



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)**

**EFFECT OF POLYCATION ADDITIVE ON ELECTROPHORETIC  
DEPOSITION OF SURFACE FUNCTIONALIZED BORON NITRIDE  
PARTICLES**

This report is submitted with requirement of the Universiti Teknikal Malaysia Melaka (UTeM)  
for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

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# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Nowadays, electronic devices are constantly shrinking in size while becoming more powerful resulting in increased heat concentration in the device. As a result, thermal management has become crucial to ensure the performance and reliability of high power chips and micro-cooling systems. Actually, when electricity is passed through transistors mounted on an integrated circuit, the transistors, particularly power transistors, generate a substantial amount of heat. Therefore, the heat must be drawn away from the transistors and dissipated to maintain low temperatures and to avoid damaging the transistors. Thus, in this case, electronic packaging is very important to provide mechanical support and manage the heat dissipation of electronics since microelectronics temperatures have significant effect on their reliability since increasing temperature will dramatically decrease electronics life time and performance.

The focus are on the transistor where the device that need the improvement to increase its performance. Transistor is the component that use to amplify and switch the signal. As for the example, one of the type of transistor is optical transistor that use to amplify and switch the optical signal. Electronic transistor is the fundamental building block of modern electronic devices. To replace electronic components with optical ones, an equivalent optical transistor is required (Wang et al., 2015). Therefore it really important to improve the development of the devices in order to increase its reliability.

Much attention is given to overcome heat dissipation problem in power transistor through improvement of materials and design of heat sink, less focus to the thermal interface materials (TIM) between power transistor and other components on Integrated circuit (IC). Usage of ceramics as TIM improves heat dissipation and give better reliability. According to Mashregi (2012), as the microelectronic devices shrinkage that means it decrease in size the demand for high performance thermal interface materials (TIMs) increases. A TIM is thermally conductive material, which is applied on surface of microelectronic component (e.g. transistor) in order to increase heat removal efficiency. There are much different type of TIMs such as, thermally conductive adhesive tapes, phase change materials, thermally conductive gap fillers, thermal greases and thermally conductive cure-in-place compounds. TIM is used to quickly dissipate the heat from the electronic devices to maintain them well (Tang et al., 2015) by decreasing the thermal contact resistance between the gap of electronic device and the other component (Garimella et al., 2008). In addition, high dielectric strength is an important property for TIM to overcome short circuit problem (Keitel et al., 2014). The dielectric strength is a measure of the electrical strength of a material against electrons flow.

The chosen of TIM should be the material that excellent in thermal conductivity. In past few years, significant attention has been paid to Alumina. Alumina possess a unique combination of many excellent properties especially in thermal conductivity. The usage of alumina will increase the thermal properties to 1-5 W/mK. In recent years, some

attention has been paid to Boron Nitride as it offers low density that exhibits exceptionally high thermal conductivity with outstanding dielectric strength. Boron Nitride (BN) is a potential material for high performance TIM because it has low density, high thermal conductivity, stability, high mechanical performance (Wang et al., 2011) and high dielectric strength. It shows no creep or migration over a wide temperature range and it has non corrosive with high dielectric strength.

According to (Ye et al., 2015), BN have exist in various type of crystallographic forms such as hexagonal, cubic, wurtzite, rhombohedral and turbostratic. However, hexagonal (h)-BN possesses anisotropic and excellent thermal conductivity (Kuroda et al., 2008). In addition, h-BN has high dielectric strength, because of its strong covalent bond and the lack of free electron (Steinborn et al., 2014). Typically, high-purity pyrolytic *h*-BN has excellent high-temperature mechanical and thermal properties (Zhang et. al., 2015). Moreover, the apparent porosity of h-BN will largely enhance the dielectric performance (Feng et al., 2015).

## 1.2 Problem Statement

The way how the h-BN TIM is prepared determines its thermal conductivity and dielectric strength performance. Among many other coating technologies used to produce Boron Nitride TIM chemical vapor deposition(CVD), physical vapor deposition(PVD), sol-gel, plasma spraying, and tape casting, the Electrophoretic Deposition(EPD) technique has emerged as one of the most promising technologies due its versatility, simplicity, and low cost. Electrophoretic deposition (EPD) method has advantages such as simplicity, controllability of complex shape coating, significant rate of deposition, low cost and being environmentally benign. The EPD is a colloidal process where charged particles in a stable suspension move and deposit onto the oppositely charged electrode under an applied electric field. However, EPD of particles leads to inhomogenous layer thickness

distribution on the workpiece because of weak mechanical locking between the deposited particles (Keller et al., 2015).

The problem that usually occurs during EPD process is lower surface charges and greater particle weight also decrease thus will decrease the mobilities of particle. In order to overcome this problem by the using of polycation that provides additional surface charge and steric stabilization. In addition, these polycation also act as binder to improve adhesion between deposited particle and substrate. The polycation are usually added to the bath formulation in order to improve green strength, deposit adhesion and to avoid cracks. Charged particles provide electrophoretic transport of electrically neutral binders to the electrode surface. Improvement in particles' bonding contributes to even and thicker film, which may result in a higher dielectric strength TIM. Polycation can provide additional surface charge and steric stabilization on the particles in EPD process (Lau & Sorrell, 2010). This improve adhesion between deposited particles and substrate. The surface charge value is directly proportional to stability of the suspension. The stability is measured by its suspension time. The longer the suspension time the higher the stability. While, surface charge value is measured by zeta potential and sedimentation testing.

