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MODIFYING ELECTROPHYSICAL PROPERTIES OF SI-CBN INTERFACE BY INTRODUCTION OF ULTRATHIN DIELECTRIC LAYER

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Abstract

This study concerns modifications of Si - c-BN interface (with and without dielectric underlayer). c-BN films produced on p-type <100> Si substrates by means of Radio Frequency (RF) CVD process. Silicon nitride and oxynitride were deposited by Plasma Enhanced Chemical Vapour Deposition technique and used as a dielectric underlayer. MIS devices were fabricated to allow electrical characterisation. Moreover, the influence of underlayers on adhesion of c-BN to silicon substrate was examined.

[Engineering of Biomaterials, 56-57,(2006),27-29]

Introduction

Several properties of cubic boron nitride (c-BN) like wide bandgap width, good thermal stability, good thermal conductivity, or chemical and mechanical resistance make this material, in combination with other wide bandgap materials, the potential candidate for certain microelectronics and optoelectronics applications, particularly in the field of high-temperature and high-power devices [1-3].

Experiment

The silicon substrates used in these experiments were: p-type <100>, 4-7Ωcm. Substrates were cleaned by the RCA method before the experiments. Then different dielectric underlayers were deposited by PECVD technique on two samples: sample 1 - silicon nitride, sample 2 - silicon oxynitride. After their deposition, samples were transferred to the (RF) CVD reactor and on top of them c-BN films were produced. Additionally, for the purpose of comparison, c-BN films were also deposited directly on silicon. The parameters of the processes are presented in TABLE 1. The thicknesses of the obtained c-BN/dielectric underlayer were measured elipsometrically by Gaertner L117B, λ=632,4 nm.

In order to enable electrical characterisation of the obtained system, round dot metal electrodes (Al) were evaporated on top of the structures and thus metal-insulator-semiconductor (MIS) capacitors were obtained. Subsequently their capacitance-voltage (C-V) and current-voltage (I-V) characteristics were measured. C-V characteristics allowed extraction of the basic parameters (effective charge density (Q_{eff}), flat band voltage (U_{FB}) or mid-bands interface trap density (D_{itmb})) of investigated systems.

At the end, adhesion of c-BN films to silicon was examined, as well as the influence of the underlayer on this parameter. The mechanical scriber technique was used to perform these investigations. Typical method of improving the adhesion is deposition of thin h-BN layer between Si and c-BN film[4-5]. The application of Si_3N_4 and SiO_xN_y interlayers was investigated in this work.

	PECVD		RF CVD	
Number of sample	*parameters*	*thickness [Å]*	*parameters*	*thickness [Å]*
1	Underlayer - Si_3N_4 Power - 10W Pressure - 45 Pa, Time - 30s, Flows: SiH_4 – 95sccm NH_3 – 60sccm	38	Voltage - 105V Time - 45s Pressure - 30 Pa Flow: N_2=20sccm Source of boron: $(C_2H_5)_3B$	~1500
2	Underlayer - SiO_xN_v Power - 10W Pressure - 65 Pa Time - 20s Flows: SiH_4 – 150sccm NH_3 – 32sccm N_2O – 16sccm	36		
3	-	-		

TABLE 1. Process' parameters and thickness of layers used in the experiments.

Results

FIG.1 shows exemplary C-V characteristics of BN films directly deposited onto silicon substrate. The curves were measured in two directions: from inversion to accumulation ("I-A" - see FIG.1) and from accumulation to inversion ("A-I"). The hysteresis loop could be a result of big amount of charge that is collected in a c-BN film. Table 2 shows basic electrophysical parameters that were extracted from C-V

Parameter	Value
ε_i	4,2
U_{FB}	- 2,44 [V]
U_{MB}	- 0,266 [V]
Q_{eff}/q	2,41 E+11
D_{itmb}	4,66 E+11

TABLE 2. Basic electrophysical parameters of the c-BN layer extracted from the C-V measurements.

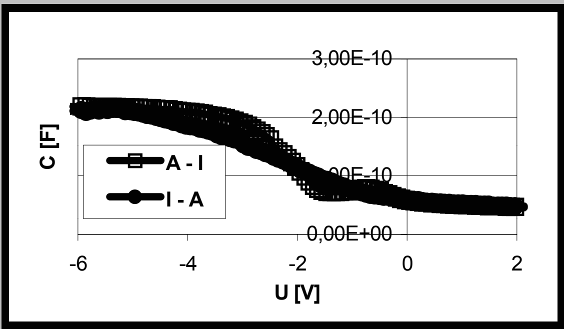

FIG. 1. Exemplary high-frequency (1 MHz) C-V curves of the c-BN/silicon structure.

