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Technology and Characterization of Silicon Carbide Films for High Temperature Applications
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Coordinator

Prof. Dr. E. Obermeier, Technische Universität Berlin, Germany

Partners

Technische Universität Berlin, Germany

University Montpelier II, France

Universitat Autònoma de Barcelona, Spain

Foundation for Research and Technology-Hellas, Greece

Aristotle University Thessaloniki, Greece

Endorsers

Etudes et Productions Schlumberger, France

Leti- Centre d'Etudes Nucleaire, France

CS GmbH, Germany

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R. Lossy, W. Reichert, E. Obermeier,
Technische Universität Berlin, TIB3.1, Gustav-Meyer-Alice 25, 13355 Berlin, Germany

C.Dezauzier, S. Contreras, J. Camassel, J. L. Robert,
University Montpelier II, 34035 Montpelier, France

M. T. Clavaguera-Mora, J. Pascual,
Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

K. Zekentes, G. Constantinidis,
Foundation for Research and Technology-Hellas, Heraklion, Greece

J. Stoemenos, V. Papaioannou, G. P. Dimitracopoulos,
Aristotle University Thessaloniki, 54006 Thessaloniki, Greece

J. Lasseur, M. P. Marechal,
Etudes et Productions Schlumberger, Rue de la Cavée 92140 Clamart, France

C. Jaussaud, L. DiCioccio,
LETI- Centre d'Etudes Nucleaire, 85X, 38041 Grenoble, France

T. Weber, Ch.Scholz,
CS GmbH, Fraunhoferstr., 85732 Ismaning, Germany

Abstract.

Several emerging applications demand electronic circuits and sensors need to be operated in harsh environments and at high temperatures. Silicon carbide is a material that is best suited for these applications having excellent mechanical and electronic properties up to very high temperatures. The objective was to investigate those properties and effects that are important for the development of sensors and integrated systems operating at high temperatures with high reliability. Deposition technologies for the growth of single crystalline, polycrystalline and amorphous silicon carbide were investigated. Characterization of deposited and imported SiC films was made using several methods in order to improve deposition schemes. Processing technologies like doping, patterning and contacting were developed to make silicon carbide films accessible to the design and development of prospective devices. Transducer effects like Hall effect, thermoresistive effect and piezoresistive effect were characterized for design of sensors with predictable performance and reliability. The main interest concentrated on the cubic type of silicon carbide. Cubic SiC may be deposited by heteroepitaxy on readily available silicon wafers and offers greater flexibility for the manufacturing of high temperature devices like sensors.

Technical Description and Results

Deposition by LPCVD

Cubic SiC films have been grown on previously oxidized, bare or carbonized Si(100) substrates in the temperature range 900-1150"C by low pressure organometallic chemical vapour deposition using tetramethylsilane(TMS) as a single molecule precursor [1]. The growth on previously oxidized wafers is motivated by the need to reduce the tensile stress in the SiC film. Polycrystalline films highly oriented in the (111) direction due to the formation of microtwins were formed at temperatures above 1000 'C. Films grown on carbonized substrates showed an improvement in the crystallinity.

Deposition in hot-wall LPCVD reactors is convenient to overcome difficulties of growth by commonly used Atmospheric Pressure CVD (APCVD) because lower pressures and lower temperatures are needed to obtain crystalline layers. The large number of wafers that can be coated simultaneously is also another interesting feature of these systems. This is a result of the large diffusion coefficient at low pressures which makes the growth rate limited by the rate of surface reactions rather than the rate of mass transfer to the substrate.

It is desirable to employ sources which are not hazardous and contain Si and C in the same molecule. The choice of tetramethylsilane (TMS) is also based on its high-vapour pressure, good availability and ease of handling, In this work the SiC growth has been carried out in a multiple-wafer-in tube reactor with a hot-wall arrangement. Our main purpose has been the growth of SiC films on Si wafers using a LPCVD equipment able to deposit simultaneously crystalline films at low temperatures on many substrates, with good uniformity over large-area substrates.

Thermodynamic calculations have been performed to determine the types and amounts of condensed phases and gases which would be present in the reactor in equilibrium at several values of total pressure and temperature.