However, need to give attention that before polycation binder is applied onto h-BN particles, h-BN need to be treated with inorganic solution ( Jin et al., 2013) such as NaOH solution to functionalize their surface with  $-OH$  groups (Kim et. al., 2014). This is because of the difficulty to modify the surface of hBN due to its special structure. In detail, hBN has molecularly smooth basal planes without functional groups for chemical bonding and/or interaction. Therefore, functionalization of h-BN is required because it increases total surface charge on the particles, and this enables chemical bonding with Polycation to occur (Kim et al., 2014), (Jin et al., 2013).

### **1.3 Objectives**

Objectives for this project are:

- (1) To prepare and characterize Boron Nitride suspension added with different PDADMAC concentration.
- (2) To deposits and characterize Boron Nitride coating prepared by Electrophoretic Deposition method using the suspension as stated in objective (1)

### **1.4 Scope**

For objective (1), the scope for this objective is to find the optimum concentration from different prepared concentration PDADMAC in fixed amount of Boron Nitride. To characterize the different concentration of PDADMAC concentration is by using sedimentation test. The optimum concentration of PDADMAC will determined by the stability of the Boron Nitride suspension that is no particle will agglomerates or sediment at the below.

For objective (2), the scope of this objective is deposits Boron Nitride coating prepared by suspension with different PDADMAC concentration by using cathodic electrophoretic deposition method. The voltage is 50 V in 5 minute. The voltage used and the time taken can be changed in order to get optimum concentration of polycation used as to increase the thickness of deposited yield. To measure the characterization of the final product is by weighted the deposited yield, study the structure of deposited yield formed or its morphology and its functional group.

## **CHAPTER 2**

### **LITERATURE REVIEW**

This chapter will make a review on the previous research that are related to this project.

#### **2.1 Introduction to Thermal Interface Material (TIM)**

Nowadays, most of the electronic industries have an intention on a progress of miniaturizing device component. It is not only concern about the miniaturizing but also accomplishing of brisk heat scattering (Liu et al., 2015). As the device is become smaller, the thermal management of the component is becoming more challenging. Thermal management is very important in electronic cooling as the power density is expected to exceed  $100 \text{ W/cm}^2$  (Roy et al., 2015). Moreover, an increasing of little temperature would

obviously decrease the life and unwavering quality of electronic components because of the strong relationship between device reliability and operating temperature. Therefore, quick dissipation the heat from electronic device is crucial to maintain them work well. In addition, it will also decrease the thermal resistance between the devices to another. One of the thermal management areas in electronic involve reducing thermal conductivity and thermal resistance is by using Thermal Interface Material (TIM) (Bhavnani et al., 2015). TIM are utilized widely to enhance thermal conduction crosswise over two mating parts. Interface is an essential structure in the materials, some fairly unconventional physical marvels can happen at the interface under the use of the outside physical field. A perfect TIM would offer low thermal resistance with a slight bond line thickness (BLT), a high thermal conductivity, comparability at low to direct weights, great wetting properties, simplicity of assembling, and minimal effort while additionally being ecologically what's more, wellbeing agreeable (Roy et al., 2015). A perfect TIM must have high thermal conductivity and low coefficient of thermal expansion. Moreover, the material must be sufficiently delicate to be effortlessly distorted by contact weight to fill every one of the holes between the mating surfaces. Figure 2.1 is the example schematic diagram of TIM placement from the previous research.

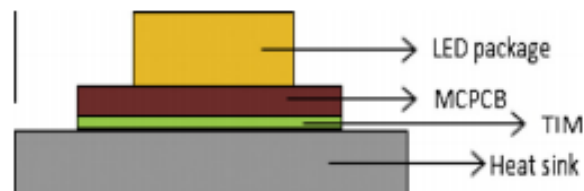


Fig 2.1. Schematic Diagram of the TIM placement in the thermal set up (Hashim et al., 2014)



### **2.1.1 Usage of Ceramic as Thermal Interface Material (TIM)**

Generally, TIM is fabricated using polymers loaded with high thermal conductivity filler ceramics material such as alumina and silica. High volume fraction of filler (50-70 vol.%) is required to achieve thermal conductivity values of 1-5 W/mK ( Hu et al., 2015). Ceramic material are popular in application of using high temperature due to their high melting point and physical stability (Li et al., 2014).

## **2.2 The chosen of Boron Nitride as TIM**

The material chosen for TIM is must has high thermal conductivity and high dielectric constant. Boron Nitride (BN) has the unique properties as well as semiconducting with constant band gap, high chemical stability, and excellent mechanical properties (Singla et al., 2015). Moreover, BN is an entirely adaptable inorganic compound that get a lot of consideration for an extensive variety of modern application for the example surface coating and insulator due to its unique properties such as larger thermal conductivity, good electrical resistance non-toxicity and environmental friendliness (Kostoglou et al., 2014).

