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UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Investigation of the diffusion behaviour of aluminium in different semiconductors

by

Thilo Michael Hauser

Submitted in partial fulfilment of the requirements for the degree

PHILOSOPHIAE DOCTOR

in the

Faculty of Science (Department of Physics)

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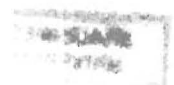
Supervisor: Professor E. Friedland



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SUMMARY

Investigation of the diffusion behaviour of aluminium in different semiconductors

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Physics Department

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In the semiconductor technology aluminium is used for the production of contacts as well as a dopant. When such a semiconductor-aluminium compound in an electronic circuit is exposed to heat or radioactivity its physical properties can alter due to thermal and radiation enhanced diffusion. It is important to know the diffusion behaviour of these compounds to predict lifetimes of circuits. However, reported diffusion coefficients of aluminium in several previously investigated semiconductors are contradictory. It is important to understand the reasons for these discrepancies and additional measurements with different analysing methods have to be performed under well-controlled conditions. Furthermore diffusion data of aluminium in several compound semiconductors investigated in this study are not available.

The semiconductors investigated in this study were silicon, germanium, indium phosphide, indium antimonide and gallium arsenide. Two different methods were applied to analyse the diffusion behaviour of aluminium in these semiconductors. Firstly thin aluminium films were deposited by vapour deposition onto the investigated semiconductors. Secondly, samples were implanted at room temperature and at T_i = 250 °C with a fluence of 5 x 10^{16} aluminium ions cm^{-2}.

Aluminium depth profiles for both methods were obtained by nuclear reaction analysis (NRA) before and after isochronal annealing at different temperatures. NRA is an isotope specific method that has various advantages over other analysing methods. The $^{27}Al(p,\gamma)^{28}Si$ reaction at a proton energy of 992 keV was applied to detect aluminium atoms. Diffusion coefficients as well as the detection limits of this method were extracted from a comparison of the depth profiles before and after annealing.

Additional channeling analysis in a backscattering geometry was performed to analyse the radiation-induced damage during the implantations and their recovery after isochronal annealing.

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SAMEVATTING

Studie van die diffusiegedrag van aluminium in verskillende halfgeleiers

deur

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Voorgelê ter gedeeltelike vervulling van die vereistes vir die graad Philosophiae Doctor in die Fakulteit Natuurwetenskappe.

In die halfgeleierindustrie word aluminium vir kontakte sowel as doteermiddel gebruik. Wanneer so ’n halfgeleier-aluminium verbinding in ’n elektroniese stroombaan aan warmte of radioaktiwiteit blootgestel word, kan sy fisiese eienskappe as gevolg van termies- en stralings-versnelde diffusie verander. Dit is belangrik om die diffusie-gedrag van hierdie verbindings te ken om die leeftye van stroombane te voorspel. In die literatuur is uiteenlopende diffusiekoëffisiënte vir aluminium in ‘n aantal halfgeleiers gepubliseer. Dit is belangrik om die redes hiervoor te verstaan en verdere metings met verskillende tegnieke onder beheerde omstandighede is derhalwe nodig. Verder is diffusie-data van aluminium in verskeie saamgestelde halfgeleiers wat in hierdie studie ondersoek is, nie beskikbaar nie.

Die halfgeleiers wat in hierdie studie ondersoek is, is silikon, germanium, indiumfosfied, indiumantimonied en galliumarsenied. Twee verskillende tegnieke is gebruik om die diffusiegedrag van aluminium in hierdie halfgeleiers te ondersoek. Eerstens is dun aluminiumlagies op die halfgeleiers opgedamp. Tweedens is die halfgeleier by kamertemperatuur en 250 °C met 'n dosis van 5 x 10^{16} aluminiumione cm^{-2} geïnplanteer.

Aluminiumdiepteprofile is vir albei metodes deur middel van kernreaksieanaliese (NRA) voor en na isochroniese uitgloeiing by verskillende temperature bepaal. NRA is 'n isotoopspesifieke tegniek met verskeie voordele bo ander tegnieke. Die $^{27}Al(p,\gamma)^{28}Si$-reaksie by 'n protonenergie van 992 keV is gebruik om aluminiumatome waar te neem. Diffusiekoeffisiënte sowel as die gevoeligheid van hierdie tegniek is verkry deur die diepteprofiele voor en na uitgloeiïng te vergelyk.

Hierbenewens is kanaliseringsanalise in 'n terugverstrooiingsgeometrie uitgevoer om die uitgloeigedrag van die stralingskade wat deur die inplantering veroorsaak is, te bepaal.

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