Experiments were performed to test the LPCVD equipment and to identify the best deposition parameters for the growth process. The experiments were conducted at different pressures and wafer positions. Different cleaning treatments of the Si wafers before deposition have also been used. From the characterization of these samples, best deposition conditions were deduced. Studies of the influence of the deposition temperature on film growth conditions were performed. All these samples were deposited on a thin SiO_2 superficial layer (-60 Å) formed inside the react or during the heating up of the (100)Si wafer.

Experiments were performed on previously oxidized Si wafers. The objective was to minimize the strain energy of SiC produced by lattice mismatch between SiC and Si. SiO_2 layers with several thicknesses were used to evaluate the influence of the thickness of the interracial layer on SiC film quality. 'The amorphous $Si0_2$ layers were produced by thermal oxidation with dry oxygen inside a quartz tubular reactor at 1100°C. In all these samples the H_2 etching process

was suppressed. Taking into account our previous results, the TMS flow rate was reduced in this set of samples to increase the quality of the layers by a decrease of the SiC growth rate. Such a decrease in the TMS flow rate enables also to increase the deposition temperature without any significant presence of homogeneous nucleation.

In general, crystallinity increases with temperature. Samples deposited above 1000 °C are polycrystalline β-SiC. At 950 "C the layers deposited are mostly amorphous, although they contain nanocrystalline particles. Samples grown at a flow of 10 cm^3/min in the temperature range 1000 to 1150"C have a columnar structure with a thin equiaxial layer at the beginning of the deposited film. This columnar morphology is associated to the presence of a high-density of nucleation centres. The growth continues in a (111) preferential orientation along a direction perpendicular to the film/substrate interface. The surface of these films shows a grain-like morphology composed of spherulitic agglomerates of small crystallit es. A high density of voids in between the grains is observed.

At low TMS flow and high temperatures, the growth is columnar from the early stages with larger cylindrical crystals. A strong decrease of the voids in between the crystals is observed on the surface of the films. The change in morphology from the porous cauliflower structure, obtained at higher TMS flow rate, is continuous with decreasing TMS flow rate and increasing temperature. For flow values around 1 cm^3/min the temperature can be raised up to **1150** "C without SiC powder formation.

We have quantitatively determined the variation of the growth rate as a function of time, TMS flow rate, position inside the reactor, and temperature. The SiC growth rate is independent of time and exhibits an Arrhenius behaviour with temperature. This behaviour shows that the film growth is surface-reaction-controlled.

Amorphous silicon carbide films were prepared at substrate temperatures 900-950 °C for various H_2 to TMS flow ratios. All of them show nanocrystals immersed in the amorphous matrix. The carbon content of the films is around 60°/0, increasing slightly with a decrease in both the H_2 to TMS ratio and the deposition temperature.

Also, deposition on Si(100) wafers without any $Si0_2$ interlayer were performed. The usual in-situ etching of the wafers under hydrogen at 0.7 torr was not appropriate to remove the native oxide on the surface and, in addition, produced etch pits, Therefore, we increased the etching pressure in the reactor to 200 torr. This reduces the density of surface defects making the etching process more effective.

Samples, that had been carbonized previously by MBE were also used. In both cases, the SiO_2 native layer was removed, with the difference that acting on bare Si(100) wafers some etch pits were still produced, while the carbonized surface, being more resistant, remained defect free.

Deposition of SiC-films by MBE

The main target is to use the MBE process advantages over other methods in order to produce single crystalline ß-SiC films on Si substrates at growth temperatures below 1000°C [2-4]. The initial effort concentrated on the carbonization of Si surfaces by solid source MBE. The large differences in lattice parameters and thermal expansion *coefficients* between the film and the substrate are partially compensated by growing an initial conversion layer. Thus, a similar procedure must be adopted for solid source MBE and gas source MBE as well.

High purity pyrolytic graphite is used as the carbon source in solid source MBE. High purity was the main reason for using pyrolitic graphite as the carbon source. Evaporation temperatures of about 2500°C are necessary to obtain practical deposition rates of carbon in solid source MBE. Under these conditions controlled co-evaporation of carbon and silicon is difficult to obtain. Therefore this deposition method concentrated on the growth of the initial carbonization layer. Electron beam evaporation was employed for the growth.