### **2.2.1 Crystallographic structure of Boron Nitride (BN)**

Boron Nitride has several variety form of its crystallographic structure. The crystallographic structure determine the properties of Boron Nitride. The crystalline structures is includes cubic, rhombohedral, wurtzite, and hexagonal. The hexagonal polymorph is the steadiest one and its display a structure like graphite.

### 2.2.1.1 Cubic Boron Nitride (c-BN) crystal structure.

c-BN has outstanding physical and chemical properties similar to diamond such as high hardness, high thermal conductivity, large band gap, and high breakdown field. Among the potential advantage of interest of c-BN over diamond is that c-BN is synthetically inert against ferrous materials and resistant to oxidation even at high temperatures up to  $\sim 1000^{\circ}\text{C}$ . c-BN can be incorporated as films from vapor phase (Teii et al., 2014). It is not found in nature but can be synthesized by application of high temperature and pressure. Thus, c-BN has important potential application in high-temperature and high-power electronic devices, and UV optoelectronic devices (Li et al., 2014). Figure 2.2 show the image shown from the SEM of c-BN crystal structure.

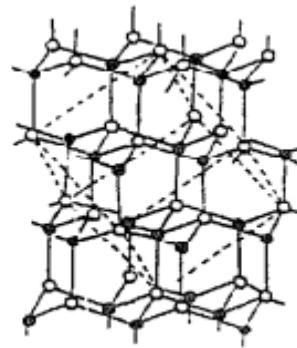


Fig 2.2 Structure model of c-BN (T. Taniguchi et al) (1997)

### 2.2.1.2 Rhombohedral Boron Nitride (r-BN) crystal structure

Rhombohedral boron nitride (r-BN) layers were grown on sapphire substrate in a hot-wall chemical vapor deposition reactor.

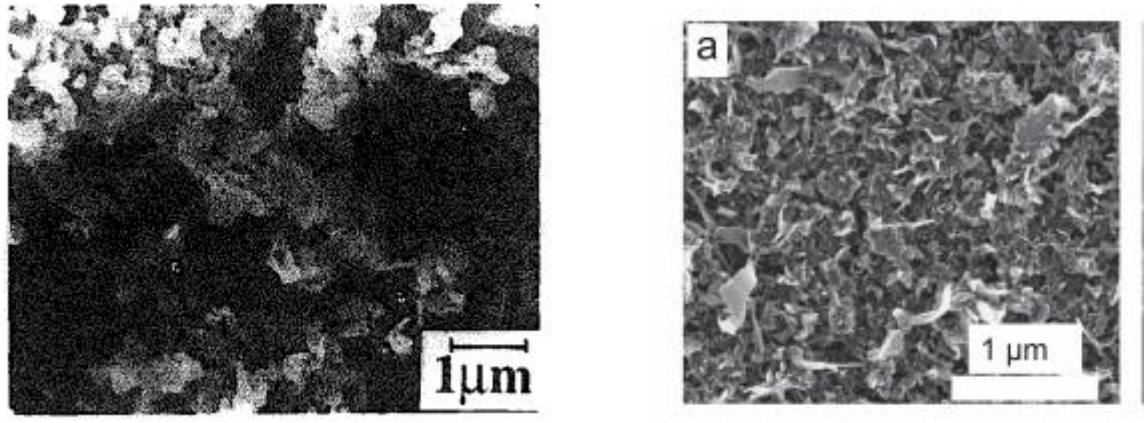


Fig 2.3 SEM image of r-BN (Tagunachi et al., 1997)

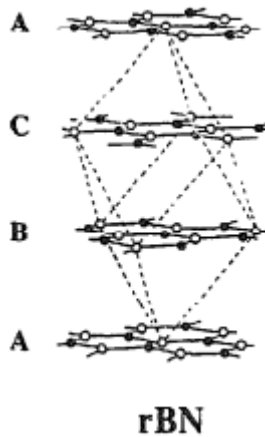


Fig 2.4 Structural model of r-BN (Taniguchi et al., 1997)

### 2.2.1.3 Wurtzite Boron Nitride (w-BN) crystal structure

Structure of Wurtzitic Boron Nitride (w-BN) can be synthesized from two way that is from hexagonal graphite-like modification (hBN) by the mechanism of layer puckering and from the rhombohedral graphite-like modification (rBN) by the process of

mechanism of layer buckling (Britun et al., 1999). The structure formed are different according to its type of modification. The modification occur is under high applied pressure onto the structure. w-BN have the lowest thermal properties compare to the others crystal structure. The graph in the Figure 2.5 show the amount of transformation of w-BN to r-BN as a function of time.

