

INVESTIGATION ON ELECTRICAL PROPERTIES OF RF SPUTTERED DEPOSITED BCN
THIN FILMS

by

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ABSTRACT

The ever increasing advancements in semiconductor technology and continuous scaling of CMOS devices mandate the need for new dielectric materials with low-k values. The interconnect delay can be reduced not only by the resistance of the conductor but also by decreasing the capacitance of dielectric layer. Also cross-talk is a major issue faced by semiconductor industry due to high value of k of the inter-dielectric layer (IDL) in a multilevel wiring scheme in Si ultra large scale integrated circuit (ULSI) devices. In order to reduce the time delay, it is necessary to introduce a wiring metal with low resistivity and a high quality insulating film with a low dielectric constant which leads to a reduction of the wiring capacitance.

Boron carbon nitride (BCN) films are prepared by reactive magnetron sputtering from a B₄C target and deposited to make metal-insulator-metal (MIM) sandwich structures using aluminum as the top and bottom electrodes. BCN films are deposited at various N₂/Ar gas flow ratios, substrate temperatures and process pressures. The electrical characterization of the MIM devices includes capacitance vs. voltage (C-V), current vs voltage, and breakdown voltage characteristics. The above characterizations are performed as a function of deposition parameters.

To my grandfather late Mr. H Hanumanthaiah and my parents

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LIST OF ACRONYMS/ABBREVIATIONS

ARC	Anti-reflection coatings
BC	Boron Carbide
BCN	Boron Carbon Nitride
BN	Boron Nitride
CMOS	Complementary Metal Oxide Semiconductor
CMP	Chemical Mechanical Polishing
CVD	Chemical Vapor Deposition
IDL	Inter Dielectric Layer
DC	Direct Current
E_g	Band gap

<i>LCR</i>	Inductance capacitance and resistance
MIM	Metal-Insulator- Metal
PACVD	Plasma Assisted Chemical Vapor Deposition
PECVD	Plasma Enhanced Chemical Vapor Deposition
PVD	Physical Vapor Deposition
RF	Radio Frequency
<i>RPLA</i>	Reactive Pulsed laser ablation
rpm	Rotations per minute
scm	Standard cubic centimeter per minute
ULSI	Ultra Large Scale Integration
VLSI	Very Large Scale integration

CHAPTER 1: INTRODUCTION

The horizontal and vertical conducting segments of transistors and other active parts of the semiconductor are connected by metallic lines. That serve as the gate metallization, contacts and metal interconnects that may consist of an adhesion promoter/diffusion barrier under and over the main current carrier metal as shown in the figure 1.1 and some processors contain nearly 10 levels of metallizations[1].

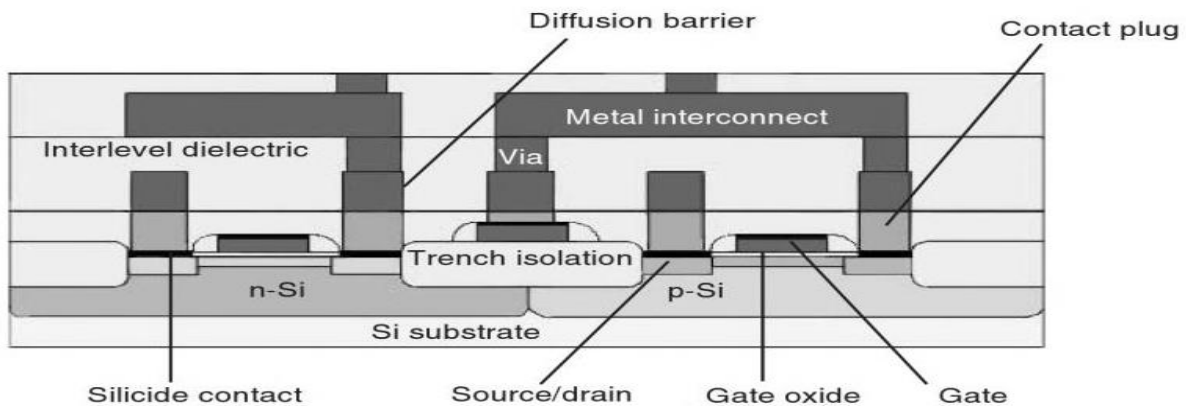


Figure 1.1: A CMOS device

1.1: Inter Dielectric Layers (IDL)

These are divided into three groups

- (i) The active dielectric layers
- (ii) Layers only for Device processing.
- (iii) Insulating layers

The first group is used for storage of charges and other kind of active operation. Examples are gate oxide and dielectric capacitor in memory devices. The second group

comprises of films which are used for device processing like (a) anti-reflection coatings (ARC) in lithography step; (b) etch stop layers and for chemical mechanical polishing (CMP) and (c) as masks.

The third group is used as insulation in microelectronic devices. The isolation between metal lines of same level is called inter-metal dielectric, and that between two metal levels is called inter level dielectric. Both are called interlayer dielectrics (ILDs). The effective speed of the devices is also due to the speed of signal propagation to and from the device through the metal interconnects. These are capacitively coupled to the insulating dielectrics surrounding them, ILDs, leading to RC time delay.

An interconnects equivalent model is given in figure 1.2, where ‘P’ is line pitch, ‘W’ the line width, ‘S’ the line spacing, ‘T’ the line thickness, and the ILD line thickness above and below is equal. The RC delay is given by:

$$RC = 2\rho\kappa\epsilon_0 [(4L^2/P^2) + (L^2/T^2)] \quad (1)$$

Where ρ is the metal resistivity, ϵ_0 the vacuum permittivity, κ the relative dielectric constant of the ILD, and L is the line length. For devices smaller than $0.25\mu\text{m}$, the RC time delay controls the overall on-chip cycle time. [2]

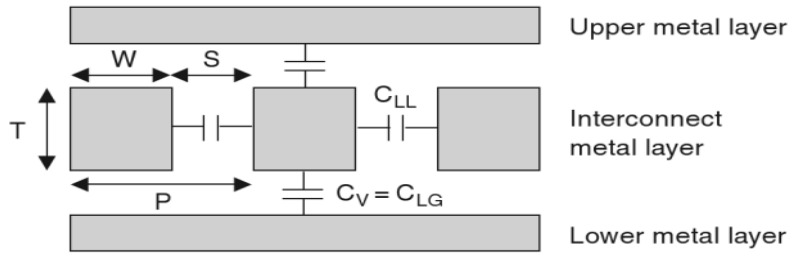


Figure 1.2: A typical interconnect element. LG and LL refer to the line-to-line and line-to-ground contributions. [2]

The power dissipation is also caused by parasitic capacitance as given by the following equation

$$P = (1/2) f_d C V^2 f \quad (2)$$

Where C is the total on-capacitance, V the supply voltage, f the operational frequency, and f_d the fraction of gates that switch during a clock period. Thus by reducing κ , the value of ‘ C ’ will also be reduced making circuits faster, hence also more portable.

In this work the electrical properties of proposed ILD material is investigated. These all relate to electrical conduction through the dielectric and polarization that lead to interaction with electrons, as a result of applied field on the conductor in contact with dielectric. Some desired electrical properties in an ILD are high electrical bulk and surface resistivity, extremely low leakage, high electric field strength, low leakage, low charge trapping, dielectric constant, low dissipation and high reliability. The table below specifies all the electrical properties desired in a dielectric material of constant lower than 3.

Table 1.1: Defining ILD characteristics

Dielectric constant at 1 MHz	1.5 - 3
Dissipation factor	<0.005
Anisotropy	Undesirable
Breakdown strength	$\geq 1\text{MV/cm}$
Bulk resistivity	$\geq 10^{15} \Omega\text{cm}$
Surface resistivity	$\geq 10^{15} \Omega\text{cm}$

The list of the requirements of the low- κ material is as given below;

- 1) Dielectric constant < 3.0
- 2) Chemical compatibility with Si
- 3) Highly insulating
- 4) Good thermal stability (up to 400°C)
- 5) High resistance to environmental degradation
- 6) Low hydrogen/moisture content
- 7) Compatibility with planarization, lithographic and etching processes
- 8) Low diffusivity for metallic impurities
- 9) High breakdown voltage
- 10) Low dissipation factor
- 11) Compositional uniformity
- 12) Low void/crack/defect density
- 13) Low compressive stress
- 14) Conformal deposition
- 15) Good adhesion

- 16) Low deposition temperature
- 17) Thickness uniformity over large areas
- 18) Low particle density
- 19) High elastic modulus
- 20) Low shrinkage
- 21) Low thermal expansion

However, the main technology limiter was not the ability to develop low- κ ILD materials but rather two fundamentally difficult problems associated with this category of materials. Firstly, is the inherent weak mechanical strength of low- κ ILD which seriously limits the ability to package chips made with such ILDs. Moreover, the lower the dielectric constant, the weaker the ILD gets as shown in Fig 1.3. The second problem is the degradation of the dielectric constant of the low- κ materials during processing. Typical processing steps used in the CMOS technology includes photo resist removal, dry and wet etch and metal cleans. All these steps extract carbon from the materials and render them to a higher dielectric constant.

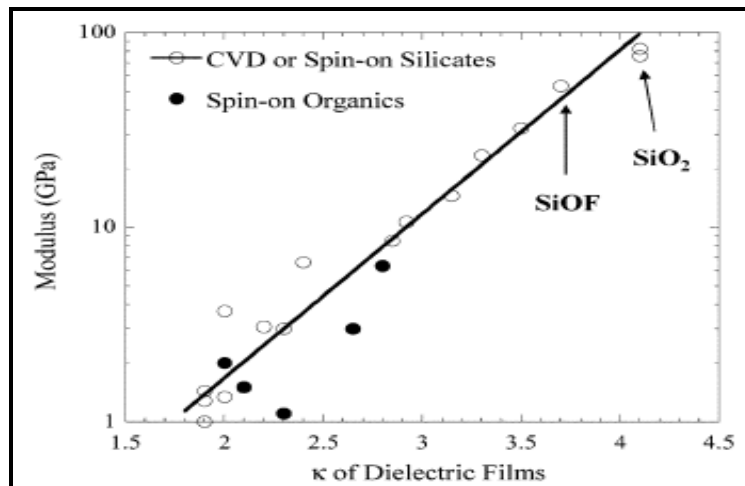


Figure 1.3: Relationship between the dielectric constant and mechanical strength, as represented by modulus of a representative ILD material.

While the existence of a low dielectric constant is a critical requirement for any new low κ dielectric material, it is far being the only requirement. It is equally important that the new material be chemically stable and compatible with Si microelectronics processing. As this work deals with the electrical properties of the BCN thin films. The desired electrical properties of an ideal dielectric material are discussed in the following section.

1.1.1: Electrical Properties

The need of good ILD material is in terms of high electrical bulk and surface resistivity, extremely low charge trapping, dielectric constant and its anisotropy, low dissipation and high reliability. Some of the desired ILD characteristics are dielectric constant at 1MHz may be from 1.5 – 3, dissipation factor could be less than 0.005, undesirable anisotropy, Breakdown strength should be greater than 1MV/Cm and the surface resistivity should be greater than $10^{15}\Omega\text{cm}$.