For very low carbon flux and high substrate temperature the Si substrate surface had not been covered by a SiC film. In the case of samples grown at intermediate carbon fluxes and at substrate temperatures higher 660°C the formation of SiC nuclei is observed by RHEED. For some of them, the RHEED pattern remained spotty until the end of the epitaxy, indicative for the epitaxy of mediocre quality, single-crystalline material. Samples grown at temperatures lower than 660°C or at very high carbon fluxes indicate the growth of an amorphous or heavily polycrystalline layer.

The carbonisation layers grown by solid source MBE were systematically studied by TEM and atomic force microscopy (AFM). From these observations the following points can be concluded:

- In the early stage of the growth the epitaxy proceeds solely by islands which develop {111} facets resulting in the formation of microtwins.
- The growth of the islands occurs mainly by Si surface diffusion from the surroundings of the SiC islands.
- Surface diffusion of Si at relatively low temperatures (650-970°C) is in agreement with recent theoretical calculations, as the activation energy for surface diffusion in Si is by a factor of 10 lower compared to bulk diffusion. As the carbonisation advances, the surface is covered by SiC which inhibits the Si surface diffusion. In this case, the Si needed for the growth of SiC is supplied by open areas on the surface which act as Si sources.
- When the substrate temperature is reduced keeping all the other deposition parameters constant, the size of the SiC nuclei is reduced while their density increases in agreement with the classical nucleation theory.

The grown carbonization samples can be classified in four groups according to the characterization results and to the growth conditions:

1. Low carbon flux and high substrate temperature T_s :

Silicon carbide dendrites appear and the Si-surface is not recovered.

2. Intermediate carbon flux and $660°C < T_s$:

The SiC is stoichiometric and with Si-surface recovered and rectangular pits (SEM). RHEED pattern indicate the formation of epitaxial SiC nuclei turning in some cases to a mixed structure, which indicates the epitaxy of a partially polycrystalline film. Heavily twinned layers containing inverted rectangular pyramidal voids, bounded by {111) facets and located in the Si subsurface region (TEM). IR measurements show in most of the samples one absorption peak characteristic to the stretching vibration between Si and C sublattices.

3. Growth at low T_s (600-660°C) or high carbon flux:

SiC/carbon alloys or C-rich SiC composition is measured. No indication of any grown SiC film in XTEM. In IR measurements there was no signature of SiC. Growth at high carbon flux is exceeding the supply of silicon by surface diffusion.

4. Growth at very low substrate temperature (<600°C) or at high carbon flux for longer time than in the case of the 3rd group samples:

In the case of very low substrate temperature, no reaction appears between C and Si atoms while in the case of long time deposition at high carbon flux, the reaction is stopped because all the diffusion channels are sealed-off at the first stages of growth and amorphous carbon is subsequently deposited.

Gas Source MBE

The growth proceeds in two steps: the initial optimized carbonization step followed by the MBE growth step with simultaneous supply of Si molecular beam and C_2H_2 gas beam. C_2H_2 molecules react easily with Si even at temperatures as low as 800°C [4]. Carbonization of Si surfaces using C_2H_2 gas molecular beams at 780°C has been performed and single-crystalline 3 C-SiC layers were obtained by this method.

In the case of our GSMBE configuration, carbon is supplied by introducing C_2H_2 in the growth chamber through a cracker cell while silicon is supplied by e-gun “evaporation. Acetylene has been chosen as the carbon containing gas and therefore a gas-source cell with a cracking zone has been installed in the MBE chamber.

The optimization of the carbonization process was targeted. Epitaxial films were also grown under simultaneous supply of elemental Si and acetylene for characterization purposes. In the following, the term epitaxial film will describe the films grown under simultaneous supply of Si and C_2H_2.

Several deposition processes have been employed for the gas source MBE experiments. They can be classified in three main categories, according to the carbonisation procedure:

1. Ordinary carbonisation process: First the substrate temperature T_s was increased to the carbonization temperature Tc (750- 1080°C) and subsequently the C_2H_2 (0.2- 12sccm) was introduced to perform the carbonisation.

