power electronic devices [1], [2] are usually huge because of their thermal management system. In this research, an effort is made to reduce the size of the huge electronic device by changing its rigid circuit board to a flexible one. The electronic components and circuits are made using an insulating board called Printed Circuit Board (PCB) [3], [4]. Typically, PCBs are rigid because of its weight management and current carrying capacity. One of the main features of this rigid PCB is its capability for accommodating temperature reducing heat-sinks. If a rigid PCB is converted to flexible, one can't attach heat-sinks on it. So, the aim is to avoid using these heat-sinks and introduce a new technique for reducing the temperature of the components in the flexible PCB. Here, a flexible PCB which conducts heat from components to the surrounding air is developed. This flexible PCB itself act as a heat sink.

In this work, for developing the heat conducting flexible PCB, a flexible copper sheet is used as a base layer, over which an insulating material is coated. Copper conductive tracks are deposited on this insulating layer. The deposition technique to coat the h-BN film [5], [6] is RF sputtering [7]–[10] and deposition method used for copper deposition is thermal evaporation. The current and voltage carrying capacity are carried out for testing the effectiveness of proposed PCB. Also, the UV-vis analysis is done for finding the band gap energy of the insulating material.

II. METHOD OF STUDY

Figure 1 shows the proposed structure of PCB. The structure contains 3 layers: conducting copper track, insulating layer and copper base layer. The heat generated from the copper tracks and components are passed through insulating h-BN layer and reaches to copper base layer. The copper base layer transfers this heat to air using convective heat transfer. The h-BN insulating layer gives very high electrical insulation strength and provides negligible heat block.

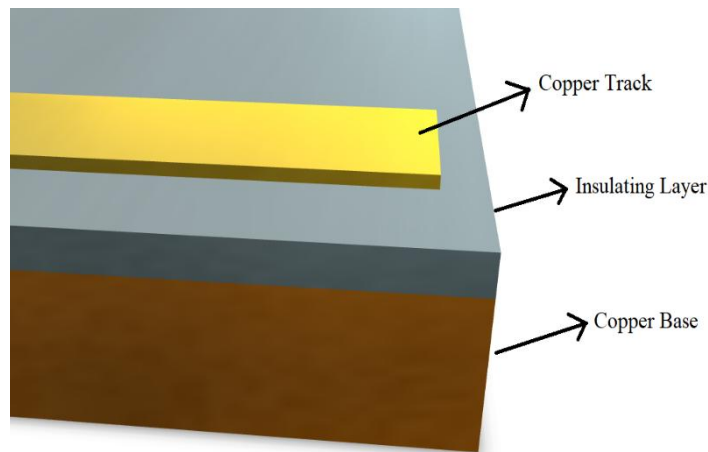


Figure 1: 3D model of proposed PCB

Two analysis are done in proposed PCB structure: UV-vis analysis and electrical analysis for the study of the proposed PCB.

In the UV-vis spectroscopic analysis, the absorption spectra of the h-BN layer after RF sputtering is obtained. The main purpose of this analysis is to study how the RF sputtering affects the properties of the h-BN material. For the analysis of RF sputtered h-BN film, 300nm h-BN film is fabricated. The chamber used for sputtering is initially pumps down to 0.007 bar pressure and applied 180w of RF power to the magnetron. It will take 30 minutes for the fabrication of 300nm h-BN film.

For electrical analysis the h-BN is coated over the copper plate and then copper is coated above the h-BN layer. The source meter probe is connected to the base copper plate and the coated copper layer. The source meter's voltage is varied from 0 v to 20 v and the value of current flow is measured. Using these applied voltage and measured current values, a V-I graph is plotted and the resistance of the layer is calculated.