1.1.1.1: Resistivity

The resistivity determines the voltage-induced current through the material. Dielectrics are subjected to very high electrical fields up to 10^7 volt/cm. Thus a very high resistivity material is chosen of the order of $10^{14}\Omega\text{-cm}$. Besides the bulk resistivity the surface resistivity also plays an important role in determining the dielectric feasibility. In surface resistivity the surfaces are defected and provide fast charge diffusion paths leading to less resistivity compared to bulk. As dielectric films become thinner the surface to volume ratio increases which in turn leads to surface and interface electrical conduction mechanisms. Similarly interface between two metal layers and metal surfaces lead to increase in gross total resistance [29].

Coming to Bulk resistivity, it is seem to be influenced by:

- (1) impurities, mostly by easily ionizable under bias ones like water, H⁺, OH⁻, Na⁺ etc.;
- (2) defects like point, line, area and volume are due to lower bulk resistivity
- (3) stress affecting the band gap of the material.
- (4) non-stoichiometry in some inorganic dielectrics will lead to higher vacancies.
- (5) the ionic dielectrics generally have lower electrical resistance than covalently bonded.
- (6) some ionizable covalent polymers due to the metal interface.

1.1.1.2: Current leakage and Dielectric strengths

Ideally dielectric should be a perfect insulator but practically it has got some finite resistance. Some of the conduction mechanisms are discussed like

Poole-Frenkel emission [30]

$$J = C_1 E \exp \left[-q \left\{ \phi_B - \sqrt{(qE/\pi\epsilon_{ILD})/KT} \right\} \right] \quad (3)$$

Fowler-Nordheim tunneling [29], J is given by

$$J = C_2 E^2 \exp(-E_0\epsilon/E) \quad (4)$$

Where C_1 , C_2 , and E_0 are constants, q is electronic charge, ϕ_B the barrier height, E is the electric field, K is the Boltzmann's constant, and T the temperature in Kelvin. Poole-Frenkel is observed only in heavily damaged insulators for field-enhanced excitation of trapped electrons into the conduction band, Whereas Fowler-Nordheim conduction is observed for electrons tunneling from metal Fermi level into the insulator (oxide) conduction band. These two mechanisms best describe the current leakage behavior in insulators. The Fowler-Nordheim

tunneling is independent of temperature but the Poole-Frenkel is temperature dependent.

The leakage current capability is defined in terms of the maximum voltage (or the electric field which is voltage per unit thickness of the dielectric) that an ILD can sustain without leading to runaway currents (Current per unit area A/cm^2) called dielectric strength defined in the unit of volt/cm. For ILD application the dielectric strength of 2-5 MV/cm is considered as feasible.

Figure 1.4 shows the schematic of current density vs. Electric field [1].

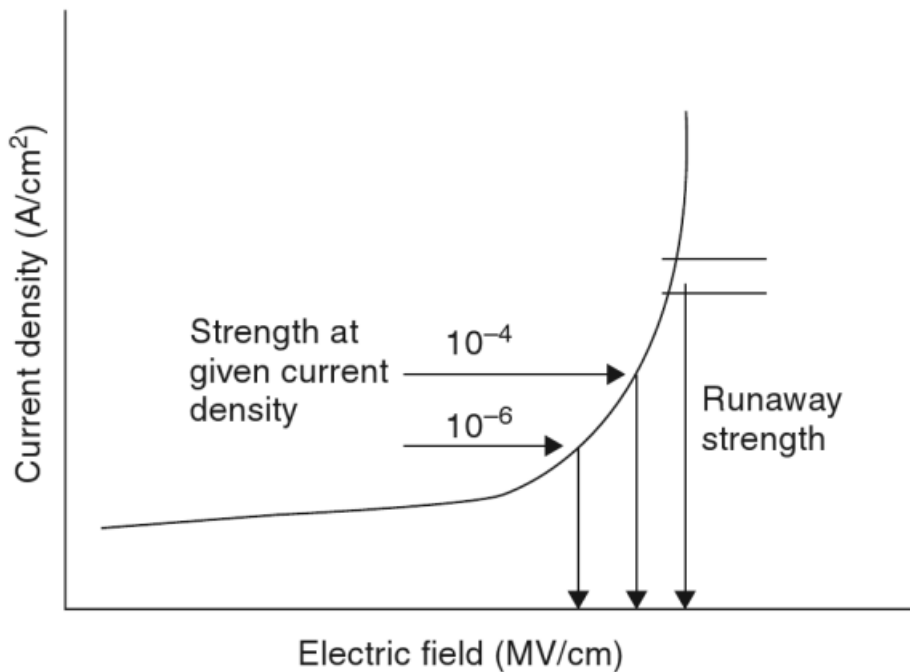


Figure 1.4: Schematic representation of current density through a dielectric as a function of the applied field.

Dielectric strength is related to the dielectric constant. The Dielectric constant of the inorganic dielectrics is shown in figure 1.5 [31]. It shows that lowest the dielectric constant higher is the field strength of a given dielectric.

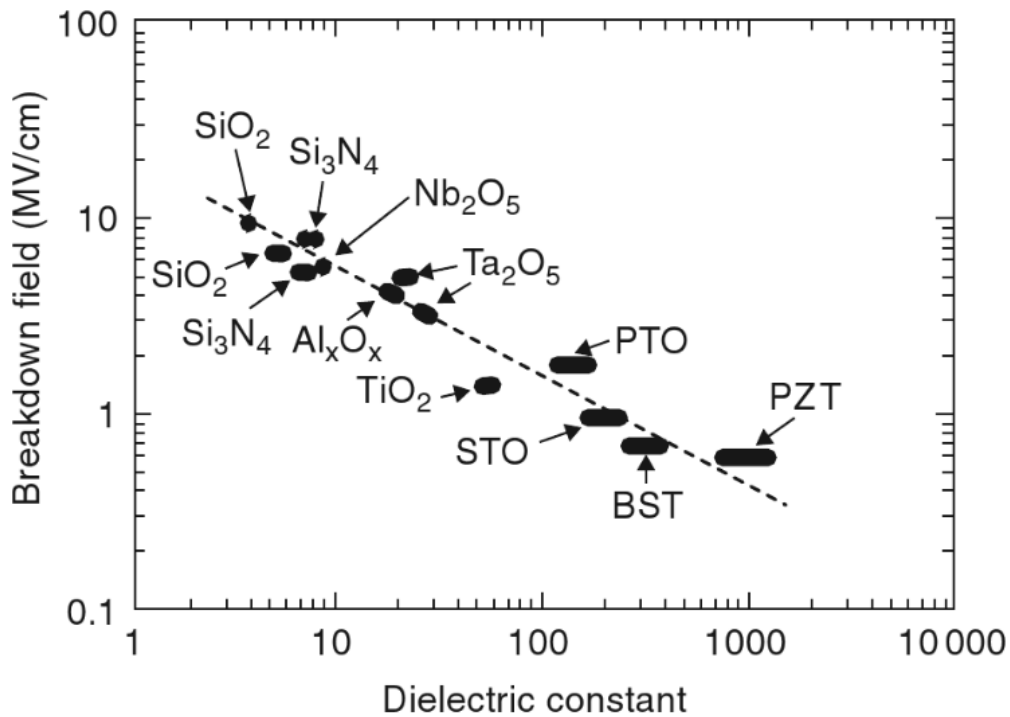


Figure 1.5: A log-log plot of the dielectric breakdown field (or field strengths), as a function of dielectric constant of dielectric.

Finally, it is noted that the dielectric breakdown field strength has dielectric-thickness dependence and decreases with the thickness. The lowering of the field strength at higher thickness is due to defects and also may be because of low thermal conductivities of the dielectric, the heating effectively raising the temperature more in thicker dielectrics than in thinner ones. Higher the temperature lower is the field strength and drop in the field strength at high temperatures could be very large.

1.1.1.3: Polarization and charges in the dielectric

Polarization (α) occurs in dielectric when an electric field is applied across a dielectric. All dipoles are aligned with applied field (permanent dipoles and field induced ones). Polarizations fall under the following categories (a) electronic, (b) atomic or ionic; (c) orientation; and (d) space-charge polarizations. The total polarizability is equal to the sum total of all the polarizations. The electronic and ionic polarizations are related with induced field displacement of electrons in an ion with respect to nucleus and positive and negative ions in an ionic dielectric respectively. The orientation and space charge polarizations are due to field induced alignment of existing dipoles and existing mobile charges at the defective sites such as interfaces etc. Polarizability is given by Clausius-Mosotti equation [32].

$$\alpha = (3/4\pi N) \{(k - 1) / (k - 2)\} \quad (5)$$

Where N is the number of molecules per unit volume and k is the dielectric constant. Also we know that the dielectric constant is given by

$$k = \epsilon / \epsilon_0 \quad (6)$$

Where ϵ and ϵ_0 are the dielectric permittivities of the dielectric under consideration and that of Vacuum respectively. Hence by clubbing the above two equations we get

$$k = \{3 / (1 - (4\pi N\alpha/3))\} - 2 \quad (7)$$

From the above equation we can conclude that higher the value of N or α higher is k . Therefore for low- k materials, they are fabricated either from larger molar volume or lower polarization materials. Hence smaller atoms/ions (eg C, B, H) have comparatively lower α and lower is the

value of k . This also concludes that higher the atomic number higher is the polarizability and eventually higher value of k [33].

1.1.1.4: Dielectric dissipation and loss

Regular dielectric the voltage lags current by 90° but practically it lags by $(90^\circ - \delta)$ where δ is dielectric loss angle which leads to power loss in the form of heat. The dissipation of energy is defined now as follows.

(a) Dissipation factor = $\tan \delta$

(b) Dielectric loss factor = $k \tan \delta$.

$$\text{Power loss (watt)} = 5.56 \times 10^{-11} E^2 f v k \tan \delta \quad (8)$$

Where E is the applied field strength in volts per meter, f the frequency in hertz and v the volume. Therefore to reduce the energy dissipation from a given material, we have to find lowest δ . Under AC conditions it should be noted that

(a) Polarizations and loss are frequency dependent

(b) Electronic polarizations dominate at higher frequencies ($>10^{12}$ Hz)

(c) Amorphous dielectric materials polarize at higher frequencies than the crystalline materials of same composition.

1.2: Overview

There exist atomic bonding similarities amongst boron, carbon, and nitrogen that allow the formation of compounds with a wide compositional range. BCN compounds have been expected to combine the excellent properties of B_4C , BN and C_3N_4 , with their properties adjustable, depending on composition and structure [3]. As graphite is semi metallic and h-BN is insulating (band gap $>3.8\text{eV}$), it is expected that such a hybrid between semi metallic graphite and insulating h-BN may show adjusted semiconductor properties [4]. Moreover, recent efforts have been devoted to develop a low dielectric constant BCN film in order to reduce the stray capacitance induced signal delay of interconnections in Si ultra large scale integrated circuits (ULSI). Dense (pore-free) BCN films with a low dielectric constant in the range of 1.9 to 2.1 have been successfully demonstrated [5]. The use of BCN films in the CMOS back end technology is really very interesting and promising. A material with a low dielectric constant and with high mechanical hardness is a perfect match for inter layer dielectrics. Several methods of preparing boron carbon nitride films have been reported, such as chemical vapor deposition (CVD), plasma assisted CVD, pulsed laser ablation, ion beam deposition, and sputtering. Also, shock wave compression or high pressure/high temperature techniques (HP/HT) have been used. The limitations in composition arise and are due to experimental restrictions like target composition or precursor mixing, so that one element is always incorporated in approximately the same while other two can be varied over a greater range.