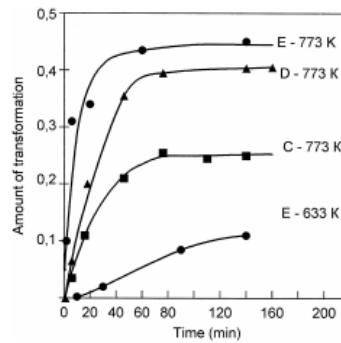
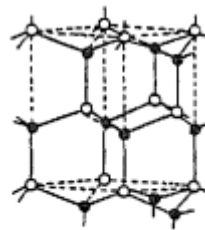


Fig. 2.5 Amount of r-BN into w-BN transformation as a function of time. (Britun et al., 1999)

Next, the figure 2.6 show the structure model of w-BN.



wBN

Fig 2.6 Structural model of w-BN (Taniguchi et al.1997)

#### **2.2.1.4 Hexagonal Boron Nitride (h-BN) crystal structure as TIM material**

Nowadays, modern industries also concern in addition of various filler to the polymer matrix. Most of them are focusing on carbon based filler. But its shape is more complex in term of process to achieve the goal of both thermal conductivity and thermal resistance (Yu et al) (2011). Therefore the ceramic material that have both properties are required. High thermal conductivity properties for the polymeric matrix can be achieved due to high filler load and good matrix-filler contact.

In the past few years, a few hexagonal nano materials, for example, h-BN have been generally manufactured and considered in both theoretically and experimentally approaches. h-BN is known to be important ceramic material that are chosen as TIM. Basically, high-purity pyrolytic h-BN has excellent high-temperature mechanical and thermal properties (Zhang et al., 2015) which make use of its high temperature resistance and chemical inertness against many metallic liquids.

Another application is its use as precursor for high pressure and high temperature (HP/HT) conversion to superhard cubic Boron Nitride (c-BN) (Schimpf et al., 2015). As we known, pure h-BN have large variety of microstructure defect. The defect are formed from the fabrication process and mechanical loading (Motylenko et al., 2013). As a results, the defect were identified to have a significant impact on electrical and dielectric properties and on the HP/HT conversion process. In the HP/HT change process, a high thickness of turbostratic issues or a high degree of basal plane creases in h-BN support the arrangement of c-BN specifically from hBN, while an almost desert free h-BN changes first into wurtzitic BN (w-BN) under generally indistinguishable conditions (Schwarz et al., 2015). Therefore, BN nanocomposites with customized stage creation can be delivered on the off chance that the stage development amid the HP/HT change process.

The concern of h-BN properties that is high thermal conductivity, low compressibility and wide band gap properties make them interesting candidates for high temperature

electronic components such as transistor. The structural of h-BN which is same with graphite could increasing the thermal conductivity. The Figure 2.7 the structural of h-BN.

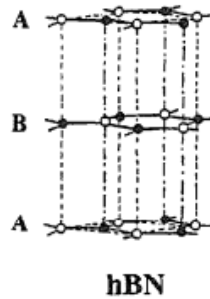


Fig 2.7 Structural model of h-BN (Taniguchi et al., 1997)

h-BN crystal structure also very related to high thermal resistance. It is very useful to the electrical resistance between the devices on the circuit. In this work, the microstructure, dielectric breakdown resistance (dielectric quality), what's more, low permittivity of diverse BN earthenware production and composites were explored. Other than displaying a high particular electrical resistivity of  $10^{13}$ – $10^{15}$   $\Omega\text{cm}$ , the materials had incredible dielectric strength (up to 53 kV/mm) and low electrical porousness (4.1). The dielectric quality depended clearly on the porosity and to a lesser degree on the substance of auxiliary stages, while the permittivity was impacted by the auxiliary stage (Steinborn et al., 2013).

Thermal conductivity and dielectric strength property also depended on the structural of the h-BN that have similarity with graphite. It crystalize in the space group  $P6_3/mmc$ . The solid covalent B-N bonding and the absence of free electrons result in a high electrical resistance ( $10^{15}$  cm). The band hole of h-BN lies in the scope of 3.6–7.1 eV (Keitel et al., 2013). Furthermore, BN materials display a low permittivity ( $\epsilon$ ) of 3.6–5.3 because of the solid covalent nonpolar bonds. In addition, individual BN layers are stacked together in the direction  $\{0\ 0\ 1\}$  direction and bonded by weak van der Waals forces. This will cause the layers will easy to gliding with respect to each other. As a results, this bonding will give a significant in good lubricants and release agents (Eichler et al., 2013).

Figure 2.8 the SEM image of h-BN that we can see the structure of Boron Nitride finer comparing to the other crystal structure.

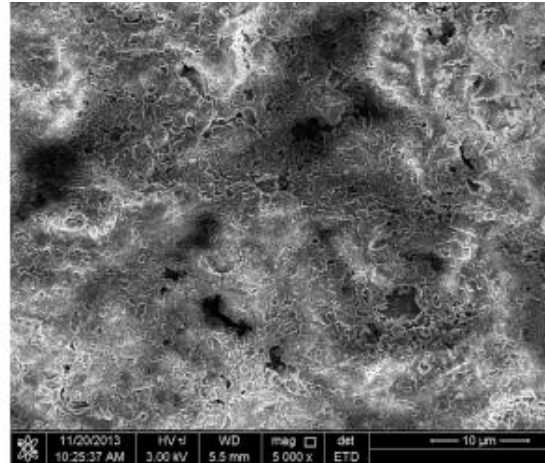


Fig 2.8 SEM image of h-BN (Anithambigai et al., 2014)