2. Extended carbonisation process : The carbonisation samples were grown with the ordinary carbonisation process at different temperatures (750-1080°C) which was followed by an increase of the substrate temperature to the highest obtainable temperature under C_2H_2 flux. It permits the growth of epitaxial films at sufficiently high temperature.

3. Modified carbonisation process: After the growth of the Si buffer layer, the substrate temperature was lowered to 400°C at which the C_2H_2 supply was started and then, the substrate was heated to the carbonisation temperature T_c. The process was finished by an increase to the temperature of epitaxial growth T_{SiC} under continuous C_2H_2 supply.

For the ordinary carbonization process, a low carbonisation temperature (750-850°C) resulted in monocrystalline SiC layers according to RHEED observations. For low acetylene flow rates the extended carbonization process gave better results than the modified process for similar conditions (Tc=800°C and 0.5 seem).

The main conclusions of GSMBE experiments are the following:

- For a molecular flux ratio (C_2H_2/Si) lower than 10 the surface of epitaxial films contains Si crystallite.
- There are no problems of unreacted carbon on the Si or SiC surface as in the case of solid source MBE.
- The crystal structure and quality of the epitaxial films depends strongly on the structure and quality of the corresponding carbonization layer.
- The ordinary carbonisation process at relatively low substrate temperatures gave the better results with single crystalline carbonisation layers and relatively low defect density.
- Carbonization processes practical for subsequent epitaxial film growth suffer from increased Si outdiffusion of the substrate which is the main reason for the inferior crystal quality and the increased density as well as size of pits.

Assessment of the SiC Film Quality

The formation of a high quality carbonization layer before the deposition of SiC by CVD is crucial for the quality of the silicon carbide film [5-9], In order to study the early stage of silicon carbide growth carbonization layers were grown by MBE at different substrate temperatures and different carbon flow rates. The following qualitative results can be drawn:

- Due to 21% misfit in the 3C-SiC/Si system the 3D-epitaxial growth is the most favorable. In this way the interfacial energy is significantly reduced. Therefore, in the early stage of the growth the epitaxy proceeds solely by islands.

- At a constant deposition temperature the density of the 3 C-SiC islands increases as the carbon flow rate increases.
- The density of the stable nuclei is reduced as the substrate temperature increases at a constant flow rate.
- The lowest temperature for the formation of 3C-SiC is 660°C, below this temperature no reaction occurs. The highest island density 1x1 0^{12} cm^{-2} was observed when a high flow rate was combined with the lowest deposition temperature for SiC formation.

The 3C-SiC islands develop along the <110> crystallographic directions and are heavily twined, very often exhibiting a dendritic growth. These islands are in epitaxial relation with the Si substrate although slightly disoriented. Misorientations of the islands up to 2.5° were found. The mean size of the nuclei is about 10 nm and due to their disorientation low angle boundaries are formed during the coalescence, which is another source of defects. The disorientation of the nuclei during the early stage of growth results in the relaxation of the two lattices as molecular dynamic calculations have shown. observations also reveal the disorientation of the 3 C-SiC islands. Most of the defects which propagate inside the 3 C-SiC films are generated by small misorientation of the 3C-SiC nuclei during the early stage of growth.

The formation of 3C-SiC islands during the carbonization process is related to a significant Si migration from the Si substrate. It was possible by AFM image processing to estimate the total volume of the missing silicon around each island and to compare it with the volume of the corresponding SiC island. It was found that the two volumes are equal. This is expected if we consider that the conversion of one unit volume of Si to SiC results in an increase in volume only by 3. **5°/0.** Surface diffusion of Si at relatively low temperatures of 650°C to 970°C is expected because according to the recent theoretical calculations the activation energy for surface diffusion in Si is very low, 0.6 eV. In contrast the activation energy of bulk Si self-diffusion is very high, about 5 eV, therefore bulk diffusion becomes significant above 1200°C. As the carbonization process advances the surface is covered by SiC which inhibits Si surface diffusion. In this case the Si which is needed for the growth of SiC, is provided by open areas on the surface which are the sources of Si supply.