The sputtering technique provides unique advantages over other techniques such as freedom to choose the substrate material and a uniform deposition over relatively large area. Furthermore, it is possible to control the deposition parameters to prepare BCN films of various

compositions. According to the chemical properties of the B, C and N during the depositing process of the BCN films, B and C can exist both as elements and as compounds reacting with N or each other, while N could be existed in the films only as compounds by reacting with B or C. Therefore, the process of N deposited into the films and the reciprocity among B, C, and N during the deposition of films becomes the main factors, which affect the composition and properties of films.

For low carbon content the h-BN is preserved in boron carbonitride compounds. By increasing the carbon content towards BCN stoichiometry ($1 < x < 2$) the hexagonal stacking sequence tends into a fullerene-like structure. Increasing the carbon content to the composition BC_4N , the sample exhibits an amorphous structure. A ternary compound of boron carbonitride (BCN) has gained increased attention due to its potential applications in electronic, optoelectronic and luminescent devices. The boron-carbon-nitrogen phase diagram contains interesting phases, such as diamond, graphite, fullerene, cubic-BN, B_4C and there is also a hypothetical C_3N_4 as shown in Fig 1.4.

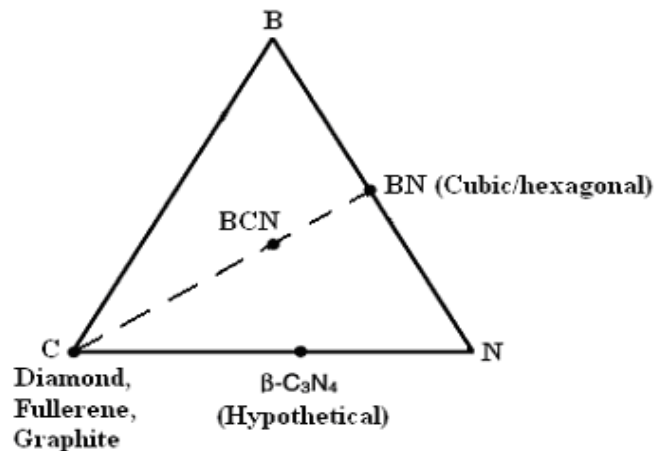


Figure 1.6: Ternary Triangle [34]

Carbon nitride (C-N) thin films are predicted to have hardness comparable to diamond due to the small bond length and low ionicity of this material. The focus of this work was to synthesize the boron carbon nitrogen (BCN) through Rf sputtering and investigating its electrical properties and access its feasibility to use as a low- κ material in the CMOS back end technology.

CHAPTER 2: LITERATURE REVIEW

2.1: Boron Carbide

Boron carbide (B_4C) is an extremely hard boron–carbon ceramic material used in tank armor, bulletproof vests, and numerous industrial applications. With a Mohs hardness of about 9.497, it is one of the hardest materials known, behind cubic boron nitride and diamond [7]. The ability of boron carbide to absorb neutrons makes it an absorbent for neutron radiation arising in nuclear power plants. Nuclear applications of boron carbide include shielding, control rod and shut down pellets. Within control rods, boron carbide is often powdered, to increase its surface area. Electrically, boron carbide is p-type semiconductor material at even high temperatures which suggests is thermally very stable. In thin film form too, this material finds applications as hard and protective coatings, hard disk drives and other corrosion-resistance applications [8]. Sputtering techniques have been commercialized more successfully in big manufacturing fabs because of their high film deposition rate and low temperature features.

The chemical formula of boron carbide is B_4C . But some time there exist a deficiency in Carbon. Hence the formula is somewhere between $B_{12}C_3$ and $B_{12}C_2$. Boron carbide has a complex crystal structure typical of icosahedron-based borides as shown in figure 2.1. [9]

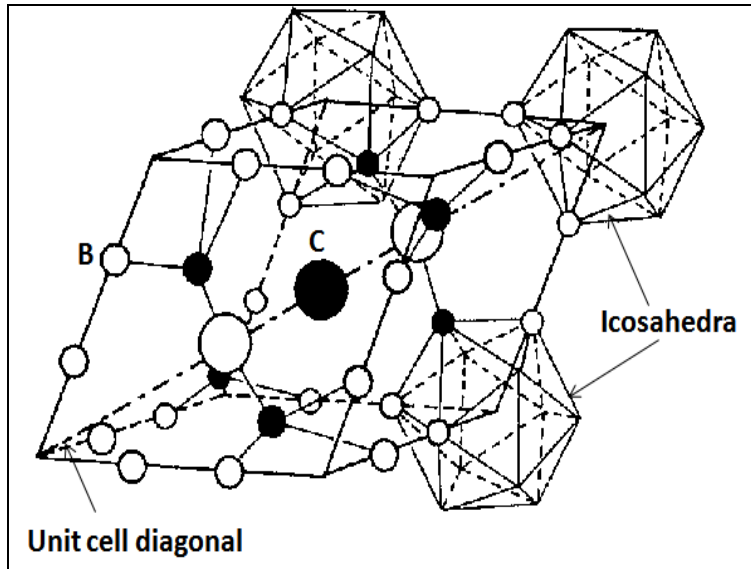


Figure 2.1: Icosahedron shape of unit cell of boron carbide. [10]

Boron carbide has the band gap of 1.2-1.8 eV [11]. But according to the literature it is given that the conductivity of Boron carbide is highest at 13% carbon percentage in the Boron carbide and later it decreases as and when the carbon content increases in the composition [9]. All sputter deposited thin films of boron carbide reported in the literature are amorphous. The boron carbide is very stable at high temperature as it has very high melting point and hence it is desired to be used at high temperatures in the form of an electronic device at inhospitable situations. In some work it is reported that amorphous hydrogenated boron carbide thin films with boron concentrations varying from 0 through 18 % by plasma decomposition of a feedstock of diborane and methane. They found out that boron acts like a dopant with increase in boron concentrations which leads to increase in acceptor densities. Similar work on amorphous hydrogenated carbon doped with boron was first done by Jones and Stewart and they reported an increase by a factor of ten in conductivity [12]. The electrical conductivity was measured for

boron carbide films that had boron to carbon ratio from 4.7 to 19.0, for temperatures from room temperature to 100°C. The electrical conductivity found to vary exponentially with reciprocal temperature. This shows that there is a little variation in conductivity as a function of Carbon composition. Hence it has been concluded that the electrical conductivity depends in the sample purity and preparation and the number of free carbon present in a given composition [13].

Table 2.1: General properties of boron carbide [16, 17].

Properties of boron carbide	
Molecular weight (g/mol)	55.26
Density (g/cm ³)	2.52 for B ₄ C
Melting Point (°C)	~ 2400
Specific Heat (Cal/mol K at 300 K)	12.7
Thermal conductivity (W/cm K)	0.35-0.16 (25-800°C)
Thermal expansion (1/K)	4-8 E ⁻⁶ (25-800°C)
Electrical Resistivity (Ω-cm)	5 (at 298K)
Electrical conductivity (1/ Ω-cm)	~10 ³
Band Gap (eV)	0.77-1.80
Dielectric Constant	5
Seeback coefficient (μV/K)	200-300
Vickers Hardness (GPa)	27.4-40
Young's Modulus (GPa)	290-460
Shear Modulus (GPa)	158-200
Bulk Modulus (GPa)	190-250
Tensile Strength (N/mm ²)	155 (980°C) 162 (1425°C)

Properties of boron carbide

Poisson's Ratio	0.14-0.18
Flexural Strength (MPa)	323-430
Lattice constant (nm)	c=1.207 a=0.561
Oxidation resistance	in air up to 600°C
Chemical resistance	Excellent. Reacts with halogens at high temperature.

2.2: Boron Nitride

Boron nitride is very similar to diamond and can be used to make crystals that are as hard as diamond. Boron nitride is an excellent conductor of heat in spite being an insulator electrically. Boron nitride is mostly found in cubic (c-BN or β -BN) and hexagonal (h-BN) phases. BN in general is not found naturally. Cubic BN has properties close to diamond and is known to be the second hardest material after diamond. Also, c-BN can be made either n or p type conductivity for electronic applications. On the other hand h-BN is a soft material with insulating properties and has a band gap of 5 eV. Cubic boron nitride is one of the physical forms of boron nitride and is made of tetrahedral bonded light elements. BN is also known as c-BN, β -BN or z-BN. The application of powdered form of c-BN in industrial abrasive and boron nitride deposits are used to minimize friction and wear. Techniques used to prepare cubic boron nitride are physical vapor deposition (PVD), plasma enhanced chemical vapor deposition (PECVD), pulsed laser deposition, DC and RF magnetron sputtering from conductive and non-conductive targets (h-BN, boron, B₄C composite).

Also, c-BN can easily be doped n-type using Si and p-type using Be and Mg. This is something that cannot be achieved with diamond. Lastly, c-BN does not react with foreign materials at high altitudes and in harsh environments [14]. It has a very large indirect energy band gap E_g varying between 5.4 and 7.0 eV at room temperature. Hexagonal boron nitride (h-BN) or α -BN or g-BN (graphite BN) is used at both very low temperature and at high temperature as a lubricant and in situations where the electrical conductivity or chemical reactivity would be problematic. Boron nitride lubricants can be used even in vacuum for space applications as the lubricity mechanism does not contain water molecules which will be trapped between the layers. h-BN can be included in ceramics, alloys, resins, plastics, rubbers and other materials, giving them self-lubricating properties. Hexagonal boron nitride is stable at temperatures up to 1000°C in air, 1400°C in vacuum and 2800°C in inert gas thus is a material which has one of the best thermal conductivities of all electric insulators. Another important characteristic of h-BN is that it is fairly chemically inert and is not wetted by many melted materials (e.g. aluminum, copper, zinc and steels, germanium, silicon, glass and halide salts). Because of its excellent dielectric and thermal properties, BN is used in electronics as a substrate for semiconductors, microwave-transparent windows, and as a structural material for seals [15]. Thin films of boron nitride can be obtained by chemical vapor deposition from boron trichloride and nitrogen precursors

Table 2.2: Comparison of various properties of BN with those of other semiconductors [100].

