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An Experimental Approach of DLC Film Deposition on Metal Substrates

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Abstract — **In this paper an experimental approach of depositing diamond like carbon (DLC) on metal substrates has been described. By electrolysis of 10% (by mass) camphoric solution in methanol, attempts were made to deposit DLC films on Copper (Cu) and Aluminum (Al) substrates at room temperature. Solution is prepared using camphor (C10H16O), a natural source in methanol solvent. At first we applied this approach on Cu substrate and then on Al substrate. The surface morphologies of deposited films were examined by scanning electron microscopy (SEM). A comparison between Cu and Al substrates has been also presented under this approach.**

I. INTRODUCTION

Interest in depositing diamond like Carbon (DLC) films has been motivated by the properties of the materials and the demand of modern technologies. These properties include chemical inertness, high electrical resistivity, high dielectric strength, optical transparency, biological compatibility, and high thermal conductivity. These economically and technologically attractive properties have drawn almost unparalleled interest towards DLC film coatings on various materials. Many studies have been reported on the deposition of DLC films [1-8]. In [1-4], the attempts were taken to deposit DLC films on Si substrate. In [1], [3], [4], liquid phase deposition techniques were applied. Electrolytic properties of organic solutions had been used. The approaches described in [5-8], were for metal substrates. The techniques, which were described in [2], [5-8], are generally known as the vapour phase deposition techniques. These include high intensity ion beam (HIPIB) ablation, plasma enhanced chemical vapour deposition (PECVD), ion beam assisted deposition ion beam assisted deposition (IBAD) etc. Since DLC films synthesized in the liquid phase have significant scientific and technological implications, it is worth pursuing research with electrolytes. Deposition of DLC films on metal substrates in the liquid phase is seldom reported. There are experimental evidences that materials that can be deposited from the vapour phase can also be deposited in the liquid phase using electroplating techniques and vice versa [9]. Based on the observations in [10], it was suggested that camphor (C10H16O) and camphor like other precursors might be the best-suited candidates as starting materials for semiconducting carbon films for electronics applications.

In this study, by electrolysis of 10% (by mass) camphoric solution in methanol, an attempt is made to deposit DLC film on Cu substrate at room temperature. Solution is prepared using camphor, a natural source in methanol solvent. We followed the same procedure for Al substrate as well.

II. EXPERIMENTAL DETAILS

A schematic diagram of the experimental set up is shown in Fig. 1. Cu or Al substrate with a size of $3.2\times1.5\times0.1$ cm^3, have mounted on the negative electrode in this electroplating technique. The pure water, CH_3COCH_3, CH_3OH cleans the substrates successively. The average distance between the substrate and positive electrode was 1.5 cm. The DC voltage applied to between electrodes could be varied from 0 to 3500 volts. A thermometer is adjusted to the system to measure the temperature of the solution during the deposition occurs. The temperature was kept below 60 ^{0}C. A DC voltmeter is connected across the power supply to measure applied voltage. A mili-ammeter is also connected to the supply line to measure current.

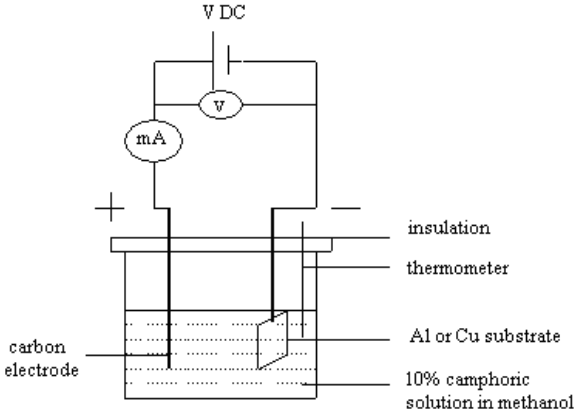

Fig. 1. Experimental set up of DLC film deposition on Cu and Al substrates

The current density of substrate plays an important role in film formation from an organic solution [11]. Higher current density indicates more polarized charged particles move from solution to electrode, which may have some effect on the growth rate of film. Fig. 2 shows comparative plots of current density versus applied voltage between Cu and Al substrates. The temperature of the solution was always kept below 60^0C, at this condition maximum current density (10 mA/ cm^2) was achieved at DC 1200 volt. According to Fig. 2, higher current density is observed in case of Cu than that of Al under same applied voltage.