Twining is an efficient way to relieve the strain developed due to the 21% misfit between SiC and Si by creating low energy defects like twins. The topology of the twins was theoretically studied using interracial connectivity. It was shown that twins are progressively annihilated, as the film grows, by the formation of triple line nodes. The symmetry-constrained twin topology gradually leads into a crystal free of twins as it is observed near the free surface in sufficient thick specimens.

The 3C-SiC/Si interface is not atomically flat due to the strong reaction of the carbonized zone with the Si substrate to form 3C-SiC. The reaction occurs in depth by interdiffusion of carbon and Si atoms. Spatial differences in the degree of interdiffusion result in the formation of

uneven nuclei having shifted lattice planes. The use of a vicinal Si substrate in the case of epitaxially grown 3 C-SiC does not prevent the formation of APBs, because the carbonization process is not a simple epitaxy but rather a strong chemical reaction. This occurs at a depth of several atomic layers by interdiffusion of Si and carbon atoms resulting in a rough interface.

Results from Raman spectroscopy are in agreement with those obtained from TEM/XTEM, showing that residual stress and strain in the epilayers are due to the lattice misfit between the Si substrate and the β-SiC epilayer.

Low temperature luminescence data reveal differences in the quality of the spectra depending on the origin of the samples. High quality spectra may be due in part to a specific treatment of the SiC surface, which was applied to yield improved surface quality.

IR absorption measurements were made and vibrational modes from resulting from Si-O and Si-C bonds could be identified. The reststrahlen band has been used to detect the surface quality of the SiC films.

Elastic Properties

The elastic modulus and intrinsic stress of SiC films are of great importance for the design of sensors based on SiC material. These properties depend on the morphology of the grown films and the actual parameters for the deposition of SiC used. Therefore the influence of the most important parameters such as the deposition temperature, the crystallinity, and the thickness of the β-SiC films on the elastic properties were investigated.

Analytic and FEA calculations were used to investigate Young's modulus, the Shear modulus and Poisson's ratio for various tryst al planes and various crystal orientations. Since the thermal expansion coefficient of single crystal β-SiC is higher than the coefficient of silicon in the whole temperature range, the β-SiC film is under tensile stress. The thermal stress increases strongly with increasing deposition temperature and is approximately independent of the wafer dimensions. For a substrate with a diameter of 30 mm and a thickness of 360 μm the FEA calculated maximum deflection in the middle of the wafer is about 30 μm for a deposition temperature of 1400 K and a film thickness of 5 pm. The anisotropic material properties of the substrate and the film have only little influence.

To determine the elastic properties of thin films experimentally, a set-up was used, which enables simultaneous measurement of Young's modulus and the residual stress. The measurements were performed with (100)-oriented single crystal material and polycrystalline β-SiC films with and without texture. Square β-SiC diaphragms of different edge length and thickness were fabricated by selectively removing the Si substrate from the back side of the wafer. This was partially done by reactive ion etching and partially by anisotropic etching in

KOH. Using the load-deflection measurement technique, the deformation of the SiC diaphragm was determined as a function of the applied pressure by a computerised laser-optical measuring system. From the center deflection of the diaphragm Young's modulus and the residual tensile stress can be calculated. The measured values for the tensile residual stress are in good agreement with values found in literature. If the experimental results for the stress are compared with the calculated values, it should be considered, that the calculation using FEA takes into account only the thermal stress, whereas the measurement yields the residual stress, which is composed of the thermal stress and the intrinsic stress. However, if one assumes that the residual stress mainly consists of thermal stress, comparison between calculated and measured results is possible.

Doping by Ion Implantation

Doping of SiC material can be obtained during the deposition process or within selected areas using diffusion and ion implantation. Diffusion processes in SiC due to its high melting point require both temperatures well above the melting point of silicon and relatively long times to allow for the mass transport required. Therefore, this process is not suitable for heteroepitaxially deposited SiC, grown on silicon. Furthermore, oxide layers that are used for masking of selective areas will vaporise at these temperatures. Under these conditions ion implantation is the most suitable solution [10, 11]. With ion implantation the depth profile and the incorporated dose can be chosen independency. Multiple implantations at different energies can be used to tailor the required doping profile.