Parameter	c-BN	h-BN	Diamond	3C-SiC	GaAs	Si
Lattice Constant (A)	3.615	a=2.504	3.567	4.358	5.65	5.43
Thermal expansion Coefficient	3.5	2.7, 3.7	1.1	4.7	5.9	2.6
Density (gm/cm ³)	3.487	2.28	3.515	3.216	-	2.328
Melting Point (oC)	>2973	-	3800	2540	1238	1420
Energy bandgap (eV)	6.4	5.2	5.45	3.0	1.43	1.12
Electron mobility (cm ² /Vs)	-	-	2200	400	8500	1500
Hole mobility (cm ² /Vs)	-	-	1600	50	400	600
Dielectric constant	7.1	5.06	5.5	9.7	12.5	11.8
Breakdown(x10 ⁵ Vcm ⁻¹)	~80	~80	100	40	60	3
Resistivity (Ω-cm)	10 ¹⁶	10 ¹⁰	10 ¹³	150	10 ⁸	10 ³
Thermal conductivity	13	-	20	5	0.46	1.5
Absorption edge (μm)	0.205	0.212	0.20	0.40	-	1.40
Refractive index	2.117	1.700	2.42	2.65	3.4	3.5
Hardness (kg/mm)	9000	-	10,000	3500	600	1000

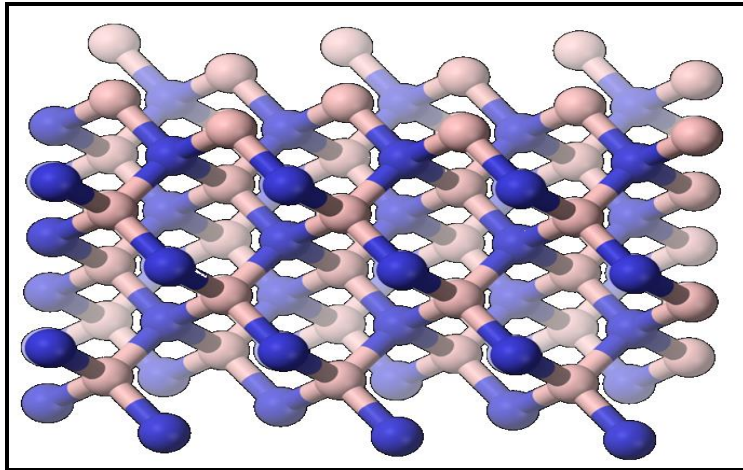


Figure 2.2: β -BN sphalerite structure

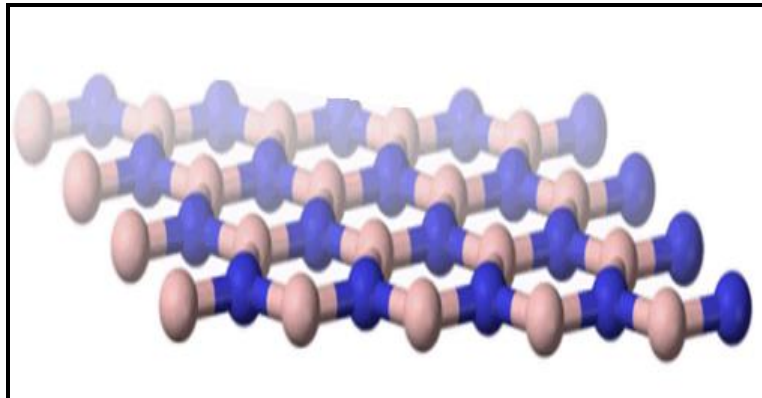


Figure 2.3: h-BN hexagonal (graphite like)

2.3: Boron carbon Nitride

The atomic sizes of boron, carbon and nitrogen are similar, also structures of carbon and boron nitride polymorphs are similar, it suggests that it is possible to produce diamond-like phase containing all three elements. Beginning in 1990, a great interest has been put in studying the possibility to synthesize dense B-C-N phases. They are expected to be thermally and chemically

more stable than diamond, and harder than c-BN, and hence it would be used as materials for high speed cutting and polishing of ferrous alloys. These characteristic properties are because of diamond-like structure combined with the sp^3 σ -bonds among carbon and the heteroatoms. BC_xN_y thin films were synthesized by chemical vapor deposition in 1972. It is unclear whether the synthesis products are diamond-like solid solutions between carbon and boron nitride or just mechanical mixtures of highly dispersed diamond and c-BN. Ternary B–C–N phases can also be made using shock-compression synthesis. It was further suggested to extend the B–C–N system to quaternary compounds with silicon included. The phase diagram of the B-C-N is showed in Figure 1.6. One of the characteristic features of the materials in the BCN ternary phase system is that they have short bond lengths and thus expected to combine the specific properties of diamond, cubic boron nitride (c-BN), hexagonal boron nitride (h-BN) and boron carbide (B_4C).

The boron-carbon-nitrogen phase diagram contains interesting phases, such as diamond, graphite, fullerene, cubic-BN, B_4C and there is also a hypothetical C_3N_4 . Also, the ability to control the band gap (E_g) by changing the atomic composition and structure makes them suitable for the application in electronic and photonic devices [16]. Different deposition techniques have been reported for depositing BCN thin films, including chemical vapor deposition (CVD), ion beam assisted deposition, cathodic arc plasma deposition, pulsed laser deposition, DC and RF magnetron sputtering. The experimental investigations reported above focuses mainly on the synthesis, characterization and mechanical properties. A group deposited BCN films by plasma-assisted chemical vapor deposition and studied the optical and electrical properties. They concur that the carbon composition had a good dependence on the optical and electrical properties of the BCN films. The band gap of the film decreased from 5.3 to 3.4 eV with increase in Carbon

composition ratio from 9 to 30%. The electrical resistivity of the BCN film decreases from 1×10^{12} to $3.4 \times 10^9 \Omega\text{-cm}$ as the carbon content in the films increased from 9 to 30% [5]. The electrical properties of BC_2N thin films with respect to temperature were found out and it was reported that there was a dependence of resistivity and Hall Effect measurements. The resistivity and Hall Effect measurements results indicated that BC_2N thin films are p-type semiconductors and the acceptor levels were between 7.5 and 23 meV. They also studied the dependency of type of substrate and found that the quality of thin film is better on Ni substrates than on quartz [17]. Other group reported the growth of c-BCN thin films by reactive pulsed laser ablation (RPLA). They used a rotating target consisted of two semi disks wherein one of h-BN and other one of graphite and this deposition was done at room temperature. They observed crystalline BCN films with the formation of c-BCN, h-BCN and h-BN. The films were hard, adherent and transparent. BCN films were also prepared by pulsed laser deposition from a sintered B_4C target. The films prepared were found to be smooth and adhered well to the substrate. They also observed that with the help of reactive nitrogen plasma they can incorporate more amounts of nitrogen in the films.

BCN thin films deposited using sputtering and the work on it is discussed from now on. One of the work reports that they prepared BCN films by RF reactive sputtering from a hexagonal h-BN target in an Ar- CH_4 discharge. They made different films with different carbon contents by varying the CH_4 partial pressure. Under optimum processing conditions they observed polycrystalline BC_2N and the calculated activation energy was approximately 0.8 eV [17]. BCN films were also deposited by RF magnetron sputtering using a composite target consisting of h-BN and graphite in an Ar- N_2 atmosphere. They studied the effect of sputtering

power on the composition of BCN films and found that the films deposited at 80W and 130W are close to the BC₂N stoichiometry and the sample deposited at 110 W is close to the stoichiometry of BCN.

Lastly the samples deposited at 100W and 120W have the chemical composition of BC₂N. Thus they were able to achieve the BCN films with different compositions by varying the power to the composite target [18]. Dual cathode magnetron sputtering was used to deposit BCN films by Kusano et al. and they sputtered from graphite and boron targets. They varied the power to the sputtering targets and concentration of nitrogen gas in the sputtering chamber. They observed the variation of deposition rate with reactive gas and the BCN films deposited at pure nitrogen exhibited a higher content of sp and sp² carbon and had lower durability in friction tests as compared to other BCN films. Another group reported that BCN thin films near B₄C composition deposited by radio frequency magnetron sputtering from a sintered B₄C target. They observed the increase in nitrogen incorporation in the films from 0 to 40 at. % while the relative atomic composition of B/C was relatively constant at 4 thus the films structure changed from B₄C to a mixture of h-BN and amorphous carbon. Same group of researchers characterized BCN films by their micromechanical and micro tribological behavior. They evaluated the adhesion and friction coefficient against diamond by micro scratch and also characterized their wear behavior at the nano metric scale. They found that the hardness is higher in the films with lower nitrogen concentration and the least hard films had nitrogen content of around 20 at.% [19].

Some work on dielectric constant studies was also performed by many groups. Takashi et al the dielectric constant of BCN is found to decrease with decrease in growth temperature. The dielectric Constant is estimated from the accumulation region of capacitance–voltage (C–V)

characteristics of Au/BCN/p-Si samples. Reduction in the crystal grain size and increase of the amorphous region of The BCN films are observed with decreasing growth temperature. Here the Polycrystalline boron carbon nitride (BCN) films are synthesized at various temperatures by plasma-assisted chemical-vapor deposition [20]. Also it has been reported by Sugino et al that boron nitride films with a dielectric constant as low as 2.2 can be synthesized by plasma-assisted chemical-vapor deposition (PACVD) [21]. It has been reported that the addition of C atoms to BN films is effective in reducing the dielectric constant.

2.4: Carbon nitride

Liu and Cohen made theoretical prediction that β -C₃N₄ which is isomorphic with β -Si₃N₄ might have a bulk modulus which can exceed that of diamond [26]. Figure 2.4 shows the structure of the carbon nitride. This has triggered a lot of research work in the development of C₃N₄ over the past two decades. C-N material along with high hardness also is expected to possess wide band gap, high thermal conductivity, high strength, high decomposition temperature and excellent resistance to corrosion and wear. Carbon Nitride possesses applications for insulator devices in III-V metal-insulator-semiconductor structures. C-N is a preferred material over Si₃N₄ for such applications because it doesn't introduce any shallow impurities.

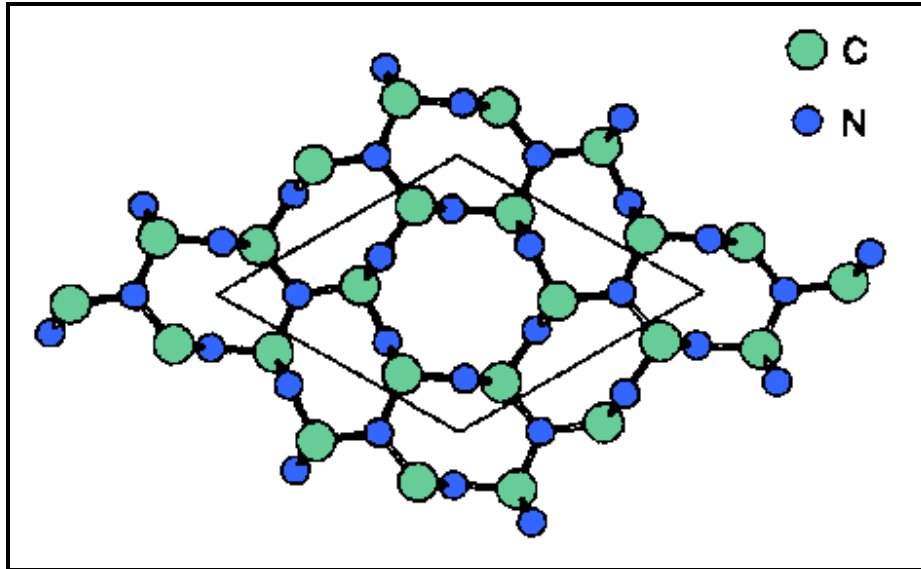


Figure 2.4: Crystal structure of carbon nitride

There have been many research reported on the deposition of C-N films such as reactive sputtering, plasma chemical vapor deposition (CVD), laser ablation, ion-assisted deposition and metal-organic chemical vapor deposition (MOCVD). The incorporation of nitrogen in the C-N films was around 40% which is lesser than that expected for stoichiometric β - C_3N_4 (57 at %) in all the work reported above. Higher amounts of nitrogen (50-57 at. %) has been reported in the hydrogenated C-N films prepared by plasma CVD and the CN films obtained by dual ion beam sputtering , laser ablation of graphite using a low-wavelength excimer laser and by using the MOCVD technique [27]. The sputtering being the most commonly used method of deposition in the industry results in relatively low nitrogen content in the carbon nitride films [28]. One group performed reactive sputtering and observed the effect of nitrogen incorporation on the growth kinetics, composition, structure and type on bonding. They noticed that the incorporation of N_2 in the plasma leads to an increase in the growth rate and that the growth kinetics and N content in

the films is dependent on physical and chemical sputtering. The alteration in growth kinetics influenced the chemical, structural and optical properties. Another group also deposited C-N films by reactive sputtering and premised that by decreasing the target power and at high nitrogen pressure results in higher N₂ contents in the film. They were able to gain equal amounts of carbon and boron for a wide range of sputtering pressures at low temperatures and the structure of the film obtained was graphite-like.