The structural of hexagonal Boron Nitride (h-BN) are formed from the several process. h-BN materials are essentially created by fluid stage helped hot squeezing. Little measures of an optional stage, for example, Boron Oxide ( $B_2O_3$ ) are required to shape a fluid stage amid sintering. Extra added substances, for example, CaO can be used to balance out the fluid stage amid sintering. Undefined or crystalline Ca borate stages having a higher compound steadiness than immaculate  $B_2O_3$  are shaped in these material. Other than these materials with low added substance, composite materials have been utilized for customizing the properties. These extra stages emphatically impact the dielectric breakdown resistance what's more, permittivity of BN materials, yet next to no data concerning the connections between the microstructure and the dielectric conduct of h-BN is accessible (Wen et al., 2000). Relationships between the microstructure and the electrical resistance of business hot-squeezed and h-BN material delivered by FAST (field assisted sintering system) were accounted for in a past paper distributed by the authors. Dielectric breakdown resistance (dielectric quality) furthermore, permittivity of h-BN materials and h-BN-based composites in connection to their microstructures are examined (Yongli et al., 2002).

In addition, the composition of h-BN can be used using Fourier Transform Infrared microscopy (FTIR). From the previous research, the example of result FTIR for h-BN is like in the Figure 2.9.

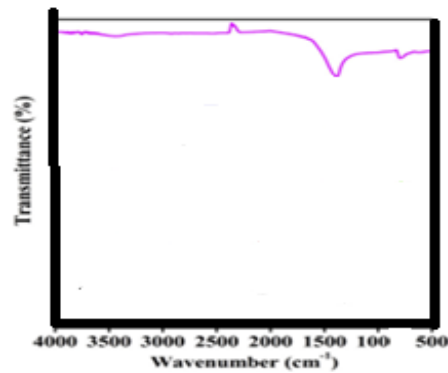


Fig. 2.9 Transmittance of wavenumber of h-BN using FTIR (Ohtani et al., 2013)

#### 2.2.1.4.1 h-BN Surface Treatment

High performance polymeric composites with high thermal conductivity furthermore, low dielectric misfortune have pulled in extraordinary considerations overall attributable to their extraordinary significance in numerous cutting-fields commercial enterprises (Verma et al., 2012). A straightforward and viable strategy for planning thermally conductive materials is including thermally conductive inorganic particles into a polymer (Zhou et al., 2007). Numerous sorts of inorganic fillers have high thermal conductivity, however few of them at the same time own attractively low dielectric constant. As of late, we arranged a composite taking into account hexagonal boron nitride (h-BN) (Gao et al., 2011), and found that the warm conductivity furthermore, dielectric loss of the h-BN composite are vastly improved than those of different composite. However, the



centralization of amine bunches on the surface of h-BN is so little (around 0.113 wt%) that the composite can't get alluring interfacial bond, and in this manner does not indicate alluring incorporated execution, particularly the glass move temperature ( $T_g$ ) and dielectric misfortune should be further progressed. In this way, it is of extraordinary enthusiasm to integrate altered h-BN with more dynamic gatherings, and creating composites with essentially enhanced integrated performance.

However, take note of that it is hard to change the surface of h-BN because of its extraordinary structure. In subtle element, h-BN has molecularly smooth basal planes without functional bunches for compound holding and/or interaction. As is well known the surface treatment process is very important to gain a good interface between two surfaces (Yan et al., 2011).

The schematic in Figure 2.10 show the surface treatment of organized h-BN which comprises of two stages, the first is presenting responsive gatherings (isocyanate) on the surface of h-BN, and the second step is appending the amine bunches through the NCO groups. The point of interest technique is depicted as takes after. H-BN was scattered in DMF with a ultrasonical unsettling under a nitrogen environment to structure a blend, and afterward an abundance measure of MDI was included into the blend with heating so as to mix took after to  $70\text{ }^\circ\text{C}$  and keeping up at the temperature for 30 min. After that the particles were rapidly vacuum-separated to totally evacuate free MDI to get a unrefined item, which was then washed utilizing DMF for 5 times, and dried, progressively. The resultant halfway item was coded as Ih-BN. The Ih-BN particles were mixed with DMF to shape a slurry, and at that point an abundance measure of DDS was gradually added to the slurry, took after by warming with mixing to  $50\text{ }^\circ\text{C}$  and keeping up at that temperature for 12 h. After that the unrefined item was separated, washed and dried, progressively, and the resultant item was the sorted out hBN, coded as Oh-BN.