A systematic study of implantation profiles for implantation of nitrogen in silicon carbide has been performed at energies from 50 keV to 180 keV. Single energy implants are used so that the doping parameters extracted here can be used to design well defined doping profiles from multiple energy implants. Depth profiling of the implanted ions is performed by secondary-ion-mass spectroscopy. Implantation profiles have been calculated from Monte-Carlo simulations using the programme code TRIM. Since these calculations are done using first principles only few basic parameters are required.

In order to allow for an unambiguous determination of the implantation profiles, analytical distribution functions are introduced to describe the doping profiles for the simulation and the measurement separately. To give a more accurate fit to the dopant concentration than is possible using a Gaussian, the Pearson family of distribution functions is used. Four parameters are extracted from the best fit of the distribution functions. By taking all the data from the 4 parameters of the distribution functions it is evident that except for the channeling effect a good agreement between depth profiling and simulation results from Monte-Carlo simulation is observed.

To increase the degree of activation of the implanted dopants the implantation process can occur at elevated temperatures or the implanted samples have to be annealed at high temperatures after the implantation. The first method was chosen for our experiments since much higher annealing temperatures than implantation temperatures are required to achieve the same activation rate.

The electrical characterization was performed on 3C-SiC samples, where the dose, energy and temperature during implantation was varied. No post anneal was performed. Resistivity and Hall measurements were made using van der Pauw structures. The resistivity and Hall measurements were made in the temperature range between 80K and 723K.

Samples with the highest implantation temperature and the highest implantation dose have the lowest resistivity and that the resistivity decreases with increasing temperature. This change in resistivity can be used to determine the temperature of a system. Since the change in resistivity with temperature is higher for the low doped samples, low doping concentrations may be preferable for the development of sensors that make use of the thermoresistive effect. However, the results show that ion implantation is a practical way to intentionally change the resistivity of SiC films.

Carrier concentration, mobility and donor activation were estimated. The measurements revealed that at the high doping levels used in these experiments the semiconductor samples are degenerate and therefore the carrier concentration in the SiC layers is independent of the measurement temperature. With increased temperatures during implantation also increased activation can be obtained.To obtain reasonable activation the temperatures required during hot implantation are much lower than those from cold implantation with post anneal. By comparing the results obtained, it can be seen that increasing the energy as well as the dose in the case of hot implantation increase the activation.

Contacts to SiC-Films

Applications of SiC working at high temperatures require ohmic, high-temperature resistant contacts and Schottky contacts [12, 13]. The work focused on a systematic study of different metallization systems for ohmic contacts and on Schottky contact formation.

Ohmic contact metallizations investigated were tantalum, nickel, titanium, chromiu molybdenum, aluminium and gold. Metal films were evaporated as thick layers or thin multilayer systems and the resulting contacts were characterised by contact resistance of as-deposited and annealed films. The results can be summarised al follows:

- Contact resistance is in the range from $10^{-4}\Omega cm^2$ to $3\cdot10^{-5}\Omega cm^2$ and is in accordance with results from other groups.

- Depending on the metallization used contacts remain ohmic up to annealing temperatures as high as 900°C.
- The gold overlayer improves the specific contact resistance,

Annealing tests showed that Ti/Pt/Mo multilayer structures are thermally stable barrier systems. Therefore, it was combined to yield a Cr/Ti/Pt/Mo multilayer structure. This system was subjected to ageing tests at 500°C and more than 400 hours survival time could be ascertained. Also, tungsten based contact systems were investigated. Sputtered contacts showed good adhesion but revealed ohmic behaviour only after annealing at temperatures higher than 700°C.

Schottky contacts on β-SiC have been investigated using gold, platinum, palladium and germanium. Results show that goId is the best Schottky contact but is also unsuitable for high temperature applications. Palladium and germanium failed at high temperatures too and only platinum showed stable contacts at elevated temperatures.

Structure Delineation/Patterning

Reactive ion etching of SiC with three different systems of reactant gases was performed, where one is a fluorine-chlorine containing gas (CCl_2F_2 or CCl_2F_2/O_2) and the two others are pure fluorine containing gas (SF_6 or SF_6/O_2 and CF_4 or CF_4/O_2) [14].