CHAPTER 3: METHODOLOGY

In this chapter, the techniques and procedure for fabricating BCN devices for characterization and measurement purposes are conducted. This chapter also elucidates various materials and electrical characterization techniques used to study the thin film samples. Also it outlines briefly about different electrical measurements like I-V Characteristics, Capacitance measurements, Breakdown voltage measurements.

Sputter deposition technique was used to deposit thin film samples. Sputter deposition is a physical vapor deposition (PVD) method of depositing thin films by eroding material from a source, which in turn is deposited onto a substrate. The advantage of sputtering is that the deposited films have the same composition as the source material. The similitude of the film and target stoichiometry will be maintained because the sputter yield depends on the atomic weight of the atoms in the target. Magnetron sputtering was instrumental in getting strong electric and magnetic fields to trap electrons close to the surface of the target. Insulating targets can cause buildup of charges that is why biasing was varied in the anode and cathode with a radio frequency (rf) power source. Sputter deposition sources (also called sputter “guns”) creates low pressure plasma by the excitation of an inert gas (typically argon) contained at 1 to 30 millitorr in a vacuum chamber. This process extracts energetic ions which accelerate toward the cathode target, striking it with kinetic energy up to several hundred electron volts. It then ejects material from the target with approximately 90% leaving as neutral atoms and 10% as ions as a result of energy transfer. Gas phase collisions between target atoms and argon atoms scatter the ejected material into a distributed cloud. As the cloud migrates towards the substrate, the random approach angles result in deposition of a uniform film, even on surfaces that have micron-sized

vertical structures.

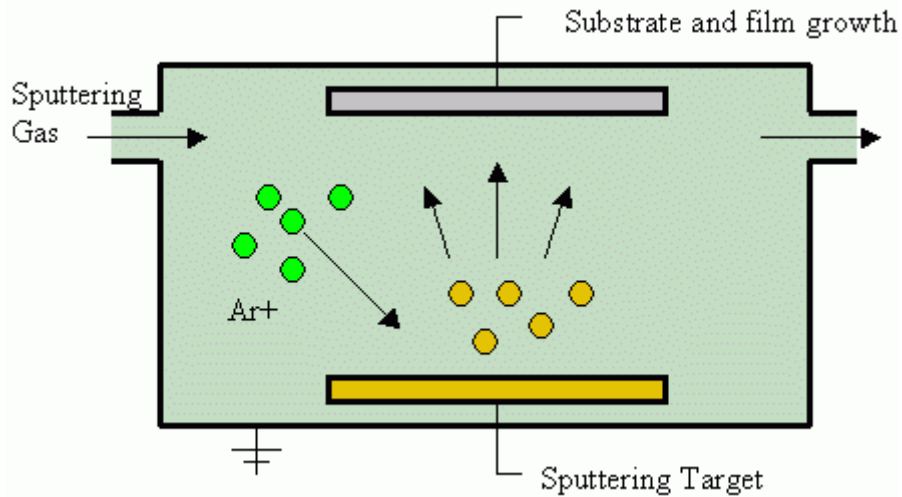


Figure 3.1: Sputtering Process Cartoon

Thin films of BCN were deposited by reactive RF magnetron sputtering in an Ultra High Vacuum system. Three inches, powder pressed, B_4C target with a purity of 99.5% was used. The system base pressure was approximately 1×10^{-8} Torr and the purity of the process gas were maintained by a hot reactive metal getter. Reactive sputtering was used where the deposited film is formed by chemical reaction between the target material and a gas which is introduced into the vacuum chamber. Oxide and nitride films are fabricated using this technique. The composition of the film is controlled by changing gas flow ratios of inert and reactive gases. In this case nitrogen was used as the reactive gas and, the N_2 to Ar ratio was varied from 0.25 to 1, in steps of 0.25 by changing the individual gas flow rate, while total gas flow was kept constant at 20 sccm and the deposition pressures were varied between 2mtorr and 5mtorr. And for each ratio the deposition temperature was varied. The deposition temperatures used are room temperature, 200°C, 300°C, 400°C, 500°C.

3.1: Fabrication of MIM devices

MIM stands for Metal-Insulator-Metal devices. The Corning glass was used as substrate to fabricate the MIM structure. The standard cleaning procedure was followed to clean the substrate that includes rinsing with acetone, methanol and DI (De-ionized) water. The substrate was then rinsed thoroughly with DI water, dried with Nitrogen gas jet and was loaded in to the sputtering chamber for subsequent BCN deposition. It is always good to make sure that there is no surface oxide before depositing the insulating film. The surface oxide if present will add an additional parasitic capacitance which may hinder the total capacitance value of the device.

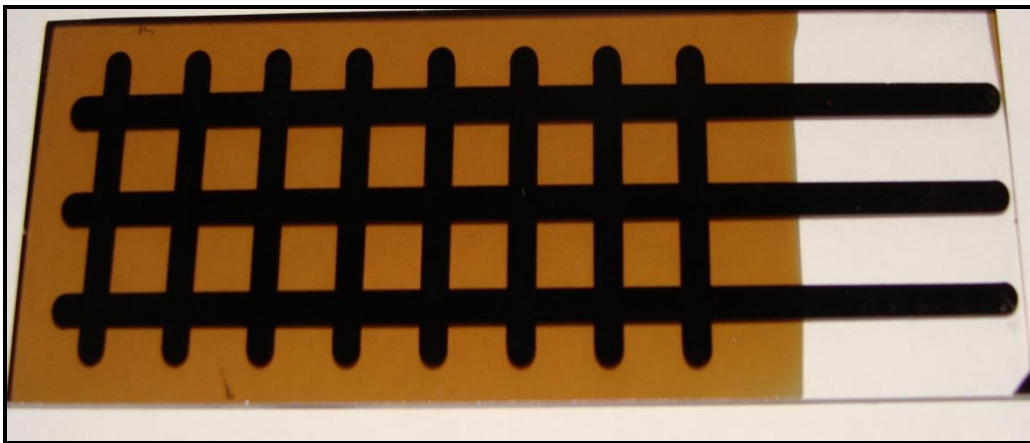


Figure 3.2: MIM structures (Al-BCN-Al) on a glass substrate

3.1.1: Preparation of the base Al electrodes

The Aluminum electrodes of 3mm wide were deposited using a mechanical mask in a Vacuum Thermal evaporation system. During the deposition of Aluminum, the Thermal evaporation chamber was first roughed from atmosphere pressure to the pressure of 50mtorr with the help of a mechanical pump (Backup pump). Then by closing the mechanical pump, the foreline pump's valve is opened. Here we have used the Cryo pump as the Foreline pump. This

Cryo pump helps in pumping down the system from 50mtorr chamber pressure to 1×10^{-5} torr. It was found out from the earlier experiments that to get the high quality films with fewer defects, the pressure around 1×10^{-5} torr would be required. The Aluminum strips were dangled on the tungsten filament in the chamber. The cleaned substrates were attached to the holder from the lid and it is closed and it is made sure that the substrates are facing the filament firming a minimal distance between the substrates and Al strips. The initial roughing is done to the chamber to achieve the pressure of 50mtorr and then the Cryo pump is used to bring down the pressure to 1×10^{-5} torr. Then the high current is passed from an induction coil current source by slowly incrementing the current from 0A to 35A. 35A is maintained for a minute for proper uniform deposition of Al on the substrate. After that another minute is left for degassing.

3.1.2: Deposition of BCN thin films

BCN film is sputter deposited on a glass substrate in a sputtering chamber. These were deposited from a 3 inch B_4C target. The reactive sputtering was used to deposit BCN films. The base pressure of the chamber was achieved in the range of 2×10^{-7} Torr. The N_2/Ar gas flow ratio was varied in the steps of 0.25 from 0.25 to 1, keeping the total gas flow in the sputtering chamber constant at 20 sccm. The R.F power of 200W to the B_4C target was kept constant. The depositions were done at 2mtorr and 5mtorr partial pressures (Plasma pressure). The time for deposition was 1 hour for all the samples. The thickness of the BCN film was measured by α -step Profilometer. The BCN thicknesses ranged from 900 Å - 2000 Å. The samples were deposited at a range of deposition temperatures from room temperature, 200°C, 300°C, 400°C, 500°C. Thermocouple attached to the substrate holder was used to measure the temperature of

the substrate. The temperature was noted in steady state condition. The rotation speed of the substrate was set around 20 rpm. There are two steps for achieving the base pressure of 1×10^{-7} torr. The samples are loaded into the load lock system attached to a substrate holder and it is pumped down (roughing) from atmospheric pressure to 5×10^{-5} torr. Then the samples are introduced to the main chamber from the load lock system by opening the valve between them and the substrate holder with the samples are placed to a pre-set distance from the target. The target is placed facing the substrate holder at an angle of 45°C . When the samples are positioned accordingly, RF power is started from 0W to 200W in small incremental steps and made sure the plasma is sustained for the rest of the sputtering process. The desired N_2/Ar flow ratio is maintained and also the partial pressure in the chamber and the desired temperature is maintained as required. Now the sputtering is started in the chamber by opening the lid covering the target and it is left open for an hour of sputtering.

Lastly, aluminum electrodes of 3mm width each running all through the length were deposited on the BCN layer to form the top layer electrode of the MIM structures using the Vacuum thermal evaporation method as explained previously. The substrates are dealt with same cleaning procedures before all three kinds of depositions.

3.2: Electrical Characterization

Current-Voltage (I-V) measurement was performed on MIM devices fabricated with BCN as an insulator. This was used to measure the resistivity and breakdown voltage of the BCN films across top and bottom Aluminum electrodes formed as a Metal-Insulator-Metal (MIM) structure. The dielectric constant was also measured from the capacitance values obtained from the LCR meter knowing the thickness of the films deposited.