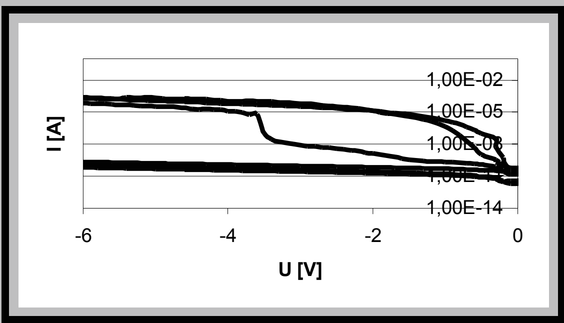

FIG. 2. Current-voltage characteristics of MIS structures with c-BN produced directly on the silicon substrate.

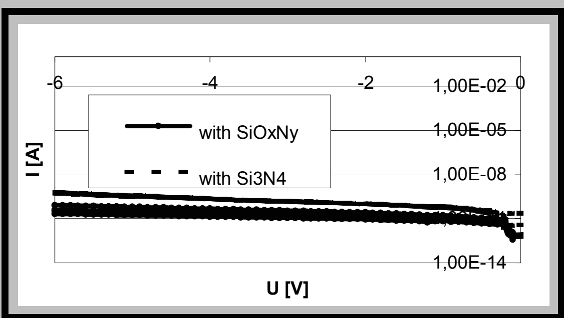

FIG. 3. Current-voltage characteristics of MIS structures with ultrathin dielectric undelayer and c-BN.

curve. The parameters of investigated layers are situated in typical range for this material (depending on method and parameters of deposition [6-8]).

The current-voltage (I-V) characteristics c-BN/silicon system are presented on the FIG. 2. There are two groups of curves. The first group represents structures, that have a break-down for quite low voltage values and high leakage The second group represents structures with a very good isolating properties (see FIG.2).

Next diagram (FIG. 3) shows I-V characteristics of the structures with ultrathin dielectric underlayer. In both cases it can be noticed that after use of ultrathin dielectric underlayer, I-V characteristics look more reproducible. Moreover, silicon oxynitride makes the dual dielectric system more effective as an insulator - there is a visible change in a current flow.

As it was mentioned above, part of this study was the investigation of adhesion. In order to perform these examinations, the samples with and without ultrathin dielectric underlayer were used.

FIG. 4 presents scratches on the c-BN surface which were made using the same weight for all investigated samples. Even without any particular load (it was used only the weight of a diamond scribe holder only) there is a noticeable scratch reaching almost to the silicon substrate. From these figures the following conclusion can be drown: the dielectric undelayer did not improve adhesion of c-BN film to the silicon substrate. Further research focused on improving adhesion, for example high temperature annealing of dielectric film, will be necessary.

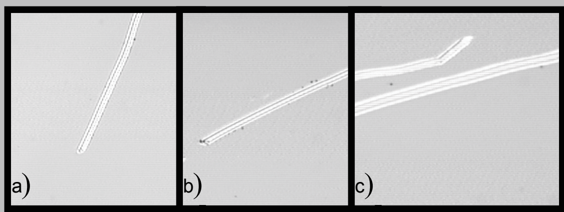

FIG. 4. Pictures of investigated layers - influence on adhesion a. BN without underlayer; b. BN with Si_3N_4 underlayers; c. BN with SiO_xN_y underlayer.

Conclusions

C-BN films were grown on the p-type <100> silicon substrates at the same technological process conditions. Ultrathin dielectric layers were introduced to the dielectric/semiconductor system. Boron nitride film was also deposited directly onto silicon substrate, for comparison. Although hysteresis loop is significant, interface state density value (in the middle of forbidden silicon band) do not exceed $4{,}66e10^{11}$ for the c-BN/silicon system. The current-voltage characteristics became more repeatable and more stable after the introduction of ultrathin dielectric underlayer introducing.

The c-BN/silicon oxynitride/silicon system indicates also a small decrease in current flow, comparing to c-BN/silicon system. Introducing dielectric underlayer did not improve adhesion of boron nitride films to the silicon substrates. Further technological process will be necessary.