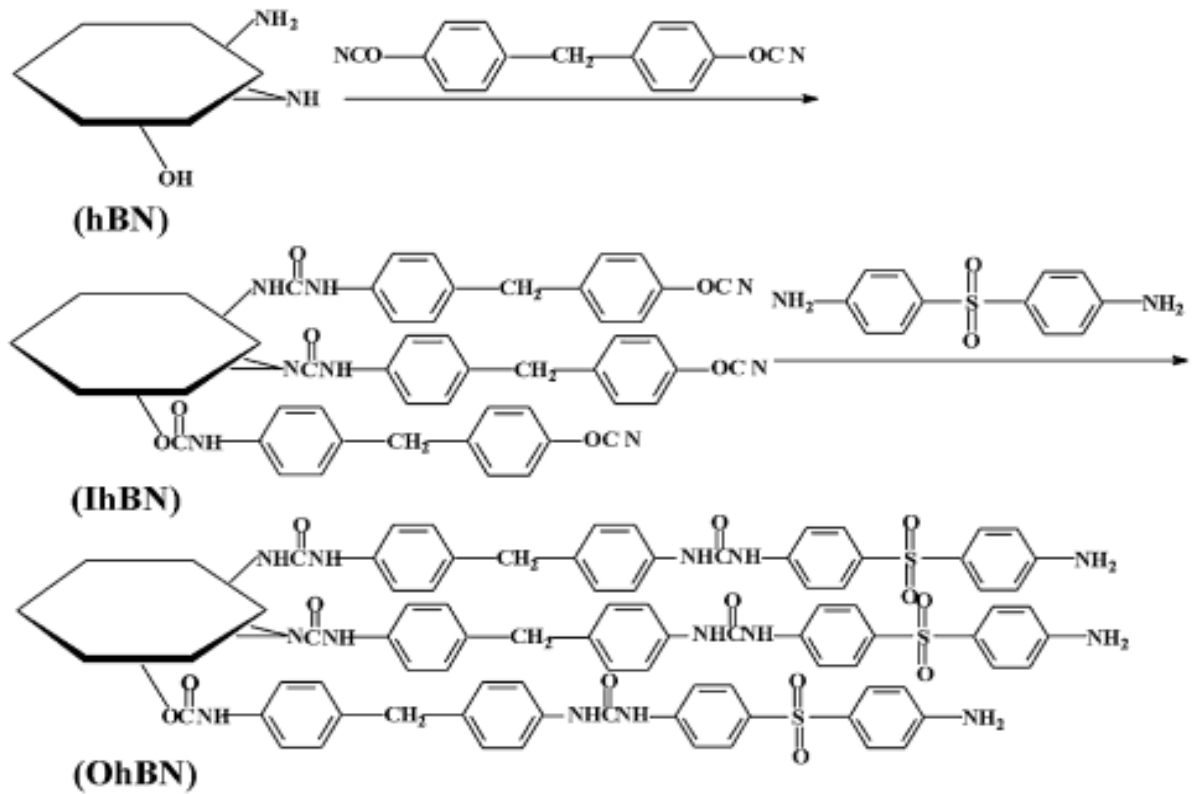


Fig 2.10 Schematic of h-BN surface treatment (Jin et al.2013)

## 2.3 Deposition of h-BN onto conductive substrate

### 2.3.1 Chemical Vapor Deposition (CVD) Technique

Chemical Vapor Deposition (CVD) alludes to methods that depend on surface responses of gas stage forerunners to frame the wanted material. Among CVD systems, (Zhang et al., 2003) demonstrated the adequacy of plasma improved CVD (PECVD) utilizing fluorine science to store h-BN mixture. This mixture delivered through electron cyclotron

reverberation microwave plasma CVD (ECR MPCVD) have demonstrated imperviousness to delamination for thicknesses up to  $3\mu\text{m}$  (Chong et al., 2003), showing generally low interior anxiety. In expansion, delivered movies were to a great extent made out of c-BN (Chan et al., 2003).

Mist CVD is a developing method that empowers the creation of astounding flimsy movies under barometrical conditions. Amid the procedure, cation sources are disintegrated in solvents and ultrasonically atomized under climatic weight. Therefore, the atomized beads, or fogs, are transported to the surface of the substrate, where the film is saved. This idea is generally like that of splash pyrolysis; on the other hand, amid the mist CVD strategy, the span of the beads is much better, permitting the arrangement of homogeneous slender movies. Since the mist CVD technique does not require the utilization of any vacuum chambers, it is a minimal effort and earth well-disposed procedure, which is promising for vast scale deposition (Murai et al., 2015).

The next figure shown is the example of CVD method by using ultrahigh vacuum (UHV) system through ECR-MPCVD chamber (Shammas et al., 2015) to yield the c-BN films. From this research, A coordinated ultrahigh vacuum (UHV) framework kept up at  $\sim 5 \times 10^{-10}$  Torr associate different chambers through a  $\sim 20$  m direct exchange line, taking into account in situ development, preparing, and portrayal. An ECR-MPCVD chamber was utilized to store c-BN films, perform  $\text{H}_2$  plasma treatment, and anneal films.