3.2.1: I-V Characterization

Current-Voltage measurement (I-V characteristics) was conducted with help of HP 4145B semiconductor parameter analyzer as shown in figure 3.3. This instrument was connected to a probing station. The samples were kept inside the probing station having two micro tip probes connected to the parameter analyzer. This parameter analyzer is interfaced to the computer. Hence all the measurements are performed through software interfaced computer. I-V characterization is done by taking the voltage sweep from 0V to 40V and subsequently the I-V characteristic graph is plotted. From the initial values of current response to the input voltage, the resistance of the film was found out. We found the resistance of the film and by observing the graph plot for sudden rise in current for a given voltage the breakdown voltage is noted down. By knowing the thickness of the deposited film and the line width of the deposited Al electrodes, the resistivity is found out.



Artisan Technology Group

Figure 3.3: HP 4145B semiconductor parameter analyzer (Courtesy: Artisan Technology Group)

3.2.2: Dielectric constant measurement

The HP 4275A Multi-Frequency LCR meter is used to measure the capacitance of the MIM structures as shown in figure 3.4. This instrument was connected to the probing station and software interfaced to the computer. The frequency of operation of this measurement is 1 MHz as the capacitance measured was in the range of couple of nano farads which is a small value of capacitance. The samples are kept in the same probing station and connected to the probes which in turn are connected to the LCR meter. Calibration is done before the measurement of capacitance for each device. By knowing the capacitance, the film thickness and the line width of the aluminum electrode the dielectric constant was found out.



Figure 3.4: Dielectric constant measurement (Courtesy: Agilent Technologies)

3.2.3: Thickness measurement

The thickness measurement was done by Veeco Dektak 150 profilometer as shown in figure 3.5. It is a surface profilometer that takes surface measurements using contact profilometry techniques. The Dektak 150 uses stylus profilometry technology, which is the accepted standard for surface topography measurements, roughness and step size. Here its property of Two-dimensional surface profile measurements is used to measure the step height. The step is created by masking a small portion on a test sample during the sputtering process using a thin strip of aluminum foil as it can withstand the high temperature and its property of less diffusivity into the BCN layer during the sputtering process. The scan length range used for measurement is 65mm and the stylus force was 15mg for a scan time of 30 second. The software profiling is done after the mechanical profiling if the profile obtained is off level. Then the Average step height is found out by placing the two cursors on either sides of the step obtained in the profile.

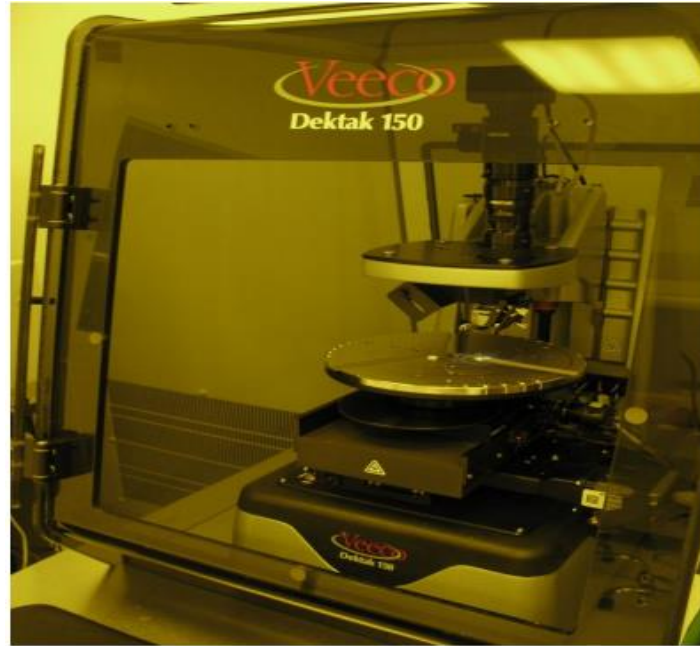


Figure 3.5: Veeco Dektak 150 profilometer (Courtesy: Veeco)

CHAPTER 4: RESULTS AND DISCUSSION

4.1: Electrical Studies

In this section various electrical properties like dielectric constant, resistivity and Breakdown Voltage are found and their consequent relationship with respect to different physical parameters like gas flow ratios, partial pressures, deposition temperatures etc. are elucidated in terms of graph plots.

4.1.1: Dielectric constant v/s deposition temperatures

The figure 4.2 shows the plot of dielectric constant vs. Temperature of different samples for range of temperatures such as as-deposited, 200°C, 300°C, 400°C, 500°C; for a deposition pressure of 2mtorr. Different N₂/Ar gas flow ratios of 0.25, 0.5, 0.75, 1. The capacitance was measured on eighteen different MIM devices formed on a single glass substrate. Then by knowing the line width of the electrodes and the film thickness of the deposited BCN thin film at a particular temperature with the help of α -step profilometer, the dielectric constant is found out and their average values are plotted against the different temperatures. Figure 4.3 shows the Dielectric constant vs. Temperature plot at 5mtorr deposition pressure at various gas flow ratios. The dielectric constants of the samples tend to decrease with increasing temperature. This can be attributed to the fact that the film is more uniformly formed and is less amorphous at high temperature. Also it is reported in the literature that the increase in deposition temperature decreases the concentration of Carbon in the sample [22]. Also the dielectric constant of B₄C is

around 4.8 to 8 [24] and the dielectric constant of BN is around 3.9 to 4.3 [25]. Hence the sample shows a more of BN characteristics thereby having lower dielectric constant at higher temperatures.

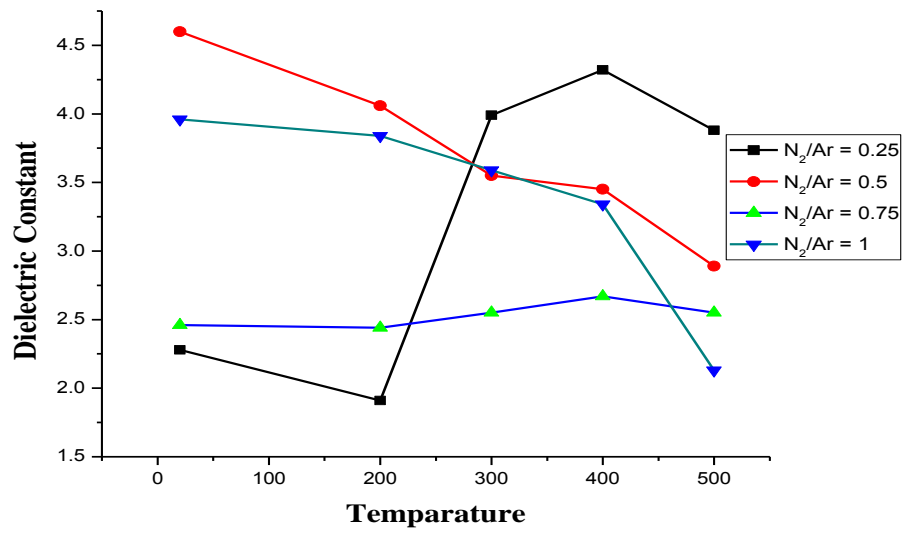


Figure 4.1: Effect of Temperature on Dielectric constant for 2mtorr pressure

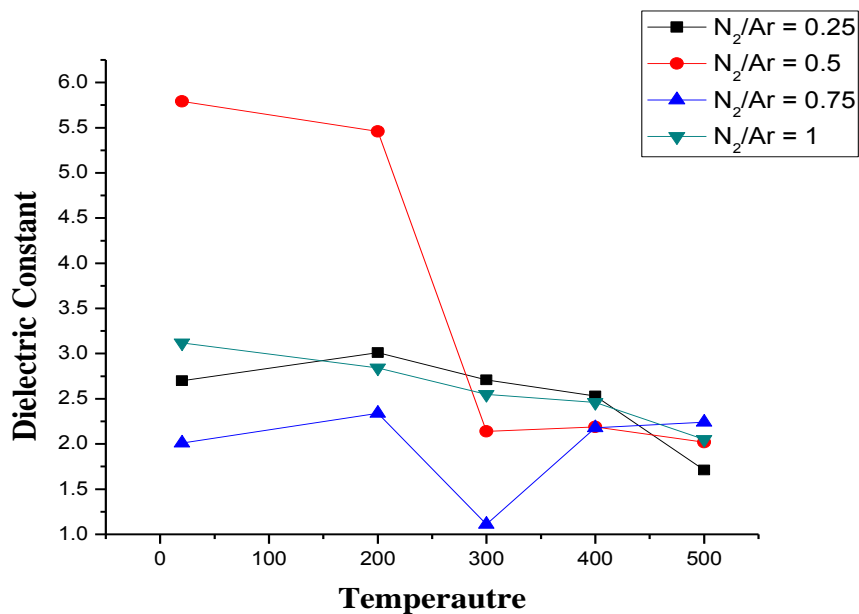


Figure 4.2: Effect of Temperature on Dielectric constant for 5mtorr pressure.

4.1.2: Dielectric constant v/s Gas flow ratios

Figure 4.3 shows the plot of Dielectric constant vs N_2/Ar gas flow ratios at different deposition temperatures and at 2mtorr deposition pressure and Figure 4.4 shows the plot of Dielectric constant vs N_2/Ar gas flow ratios at different deposition temperatures and at 5mtorr deposition pressure. Both the plots show a decreasing trend of dielectric constant with the N_2/Ar gas flow ratio initially and an increasing trend at the end. This may be attributed to the fact that the contents of nitrogen and carbon are associated with the dielectric constant variations. More the carbon content and lesser the nitrogen content may bring the characteristics of B_4C . As we know from the literature the dielectric constant of B_4C is around 4.8 to 8 [24] and the dielectric constant of BN is around 3.9 to 4.3 [25]. Also the fact that the concentration of nitrogen in the films deposited at $N_2/Ar = 1$ may be lesser because of less sputtering as the amount of argon

decreases with the domination of nitrogen in the sputtering ambient. Hence the dielectric constant is found to increase towards $N_2/Ar = 1$ flow ratio towards the end.

