Electrical and structural characterization of metal germanides

BY

Albert Chawanda

Submitted in partial fulfilment of the requirement for the degree of

DOCTOR OF PHILOSOPHY (PhD) IN PHYSICS

Department of Physics in the Faculty of
Natural and Agricultural Sciences at the
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Co-supervisor: Dr. J.M. Nel

UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

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Metal-semiconductor contacts have been widely studied in the past 60 years. These structures are of importance in the microelectronics industry. As the scaling down of silicon-based complementary metal-oxide-semiconductor (CMOS) devices becomes more and more challenging, new material and device structures to relax this physical limitation in device scaling are now required. Germanium (Ge) has been proposed as a potential alternative to silicon.

In this thesis a systematic study of the thermally induced reaction of transition metals with the n-Ge substrate is outlined. Investigations in the change of the electrical properties of the metal germanide structures is studied in a wide range of temperatures. Current-voltage (*I*-*V*), capacitance-voltage (*C*-*V*), deep level transient spectroscopy (DLTS) and high-resolution Laplace-DLTS (L-DLTS) techniques have been used for the electrical characterization of the fabricated Schottky contacts. Results obtained indicate the variation of the electrical properties of these Schottky contacts can be attributed to combined effects of interfacial reactions and phase transformation during the annealing

process. The barrier height distribution in identically prepared Schottky contacts on n-Ge (100) showed that the barrier heights and ideality factors varied from diode to diode even though they were identically fabricated. The properties of the n-Ge Schottky contacts have revealed a strong dependence on temperature. The current transport mechanism has been shown to be predominantly thermionic emission at high temperatures while at low temperatures, the Schottky contacts have exhibited the dominance of the generation-recombination current mechanism. The variation of the Schottky barrier heights at low temperatures have been attributed to barrier inhomogeneities at the metal-semiconductor (MS) interface. Results from defect characterization by DLTS show that the *E*-centre is the dominant defect introduced in n-Ge by electron beam deposition during contact fabrication and substitutional related defects are induced during the annealing process. The identification of some of the defects was achieved by using defect properties, defect signature, annealing mechanisms and annealing behaviour and comparing these properties to the results from theoretical defect models. Annealing showed that defects in Ge can be removed by low thermal budget of between 250–350°C.

Finally, structural characterization of these samples was performed by scanning electron microscopy (SEM) and Rutherford backscattering spectrometry (RBS) techniques. From the SEM images it can be observed that the onset temperature for agglomeration in the 30 nm Ni/n-Ge (100), and Pt/-, Ir/- and Ru/n-Ge (100) systems occur at 500–600℃ and 600–700℃, respectively.

To

MY WIFE ESTELLAH

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DECLARATION

I, **Albert Chawanda**, hereby declare that I am the sole author of this thesis. I authorize the University of Pretoria to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Signature ______________________________Date__________________

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