ABSTRACT

Key words: *Polysilicon, silicon-germanium, ion beam sputtering, salicide, titanium silicide, germanosilicide, nucleation, polymorphic phase transformation, agglomeration, preamorphisation implantation, ellipsometry, grain, grain boundary, annealing, resistivity, diffusion, trap states, thermionic emission, kink effect, grain boundary barrier, scattering potential, thin film transistor, channel length modulation, avalanche multiplication*

Films of polycrystalline silicon, silicon-germanium, silicides and germanosilicides are useful in different stages of IC processing for various applications in advanced VLSI/ULSI technology. The thesis deals with some experimental investigations on polycrystalline SiGe films, advanced silicidation techniques, and germanosilicide formation and characterisation. It also includes a theoretical study on the analytical modelling of polycrystalline thin-film transistors.

The ion beam sputtering method has been investigated for the deposition of polycrystalline silicon-germanium films of controllable composition from specially prepared Si-Ge targets. The microstructural and electrical properties of the films, both as-deposited, and crystallised by furnace annealing, have been investigated by various characterisation techniques. Fine grain polycrystalline films of average grain size 35-60nm and dominant growth along <220> texture is observed. Hall measurements indicate an average mobility and concentration of 33 $cm^2/V\text{-}s$ and $4.85\times10^{18} cm^{-3}$ respectively in boron doped polycrystalline $Si_{0.73}Ge_{0.27}$ films.

The silicidation of undoped polysilicon by solid phase thermal reaction of Ti/polysilicon bilayers at different temperatures has been studied. The sequence of phase formations, polymorphic phase transformations and the effect of phase transitions on surface morphology are investigated in detail. It is found that C49-$TiSi_2$ phase nucleates first which grows by diffusion-controlled growth through Ti layer and subsequently gets transformed into low resistivity C54-$TiSi_2$ phase at high temperature. The nucleation of the observed silicide phases is discussed based on the classical nucleation theory considering nucleation barriers. The results establish a correlation of the structural, compositional and electrical properties of Ti-polycide films as a function of annealing parameters.

An advanced Ti silicidation technique suitable for very thin and narrow silicides of low resistance and better thermal stability required in submicron shallow junction technology is

studied. The technique, involving arsenic preamorphisation implantation (PAI) before Ti deposition and sequential RTA is investigated and compared with the conventional silicidation process. The thin silicides are characterised by various methods including spectroscopic ellipsometry (SE) and thermal wave analysis (TWA). As-PAI process renders very low resistivity (~19.6μΩ-cm) compared to conventional process (~26μΩ-cm) and exhibits better uniformity, homogeneity, surface smoothness and good thermal stability. It enhances the polymorphic transformation rate and also promotes resistance to agglomeration by providing greater number of nucleation sites for easy nucleation of smaller-grain C54-$TiSi_2$. The determination of thickness of thin silicides by SE is also presented.

Thin titanium germanosilicide films from thin Ti films (~27.5nm) are formed by solid phase reaction of Ti/$Si_{0.62}Ge_{0.38}$ bilayer at different annealing temperatures ranging from 600^0C to 800^0C. The effect of crystallographic state of SiGe alloy film on the reaction, phase formations and polymorphic transformations, surface morphology and thermal stability of germanosilicides have been investigated by various characterisations techniques. Both amorphous and relaxed epitaxial SiGe films for the study are prepared by Ge implantations into Si wafer with appropriate dose and energy followed by different post-implantation RTA schemes. The reaction sequence is found to be similar to that in pure silicidation with sequential nucleation of C49-$Ti(SiGe)_2$ and C54-$Ti(SiGe)_2$ phases. The films formed on amorphous alloy layer exhibit lower polymorphic transition temperature (~750^0C), smoother surface and lower sheet resistance compared that on c-SiGe films due to enhanced nucleation of C54 phase in the nucleation-limited polymorphic transformations observed in the films.

Polysilicon thin-film transistors are used in large area electronics for flat panel LCD displays. They, however, exhibit inferior saturation behaviour and enhanced kink effect at high drain voltages as compared to their crystalline silicon counterparts. The presence of grain boundaries makes it difficult to develop appropriate analytical model for I-V characteristics of the devices over a wide range of drain bias including the kink effect. A simple analytical model based on thermionic emission over grain-boundary barrier and scattering potential is proposed to predict the device behaviour in above-threshold-to-saturation region. It considers the channel length modulation and avalanche multiplication of carriers in the grain boundaries near the drain and hence computes the drain currents for a wide range of drain bias that match well the published device characteristics exhibiting kink effect. The model is applicable to poly-SiGe TFTs also with appropriate values of parameters relating to grains and grain boundaries.