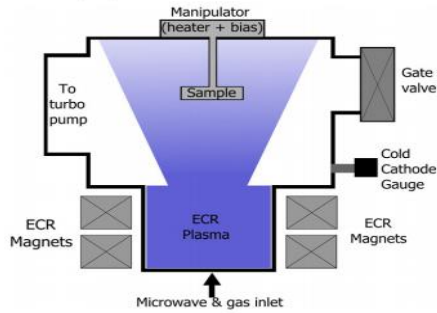


Fig 2.11. Diagram of the ECR MPCVD deposition chamber used to deposit c-BN films. Microwaves and a gas mixture are delivered into the bottom of the chamber. With the ECR magnets, an ECR plasma is generated in the lower part of the chamber and extends to the sample in the upper part of the chamber. (Xu et al.2014)

### 2.3.2 Physical Vapor Deposition (PVD) Method

Nowadays, physical vapor deposition (PVD) method has been utilized to give thick movies with a little number of deformities by controlling the deposition parameters (e.g., plasma thickness, substrate temperature, inclination voltage, pre-cleaning step, and vapor organization) (Bunshah et al., 2001). PVD coatings can be saved at temperatures that are lower than those for hot plunging or CVD, and subsequently can be connected to steel substrates. They are once in a while harder and more consumption safe, and are utilized as a part of the assembling of things including semiconductor gadgets, and covered cutting devices for metalworking.

By utilizing a higher particle flux, higher plasma thickness, and higher particle ion to atom landing proportion, h-BN films can be successfully created by PVD method (Matsumoto et al., 2000). A steady anode current is particularly essential for h-BN coatings. Controlling the anode current yields stable plasma parameters for example, particle flux and radical densities and subsequently empowers the arrangement of steady and stoichiometric h-BN films. The h-BN films are gotten at a lower substrate voltage

that creates a higher plasma thickness and higher particle to-molecule landing proportion. With respect to the h-BN film arrangement, numerous major issues have been found as such. A standout amongst the most basic issues is the delamination of h-BN films from the substrate. It is generally acknowledged that both mechanical stretch and film stoichiometry are predominant elements of this instrument. It has been accounted for that h-BN films have high compressive anxiety that ranges from 1 to 25 GPa (Noma et al., 2014). The delamination of non-stoichiometric h-BN films is activated by surface oxidation inferable from mugginess upon air presentation.

In this study, (Tamura et al., 2014) have made a research on the hydrogen-permeation behavior of PVD coatings of material such as TiN, SiC and BN. The Figure 2.12 show the configuration of magnetically enhanced plasma-ion-plating system.

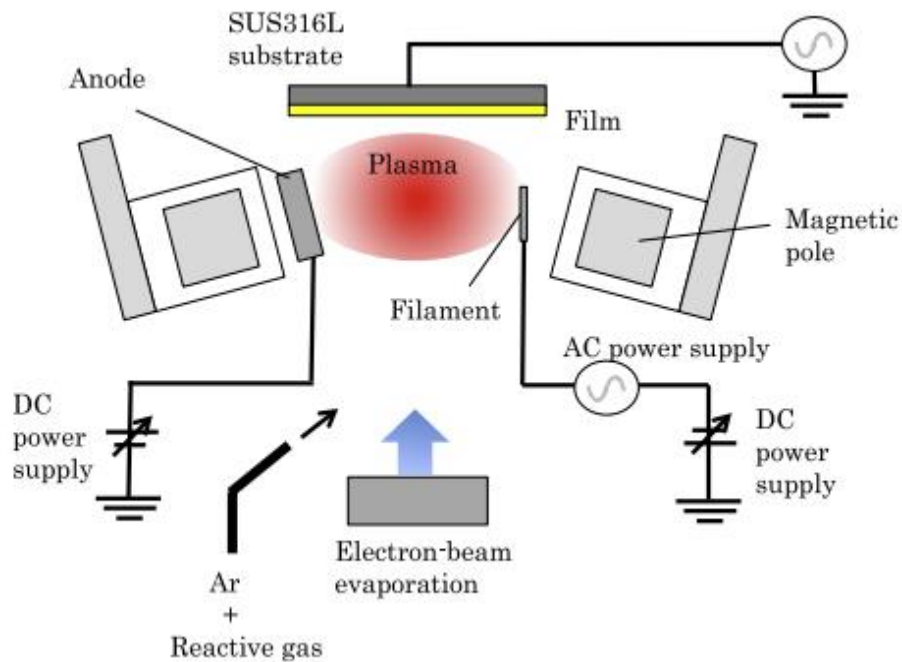


Fig 2.12 : Schematic diagram of magnetically enhanced plasma-ion-plating system.  
(Kim et al. 2003)

TiN, SiC and BN coatings were stored by an attractively upgraded plasma particle plating, utilizing the setup appeared as a part of Fig. 12. This procedure utilizes a bound plasma source comprising of two attractive posts in an extraordinary game plan and a substrate-current control unit for progressing the mass and interface properties of coatings.

### **2.3.3 Electrophoretic Deposition (EPD) Method**

The fabrication process chosen to deposited h-BN onto the devices as Thermal Interface Material (TIM) is electrophoretic deposition method (EPD). Recently, many low-temperature electrochemical depositions including electroless plating (EP) and electrophoretic deposition (EPD) method. These two deposition are said can improve the weakly dependent phenomenon on a surface (Chen et al., 2014). EPD approach are noticeably shows the high flexibility and blends with distinctive materials in light of its simple adjustment for each particular application (Dickerson et al., 2012). When contrasted with EP approach, the EPD could offer flexible grain-size materials onto subjective formed substrates. This generously advances electric properties and statement practicality (Dickerson et al., 2012). Specifically, the flexible parameters of an EPD prepare seriously influence the materials morphology and related gadget execution. Thusly, it is important to concentrate on the relationship between material properties and EPD procedure conditions. An optimum volume suspension are very important to give more even deposited yield. The Figure 2.13 will show the differences of difference deposited yield.