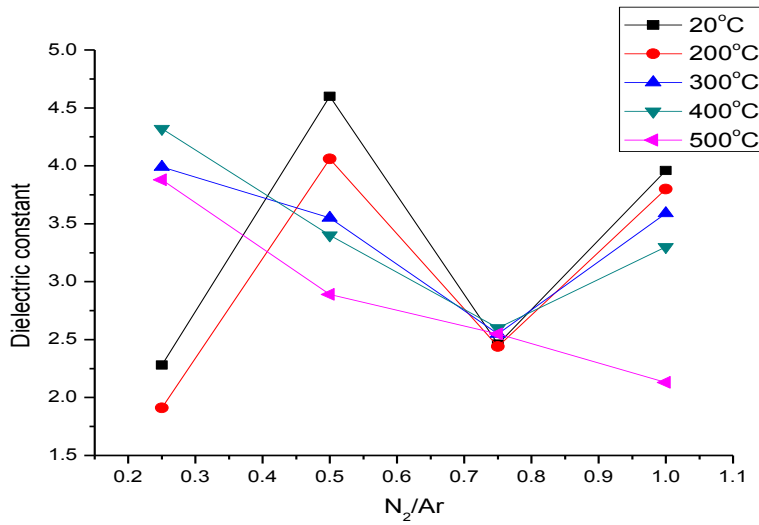


Figure 4.3: Effect of N_2/Ar flow ratio on Dielectric constant at 2mtorr pressure

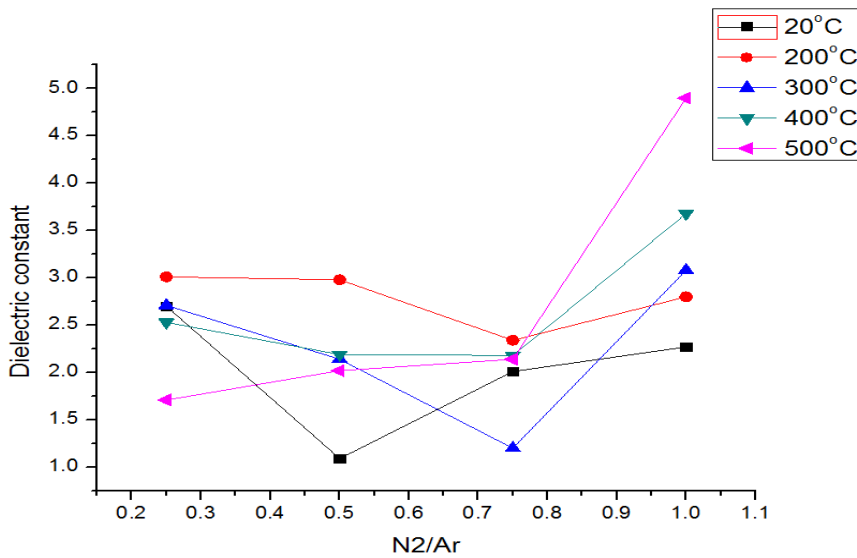


Figure 4.4: Effect of N_2/Ar gas flow ratio on Dielectric constant at 5mtorr pressure

4.1.3: Resistivity vs N_2/Ar Gas flow ratios

Figure 4.5 shows the plot of resistivity vs N_2/Ar gas flow ratios at different deposition temperatures and at 2mtorr deposition pressure and Figure 4.6 shows the plot of resistivity vs N_2/Ar gas flow ratios at different deposition temperatures and at 5mtorr deposition pressure. As shown in the figure 4.5 for films deposited at 2mtorr pressure, the resistivity has an increase in trend initially but then tends to stabilize at a constant value towards the higher N_2/Ar gas flow ratios. When considering the figure 4.6 for films deposited at 5mtorr pressure at different temperatures, resistivity shows an initial decrease in trend at higher temperature and later on it seems to stabilize with less variation with the increase in N_2/Ar gas flow ratios. From the below two graphs it can be concluded that high resistivity films can be deposited at lower range of temperatures than the higher range. Also at lower temperature range we can obtain high resistivity films for a wide range of N_2/Ar gas flow ratios at 2mtorr and 5mtorr pressure.

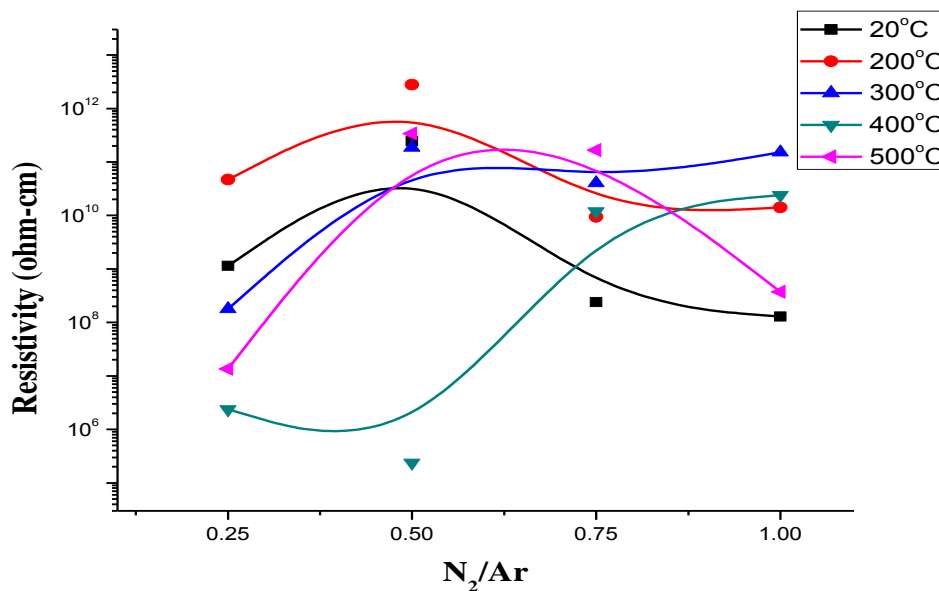


Figure 4.5: Effect of N_2/Ar gas flow ratio on Resistivity for 2mtorr pressure

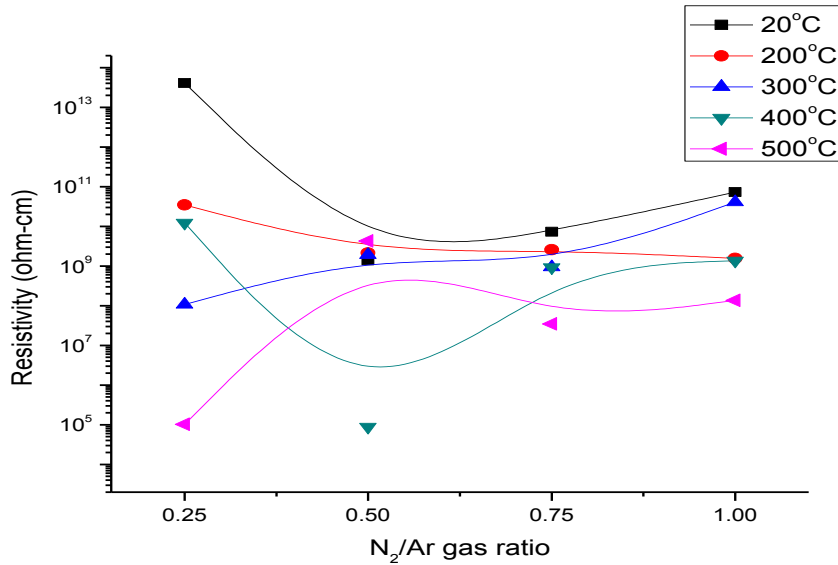


Figure 4.6: Effect of N₂/Ar gas flow ratio on Resistivity for 5mtorr pressure

4.1.4: Resistivity vs Deposition temperature

Figure 4.7 shows the plot of resistivity vs deposition temperatures at different N₂/Ar gas flow ratios 5mtorr deposition pressure and Figure 4.8 shows the plot of resistivity vs deposition temperatures at different N₂/Ar gas flow at 2mtorr deposition pressure. The resistivity has a decreasing trend with respect to deposition temperature for 5mtorr deposition pressure and even for the deposition pressure of 2mtorr the resistivity decreases with respect to increase in deposition temperature. As from the graphs below we can see that the resistivity values maintain a constant value for a wide range of temperatures which shows the robustness of BCN films at wide range of temperature but shows a slight decreasing trend at very high temperatures. This can be due to the aluminum diffusion into the BCN films at high temperatures thereby causing

induced polarization and hence bringing down the resistivity considerably.

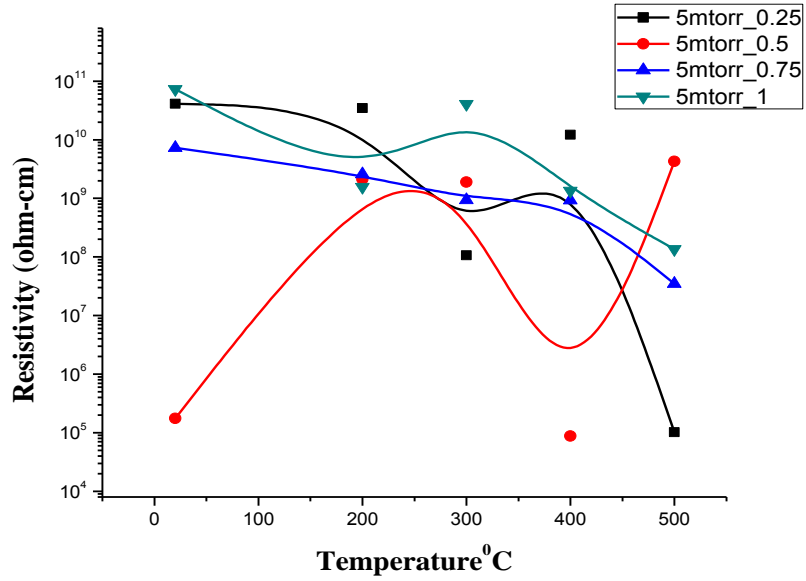


Figure 4.7: Effect of deposition temperature on Resistivity for 5mtorr pressure

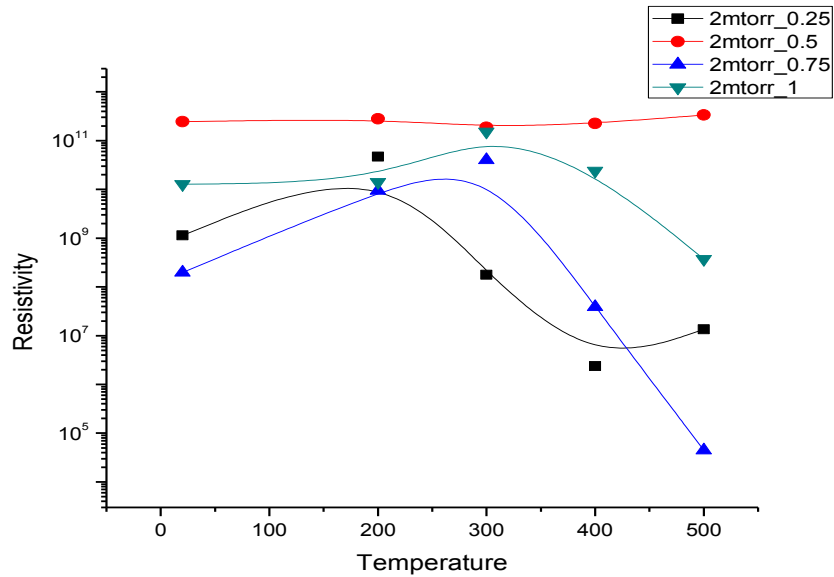


Figure 4.8: Effect of deposition temperature on Resistivity for 2mtorr pressure

4.1.5: Breakdown Voltage vs N₂/Ar gas flow ratio

Figure 4.9 shows the plot of Breakdown Voltage vs N₂/Ar gas flow ratios at different deposition temperatures and at 2mtorr deposition pressure and Figure 4.10 shows the plot of Breakdown Voltage vs N₂/Ar gas flow ratios at different deposition temperatures and at 5mtorr deposition pressure. As shown in the figure 4.9 for films deposited at 2mtorr pressure, the Breakdown Voltage has a slight increase in trend with increase in N₂/Ar ratio but becomes almost stable in the end. When considering the figure 4.10 for films deposited at 5mtorr pressure at different temperatures, breakdown voltage shows a stabilizing trend with the slight increase in N₂/Ar gas flow ratios from N₂/Ar = 0.25 to 0.75, but has a kind of decreasing trend at the end. This property of maintaining constant breakdown voltage over a range of gas ratios shows that devices can be fabricated with BCN as ILD at different range of gas flow ratios depending upon the feasibility of fabrication. The decrease in breakdown voltage at N₂/Ar = 1 may be due to the lesser concentration of nitrogen at that ratio and hence more the characteristic of B₄C (which has lower resistivity than BN).