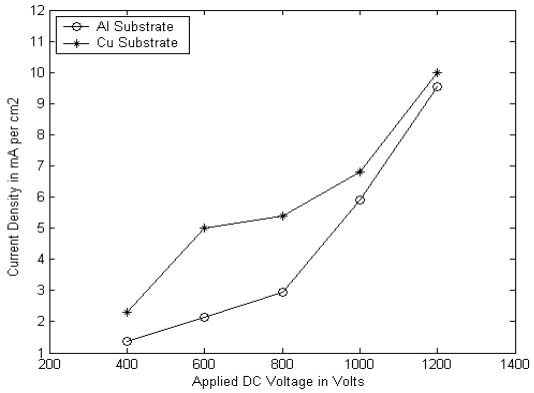

Fig. 2. Comparative plots of current density versus applied voltage for Cu and Al substrates.

III. RESULTS AND DISCUSSIONS

We obtained two samples of Cu substrate. The first one was taken for 3 hours and the second one was taken for 10 hours of deposition time. The surface morphology of the deposited films was examined by scanning electron microscopy (SEM). Fig. 3 and Fig. 4 show the micrograph of front and back surface of the first sample respectively. Fig. 5 and Fig. 6 show the micrograph front surface and cross section of the second sample respectively. It is clear that the micrograph of front surface (see Fig. 3) and that of back surface (see Fig. 4) are totally different. The films were deposited only on front surface of Cu substrate. The microgr-

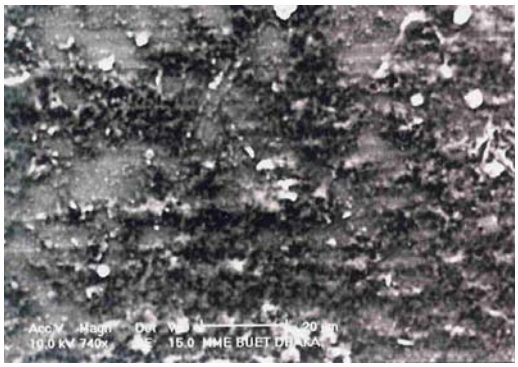

Fig. 3. SEM micrograph of the front surface of Cu substrate with 3 hours deposition.

ph of cross section (see Fig. 6) shows almost no film. However it was taken under deposition process for 10 hours. Let us observe the micrographs of the front surfaces shown in Fig. 3 and Fig. 5. The density of the deposited films in Fig. 5 (deposition time 10 hours) is higher than that of in Fig. 3 (deposition time 3 hours). It reveals that deposition density increased with increasing deposition time.

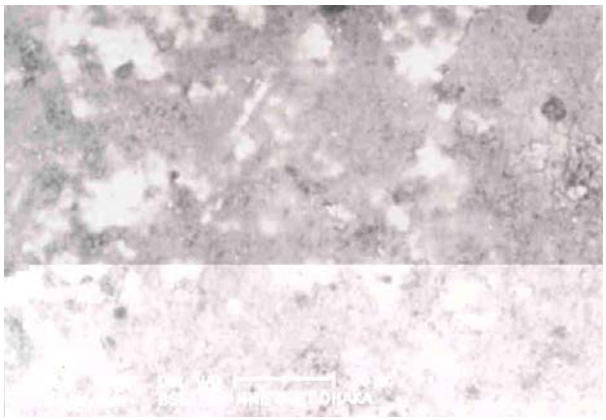

Fig. 4. SEM micrograph of the back surface of Cu substrate with 3 hours deposition.

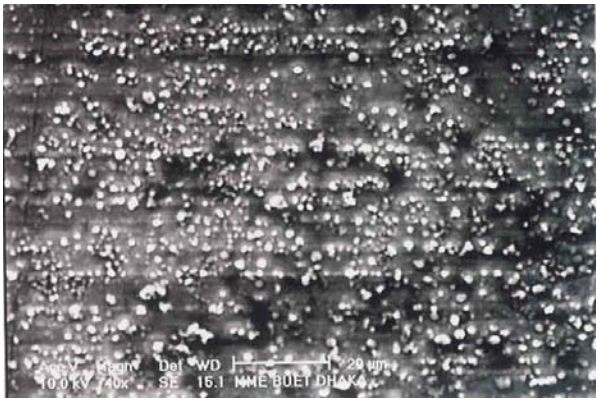

Fig. 5. SEM micrograph of the front surface of Cu substrate with 10 hours deposition.