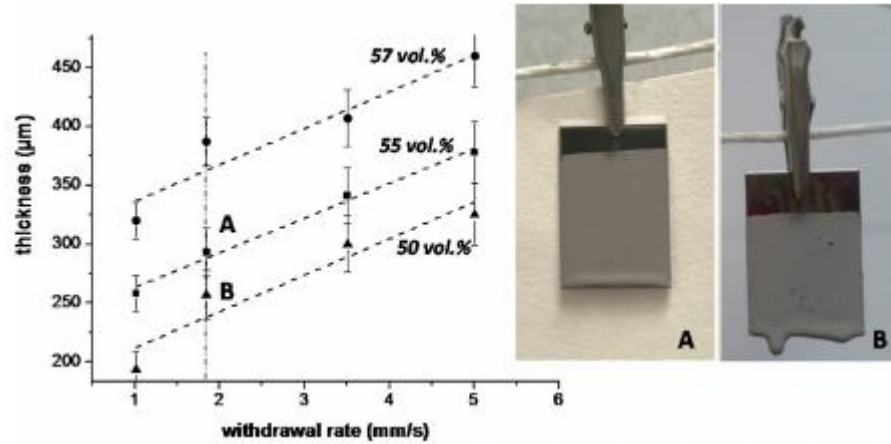


Fig 2.13. Coating thickness vs. withdrawal rate for Ti suspensions with 50, 55 and 57 vol% of solid loading. (A) Picture of the Ti layer obtained from 55 vol% suspension. (B) Picture of the Ti layer obtained from 50 vol% suspension (Frajkorova et al., 2015).

Those research is to investigate the surface modification methods for metallic prostheses (based on Ti-based alloys, or stainless steel) due to the intrinsic bioinert character of these metals and possible ion release from their surfaces, which could potentially induce the interfacial loosening of devices after implantation (Shah et al., 2012).

In addition, this method permits the generation of both thick and dainty uniform, controllable coatings with a very much controlled thickness subordinate on the molecule size of the kept powder (Dickerson et al., 2006). Composite coatings can be acquired as monolayers or practically evaluated composites of two or more segments (Grandfield et al., 2008). Homogeneous covering can be store by EPD onto substrates with complex shapes and indeed, even onto permeable structures. Furthermore, EPD system requires moderately basic equipment. The Figure 2.14 show the setup equipment of EPD method from the previous research.

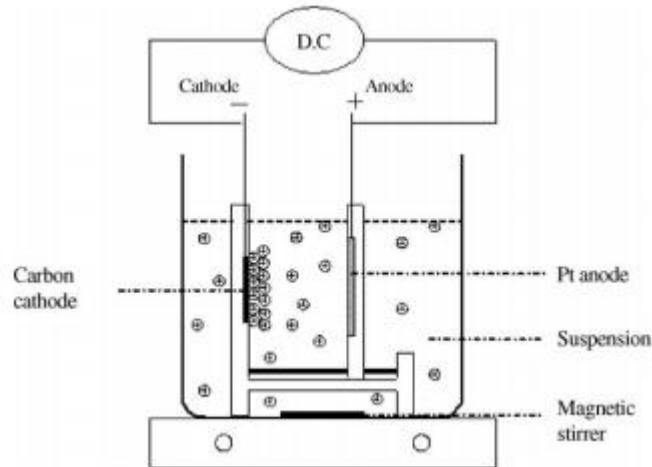


Fig 2.14. EPD setup (Besra et al., 2006)

For the suspension preparation, the initial phase in electrophoretic deposition is to plan a steady, without agglomerate colloidal suspension containing the fired particles. The artistic particles are should have been be scattered in a suitable dissolvable which can create stable suspension and upgrade deposition rate and produces homogenous and crack free deposit. In contrast to many EPD processes where it needs addition of suitable additives like binders, there was no necessity of any dispersing agent or binder addition. This lead to using the polymeric agent such as PEI, PDADMAC etc. These binder leads to additional of the surface charge into the suspension to easier the binding onto the substrate. In this process the positive charges facilitated migration of the particle towards the oppositely charged cathode during EPD. (Besra et al., 2006). In addition, the substrate for EPD is must be electrically conductive to perform the process.

The special importance is the nature of the charged groups of the dispersant molecules. The electrostatic repulsion allows for the dispersion of the particles in the bulk of the suspension; however the mutual repulsion of the particles is detrimental to particle coagulation and deposit formation at the electrode surface. This problem was addressed by the use of dispersants with pH dependent charge. In this strategy, the local pH decrease at the anode and pH increase at the cathode, caused by the electrode reactions, was used to achieve charge neutralization of the dispersant molecules. The charge neutralization of