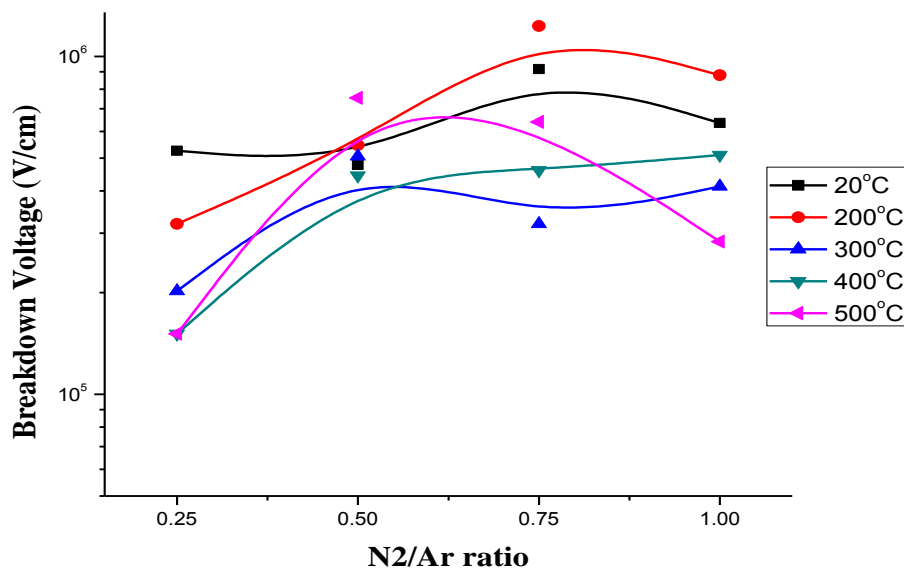


Figure 4.9: Effect of N₂/Ar gas flow ratio on Breakdown voltage at 2mtorr pressure

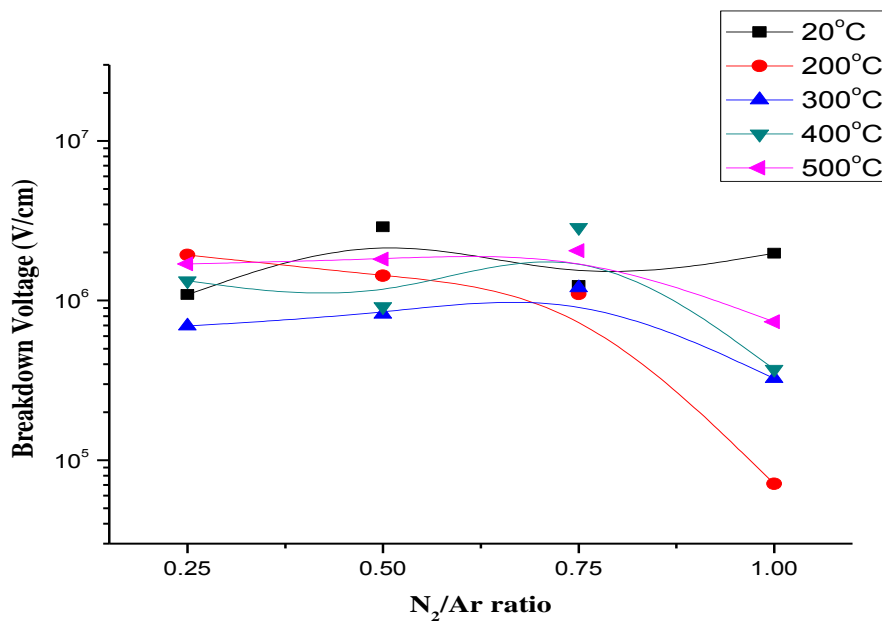


Figure 4.10: Effect of N₂/Ar gas flow ratio on Breakdown voltage at 5mtorr pressure

4.1.6: Breakdown Voltage vs. Temperature

Figure 4.11 shows the plot of Breakdown Voltage vs. Deposition temperatures at different N₂/Ar gas flow ratios and at 2mtorr deposition pressure and Figure 4.12 shows the plot of Breakdown Voltage vs. Deposition temperatures at different N₂/Ar gas flow ratios and at 5mtorr deposition pressure. As shown in the figure 4.11 for films deposited at 2mtorr pressure, the Breakdown Voltage has an increase in trend with increase in temperature initially but has a kind of decreasing trend overall. When considering the figure 4.12 for films deposited at 5mtorr pressure at different temperatures, breakdown voltage shows an initial increase in trend and later on it shows a decreasing trend with the increase in temperature but has a kind of Increase in trend in the end. Comparing both the graphs it can be concluded that for a range of deposition temperatures the breakdown voltage of the BCN film deposited at 5mtorr showed more robustness than that of 2mtorr ones as the value of resistivity didn't fall much below the order of 5×10^5 V/cm.

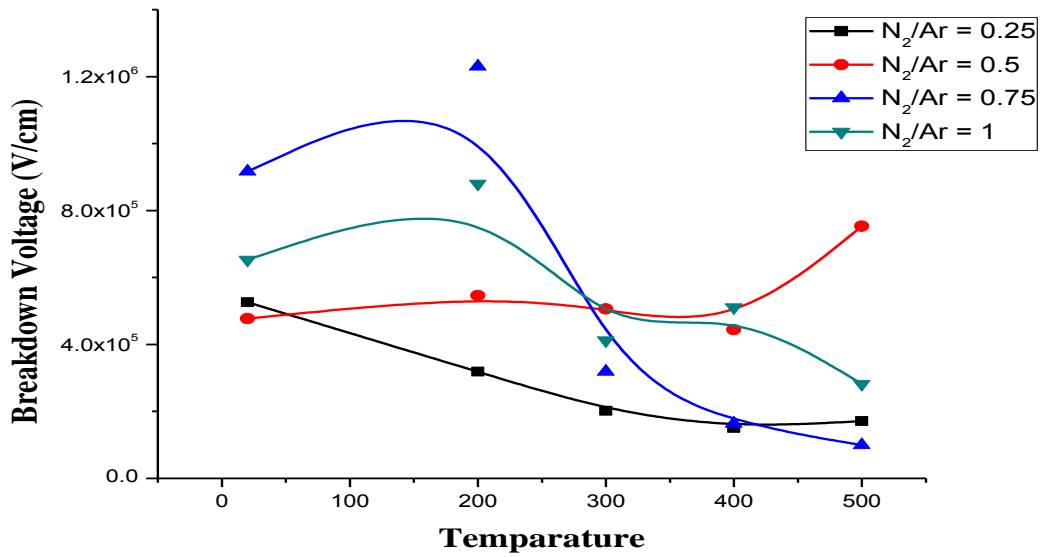


Figure 4.11: Effect of Temperature on Breakdown voltage at 2mtorr pressure

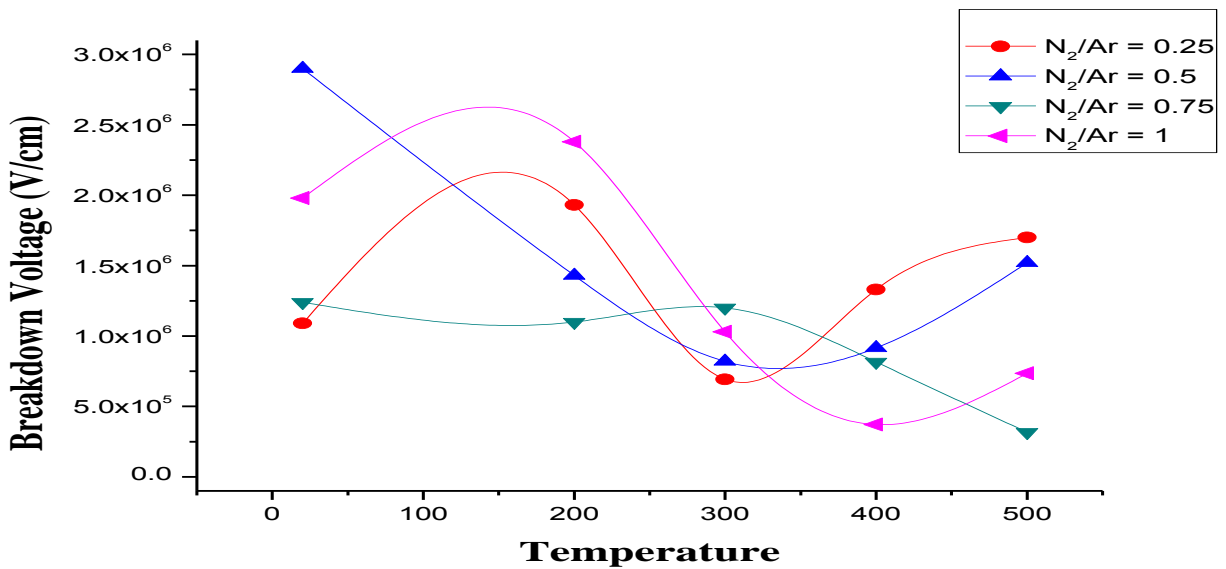


Figure 4.12: Effect of Temperature on Breakdown voltage at 5mtorr pressure

CHAPTER 5: CONCLUSION

BCN thin films were deposited successfully by RF magnetron sputtering from B₄C target in argon and nitrogen gas ambient. Electrical characteristics are strongly dependent on the N₂/Ar flow ratio during deposition and various other parameters like deposition temperatures, RF power, and deposition pressures. The electrical properties BCN thin films have been investigated to see it as a possible material having a low dielectric constant to be used as an interlayer dielectric (ILD) in the VLSI and ULSI. The Current-Voltage (I-V) plots were attained for the Al-BCN-Al (MIM) structures. By using the I-V characteristics the Breakdown voltage was found out as well as resistivity. Dielectric constant of the BCN films was also calculated from capacitance across the MIM structures. This work has been conducted to forge a relationship between various electrical parameters as a function of various deposition temperatures and N₂/Ar gas flow ratios under different deposition pressures. The dielectric constant decreases with increase in nitrogen in the BCN film and also with the increase in substrate temperature as it shows more BN kind of characteristics. The Breakdown voltage increases with N₂ and also with the substrate temperature it increases initially but shows a slight decreasing trend thereafter. The resistivity of the film is found to be almost constant and tend to vary very little with increase in substrate temperature and this shows its wide range of operability in different conditions of temperature, gas ratios and deposition pressures. BCN can thus be chosen for IDL as a trade off between the high resistivity, high breakdown voltage, higher dielectric constant of Boron Nitride and low dielectric constant, lower resistivity, and lower breakdown voltage of Boron nitride.

FUTURE WORK

Dual target reactive magnetron sputtering can be used to produce BCN thin films from B₄C and BN targets and related optical, electrical and mechanical characterization can be studied and its feasibility as a new low-k dielectric material which could replace the existing low-k Inter dielectric layer (IDL) will be determined. Also many of its other applications related to hardness and wear resistance can be studied. BCN as a possible optical sensor can be fabricated, as it has potential for many optical applications

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