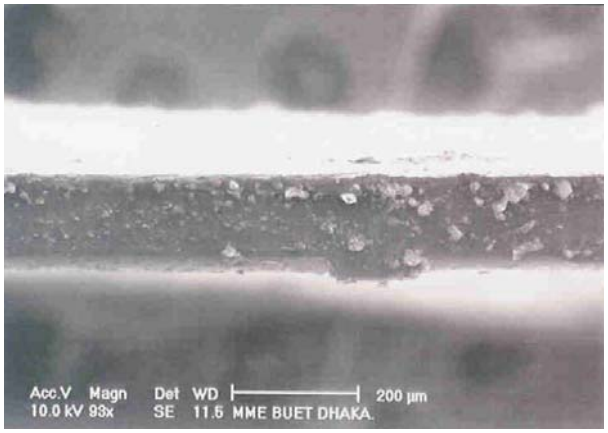

Fig. 6. SEM micrograph of the cross section of Cu substrate with 10 hours deposition.

During the deposition of film, the carbon atoms might combine at the surface to form all possible combination of sp1, sp2, and sp3 bonds. The trigonal (sp2) or tetrahedral (sp3) configurations dictate graphite or diamond structure. Amorphous carbon refers to carbon network that has sp2, sp3 bonding structures and almost no sp1 bond. Similar types of micrographs were also observed in the previous attempts of DLC film deposition. From the configuration of the deposited film that seen in the micrographs (see Fig. 3 and Fig.5), we assume that the films deposited on Cu substrate are DLC films.

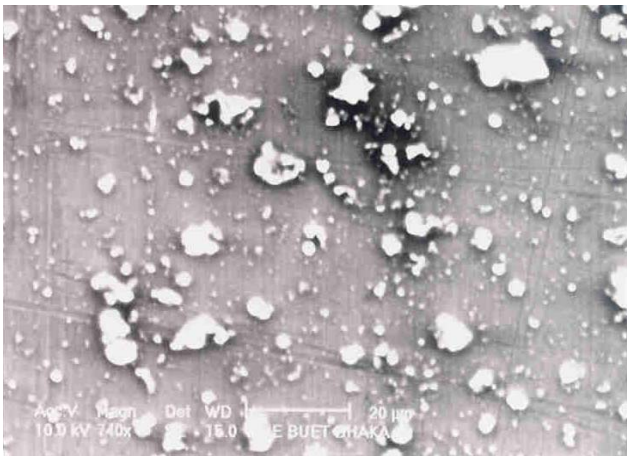

Fig. 7. SEM micrograph of the front surface of Al substrate with 4 hours deposition.

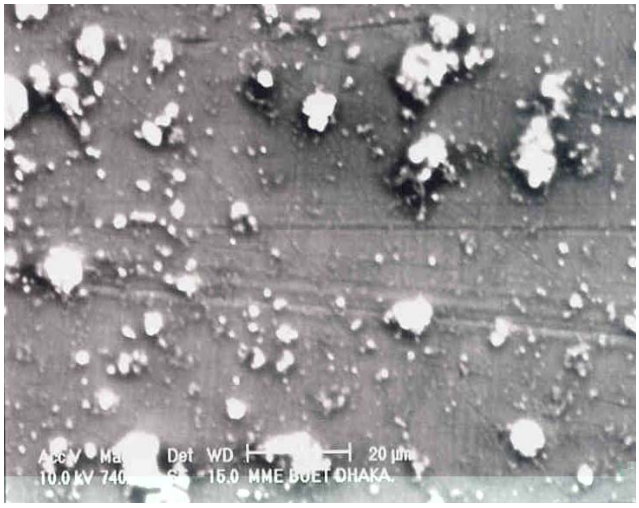

Fig. 8. SEM micrograph of the front surface of Al substrate with 10 hours deposition.

Fig. 7 and Fig. 8 show the micrographs of Al substrates (front surfaces) for 4 hours and 10 hours respectively. According to Fig. 5 and Fig. 8, it is clear that density of deposited films on Cu substrate is much higher than then of Al substrate (for both deposition time was 10 hours). Earlier, it was predicted from the plots shown in Fig. 2. The density of deposited films on Cu substrate shown in Fig. 5 (deposition time 10 hours) is much higher than that of Fig. 3 (deposition time 3 hours). It reveals that deposition density increased with increasing deposition time. The technique which is described here, works better on Cu substrates as shown in the micrographs of Fig. 3 and Fig. 5. We do not find any significant change between micrographs of Fig. 7 and Fig. 8, since the Al substrates were used for film deposition.

IV. CONCLUSIONS AND FUTURE WORKS

In this study, we described a novel approach of DLC film deposition on metal substrates, which is a liquid phase deposition technique. We applied the technique on Cu and Al substrates. We examined surface morphology of the obtained samples by using SEM. It is found that the technique is efficient for depositing DLC films on Cu substrate. Future work can be carried out on Raman spectroscopy of the deposited samples of Cu substrate. It will help to know the structure (sp3 and sp2 ratio) and the quality of the deposited film.

V. ACKNOWLEDGEMENTS

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