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THE EFFECT OF PARTICLES, INCLUDING NANOPARTICLES, ON MACROPHAGES *IN VITRO* AND *IN VIVO*

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Abstract

Macrophages remove foreign material from the body and are recruited to sites were there are particles present. Multinucleate giant cells form by the fusion of macrophages. In the presence of particles, macrophages produce various chemical mediators, known as cytokines, as well as enzymes. Some of the cytokines are pro-inflammatory (for example, IL1ß, IL6 and TNFα) while others promote giant cell formation (GM-CSF, M-CSF, TGF). The presence of these cellular products can be shown by examining tissue sections with immunohistochemistry and by western blotting. The message (mRNA) for the synthesis of these molecules can be demonstrated by in situ hybridization and the polymerase chain reaction.

Macrophages process ingested material and present it as antigen to lymphocytes. Antigen-presenting macrophages play an important part in the initiation of metal sensitization. Surface receptors and their counterligands are expressed on macrophages and lymphocytes during antigen presentation.

The particles present in tissues around joint prostheses have been isolated and characterized. Over 95% of these are less than 1 micron (ECD) in size. Transmission electron microscopy has revealed nanoparticles of metal in the range 15-20 nm. Such particles are too small to be phagocytosed. Hydroxyapatite, diamond-like carbon (nano-diamond) and metal particles are being studied and results compared with those of particles in the micrometre range. There is a different response to different nanoparticles.

Key words: *Macrophage; lymphocyte; particles; cytokines; immunity; sensitization; nanodiamond.*

[Engineering of Biomaterials, 56-57,(2006),29-31]

Introduction

After the acute phase of inflammation, macrophages and multinucleate giant cells (MNGC) are responsible for removing foreign material, micro-organisms and dead tissue from the body. MNGC are formed by fusion of macrophages. Both of these cells are recruited to sites were there are particles, for example, wear debris around prosthetic joints. Macrophages are derived from circulating monocytes, migrating from vessels. In the presence of particles, macrophages and MNGC produce chemical mediators, known as cytokines. These can be demonstrated in situ and their production can be induced in cell culture when macrophages are incubated with particles.

It is clear from in vitro studies that macrophages are induced to produce these factors when they phagocytose (engulf) particles. Recognition of foreign material depends on a variety of mechanisms including surface receptors for the Fc component of immunoglobulin and for complement. The particles found adjacent to prosthetic joint components are derived mainly from the load-bearing surfaces and shed into the synovial fluid. It is likely that particles in the body become rapidly coated with proteins, including albumin, globulins, and complement components.

An important function of some macrophages is the processing of ingested material and its presentation as antigen to lymphocytes, the specific mediator cells in immune responses. Antigen-presenting macrophages are found in relation to particles in vivo, and these cells play an important part in the initiation of the process of sensitization to metal. Surface receptors and counterligands are expressed on macrophages and lymphocytes and can be detected in cell culture and in tissue sections. Macrophages and MNGC also contain nitric oxide synthase (iNOS) which gives rise to nitric oxide, a signalling molecule, and superoxide dismutase (SOD), involved in oxygen free radical production. Acid phosphatase (AcP) and non-specific esterase (NSE) play a part in the breakdown of ingested biological material, though there is no intracellular mechanism for intracellular breakdown of particles of man-made materials, such as metal or polyethylene.

The particles present in tissues around joint prostheses have been isolated and characterized. While there are occasional large shards visible by light microscopy, over 95% of particles are less than 1 micron (ECD) in size [1-3]. Transmission electron microscopy has also revealed the presence in some samples of nanoparticles of metal, in the range 15-20 nm. Such particles could not be taken into the cells by the usual phagocytosis process and might be pinocytosed. The study of the effects of nanoparticles on inflammatory cells is at a preliminary phase. Hydroxyapatite, diamond-like carbon (nanodiamond) and metal particles are being studied and results compared with those of particles in the micrometre range.

Materials and methods

Detailed materials and methods are not provided here in this short review. The effect of micro- and nanoparticles on macrophages has been studied in tissue retrieved from man after revision surgery for prosthesis loosening and from animals after experimental procedures. Cell culture studies use primary monocytes and lymphocytes derived from peripheral blood (PBM, PBL) as well as cell lines. Methods of investigation include immunocytochemistry (IHC) with monoclonal antibodies (mab), western blotting, in situ hibridisation (ISH), polymerase chain reaction (PCR) and reverse transcriptase PCR (RT-PCR) as well as ELISA, biochemical assays (eg citrulline- arginine for iNOS) and enzyme histochemistry (eg for AcP and NSE).

Results and discussion

Macrophages and MNGCs

Examination of tissue sections from patients undergoing