III. RESULTS

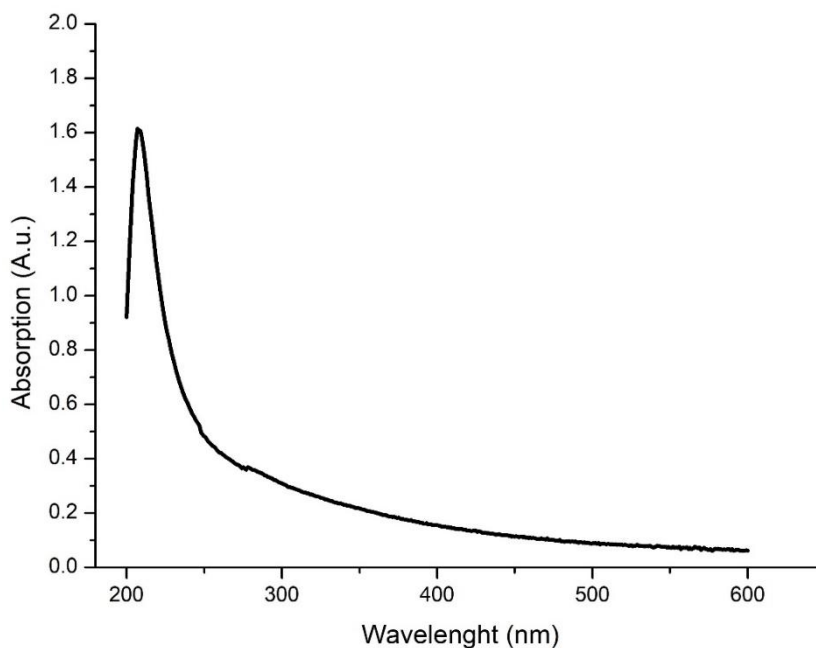


Figure 2: UV - vis absorption graph of h-BN layer



From the results, the wavelengths at which peak absorption occurred is at 300 nm. The absorption wave length and absorption peak of 300nm films is 207nm and 1.63228 respectively. From the absorption data, the band gap energy of the h-BN film can be calculated[11]–[13]. The band gap of h-BN film of 300nm thickness is taken because, the properties such as band gap energy gets changed due to the sputtering. Figure 2 shows the UV spectra of 300nm film of h-BN. The band gap energy of the insulating material is found out from UV – vis absorption data using equation 1.

$$E = hc/\lambda \quad (1)$$

In equation 1, E is the band gap energy, h is the plank’s constant c is the speed of light and λ is the absorption peak. Using the values from UV-vis analysis the value of band gap is calculated. The value of band gap is 6.05 eV.

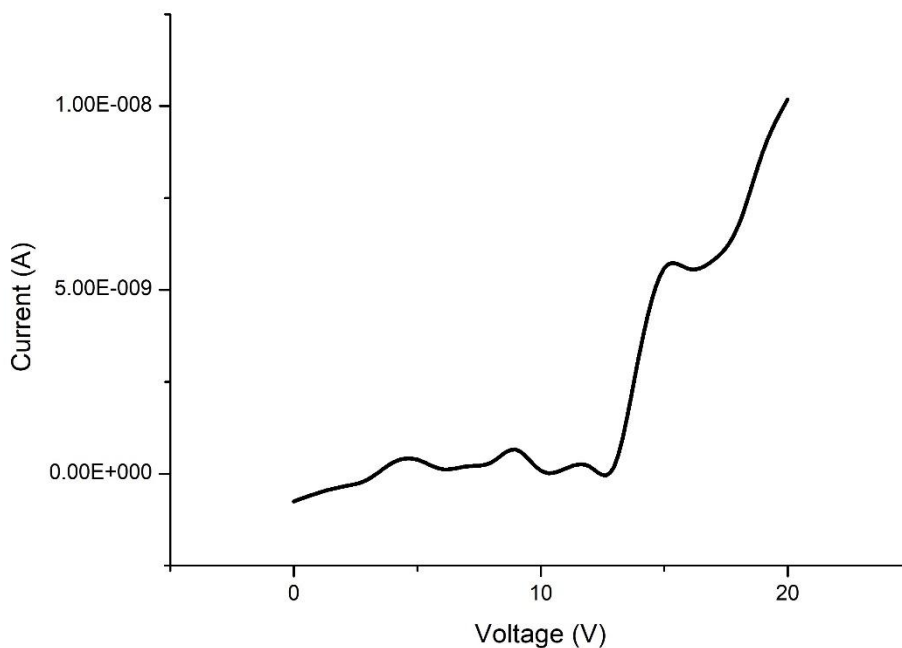


Figure 3: V-I characteristics of the h-BN layer

From the electrical analysis of h-BN layer, V-I characteristics is plotted using source meter. The V-I analysis shows that the voltage increases as the current through the layer increases. But this current is very small and it is in the range of nano amperes. But after 12V the current rises sharply due to the layer breakdown. The resistance of the h-BN layer is calculated as 4.3302 Giga Ohms which is very large and it is enough for an insulating layer in the proposed PCB. Figure 3 shows the V-I characteristics of h-BN layer.

IV. CONCLUSION

The electrical, UV-Vis absorption and band gap energy properties of the h-BN film are not changing with RF sputtering. So, RF sputtered h- BN layer can be used as an insulating layer in high power circuitry. The main drawback of sputtering is, it can be used only for small area of coating. For a large area coating, substrate rotation should be added during the sputtering. Also, the rotation of the substrate helps to get uniform thin film. In future studies, the XRD and SEM analysis helps to identify further structural variation and surface properties of the h-BN film. The RF sputtering is a physical vapour deposition method and hence it avoids the usage of dangerous chemicals. Thus, it is an eco-friendly and low-cost fabrication technique.



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