INTEGRATED ELECTRONIC DEVICES REALIZED ON SILICON CARBIDE

MATNANTECH Project no. 23 (2001-2004)

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1. RESEARCH OBJECTIVES

The project proposed will include the modelling, computer simulation, and design describing and manufacturing of the integrated electronic devices realized on silicon carbide. The main objective of the project is to elaborate, consolidate and transfer to the industrial environment the know-how for mass production.

2. RESULTS

Compared to Si, SiC exhibits a larger band-gap, a higher breakdown field, a higher thermal conductivity and a high saturation velocity. These properties make SiC very attractive for the fabrication of high temperature, high-power and high frequency electronic devices. In addition, its favorable mechanical properties such as high elastic modulus and toughness, in combination with its large bandgap, make this conductor an excellent material for the fabrication of microsensors that can operate at temperature higher than 600^{0}C.

Compared to Si, SiC has demonstrated higher chemical inertness and radiation resistance which also increase its potential for sensors operating in adverse environments. Such applications are in instrumentation and control of nuclear power systems, which require high temperature transducers capable of operating in radiation environment. In comparison to diamond, attractive features of SiC are that it can be doped both p- and n- type and it allows a natural oxide to be grown on its surface.

Simulation results

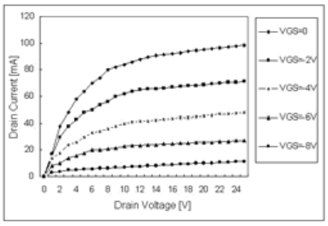


Fig. 1. ID - VD characteristics simulation of the power MESFET design on 4-H SiC

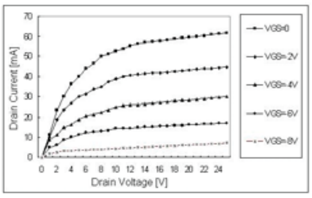
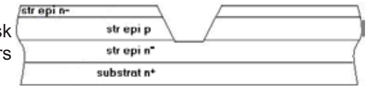


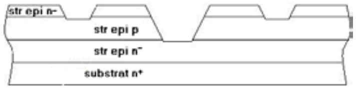
Fig. 2. ID - VD characteristics simulation of the power MESFET design on 6-H SiC

Technological Process

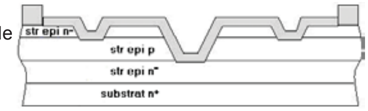
Gate groove formation
- ➢ Deposit and pattern Al hard mask
- ➢ Dry etching SiC n+ and epi-layers



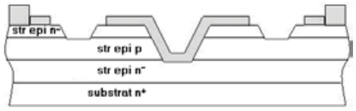
Source groove formation
- ➢ Deposit and pattern Al hard mask
- ➢ Dry etching SiC n+



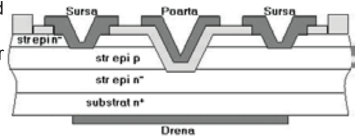
Oxide formation
- ➢ Deposite and pattern oxide (LPCVD)
- ➢ Grow gate oxide



Contact windows formation
- ➢ Pattern gate oxide



Metallization
- ➢ Deposit and pattern Ni gate and source contacts
- ➢ Remove oxide from the wafer backside
- ➢ Deposite Ni drain electrode



The important results obtained in the project frame of this project consist in modelling, computer simulation and design of the technologic process and structure of the power MESFET realized on silicon carbide.
A demonstrator will be realised in the multiproject-wafer system such resulting different chips for every class of structures.

3. EFFECTS

Uncooled operation of 300 - 600^{0}C SiC electronics and sensors mounted would save weight and increase reliability by replacing hydraulic controls with "smart" electro-mechanical controls. SiC-based distributed control electronics would eliminate wiring and connectors needed in conventional sheltered-electronic control systems.

FORCE MICROSENSORS FOR ATOMIC FORCE MICROSCOPY

MATNANTECH Project no. 91 (2002-2004)

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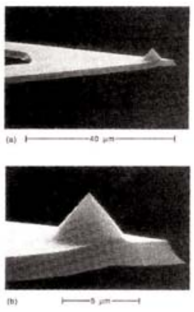
1. RESEARCH OBJECTIVES

- development of microfabrication techniques for constructing SiO_2 and Si_3N_4 cantilevers without tips for atomic force microscopy
- development of novel process for microfabrication Si_3N_4 cantilevers with integrated pyramidal tips
- development of a new method for constructing SiO_2 cantilevers with integrated conical tips

2. RESULTS

The atomic force microscope (AFM) has become a powerful tool for investigating surfaces on atomic or nanometer scale. An AFM consists of a sharp cantilevered tip that is scanned within nanometric proximity over a surface. The forces between the tip and sample cause a minute cantilever deflection, which is sensed to obtain a topographical map of the surface of a nanometer or atomic scale. Depending on the intended application, the cantilever stylus used in the AFM should meet the following criteria:
- a low force constant
- a high resonant frequency
- a high mechanical Q
- high lateral stiffness
- short lever length
- incorporation of a mirror or electrode for deflection sensing



SEM micrographs of conical tips on SiO_2 cantilevers

The low mass of these cantilevers allows them to have high resonant frequencies (10 - 100 kHz) with force constant small enough to detect forces of less than 10-8 N.
Conventional microfabrication techniques are ideal for constructing planar thin film structures which have lateral dimensions down to about 1 mm. In order to take advantage of the good mechanical properties of microfabricated cantilevers, thin film cantilevers without integrated tips were proposed in the AFM before methods of fabricating integrated tips were developed. A corner of the cantilever can be used as a crude tip or, if a better tip is needed, a diamond fragment can be attached to the end of the cantilever by hand.
Two of the fabrication processes presented below include the fabrication of a sharp tip as an integral part of the cantilever, which significantly simplifies the preparation of force - sensing styli for the AFM in comparison to older techniques. These fabrication processes include: a method for producing Si_3N_4 cantilevers with integrated pyramidal tips formed by using an etch pit on the (100) surface of a silicon wafer as a mold and a method for producing SiO_2 cantilevers with conical tips formed by a combination of isotropic and anisotropic plasma etching of a small silicon post. Each of these processes uses a (100) silicon wafer as a substrate and relises on conventional batch fabrication techniques. The quality (i.e., sharpness) of the tips produced by the above methods matches or exceeds that of conventional tips used in the AFM.
This project presents in detail several simple processes that allow microfabrication silicon oxide and silicon nitride cantilevers with integrated silicon tips which are capable of mapping surfaces at a atomic resolution. Since these batch fabrication processes can easily be used to produce large quantities of cantilevers, this critical and fragile component can be replaced as often as necessary.

3. PARTNERSHIP

- National Institute for Research and Development in Microtechnologies (IMT - Bucharest)
- ROMES - SA
- INCD - FM
- University of Bucharest, Faculty of Physics

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