The material used in this investigation consisted of β-SiC epitaxially grown by chemical vapour deposition (CVD) and polycrystalline SiC grown by LPCVD. The dependence of the SiC etch rate on the different process parameters was studied. Parameters investigated were rf-power, gas pressure, gas flow and oxygen concentration in the gas mixture. From the work it can be concluded that the DC bias which is related to rf-power is the dominant factor influencing the etch rate for both gas systems.

Etching with CCl_2F_2 gas shows a constant etch rate vs. time. After long term RIE samples acquire rough surfaces. The surface morphology is independent of the temperature at which the etching takes place. Examination of rough etched surfaces by AES showed considerable change in the Si/C ratio as compared to the ratio of the same surface prior to etching. All RIE conditions lead to highly anisotropic etching.

For CF_4/H_2 gas mixtures the etch rate varies linearly with the hydrogen content. For H_2 concentration higher than 40°/0 there is no etching. The addition of hydrogen into the mixture improves the smoothness of the etched surface. This is attributed to the formation of AI-H volatile compounds that remove the Al micro masks. Extremely smooth 1µm deep NE-etched surfaces are obtained for 25°/0 H_2 content. Typical etch rate is of 15nm/min. Increase *in RF* power to more than 100W leads to rough surfaces.

For the SF_6/O_2 gas mixture the maximum etch rate of 600 Å/min was obtained at an SF_6/O_2 ratio between 10-200/0 0_2. The value of the DC bias increased with increasing 0_2 concentration. For the CCl_2F_2/O_2 gas mixture the addition of oxygen gas only for polycrystalline SiC yields enhanced etch rates whereas for monocrystalline β-SiC no increase is observed. This leads to the concision that a physical reaction is the controlling step in etching process of monocrystalline SiC.

Micromasking during etching of SiC may seriously change etch rate and surface roughness. This type of micromasking is not observed in the case of silicon etching and stems from aluminium deposits that are due to abrasion of material from the chamber walls of the etcher. This effect can be prevented by a graphite coating of the chamber walls.

Electrical Characterization

The piezoresistive effect describes the dependence of the resistivity on the mechanical stress in a resistor. The effect was examined in relation to doping and temperature. For monocrystalline SiC films the dependence on the crystallographic orientation of the resistors must be considered. The gauge factors of the thin SiC films were determined using the beam deflection technique. Piezoresistors on a bending beam were fabricated and strain was applied to the films. From the ratio of the change in resistance due to the applied strain the longitudinal and transversal gauge factors were determined.

The diode characteristics of the SiC/Si interface was analysed to evaluate the influence of the substrate on the electrical behaviour of the 3C-SiC layer. Results from this investigation show that SiC/Si interfaces from standard deposition processes start leaking at temperatures above 200°C. Other interfaces that can be integrated into SiC/Si material and further reduce the leakage current are interesting from viewpoint of application. Therefore, silicon carbide films were deposited on SIMOX wafers. The use of SiC pn-junction already reduces leakage drastically. Best results were obtained using SiC/SIMOX technology even though measurable leakage is still observed at high temperatures [15-19].

Investigations of the Hall Effect in hexagonal SiC epilayers show that a clear distinction can be made for the transport properties of the charge carriers in the epilayer and the substrate.

Conclusions

Deposition of silicon carbide films using Molecular Beam Epitaxy and Low Pressure Chemical Vapour Deposition were investigated. Deposition by MBE was performed using Solid Source MBE and Gas Source MBE. The different stages of film growth were investigated and special emphasis was laid on the initial growth phase, where film nucleation and growth under different growth conditions were analysed.

Polycrystalline and amorphous silicon carbide films were grown by LPCVD. This technique when compared to other methods has the advantage of deposition over a large area. A thorough investigation of the silicon carbide film quality depending on different deposition parameters was performed in order to establish optimised film characteristics.

Processing technologies for silicon carbide are important as they provide test devices for the characterization of the silicon carbide material deposited and also lead to enabling technologies that are required for the design of prospective devices. Technological areas that have been successfully investigated include doping of SiC films by high temperature implantation, electrical contacts to SiC material and etching of SiC films.

Transducer effects like Hall effect, thermoresistive effect and piezoresistive effect were characterized. The gauge factors of the thin SiC films were determined using the beam deflection technique, The piezoresistive effect was examined in relation to doping and temperature.

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