PREFACE

All semiconductors contain impurities to some extent. Some impurities are intentionally introduced as dopant atoms (shallow-level impurities), as recombination centers (deep levels), to decrease the resistivity and to reduce the carrier life time, whereas some impurities are unintentionally incorporated during the crystal growth and device processing stages. The impurities may be foreign impurities (elemental), crystallographic point defects (vacancies and interstitials) or structural defects (stacking faults and dislocations). Many impurities (unintentional) can be removed during processing through gettering.

Shallow impurity concentrations are measured electrically, and their energy levels in the bandgap are measured optically. However, in the case of deep levels, both concentrations and energy levels are best measured electrically. Excellent reviews on impurities in semiconductors [1,2,3] and on theoretical aspects [4] are dealt in detail in the literature.

Deep level impurities seem to be present in all known semiconducting materials. One of the most important properties is their ability to control the carrier lifetime significantly. If an impurity has sufficient binding energy, it affects the carrier lifetime even when it is present in such a small quantity where identification of the impurity experimentally becomes difficult. The current interest in deep level impurities is to identify their presence inadvertently in semiconductors in order to avoid the undesirable consequences such as trapping effects (which may change switching times in semiconductor devices like thyristors, photoconductors etc.,) and nonradiative recombination processes (which can affect the efficiency of light emitting diodes).

However, deep level impurities may also create desirable effects in devices. The use of gold and platinum to give fast recombination thereby improving the switching times in silicon devices is well known.

However, better understanding of the physical properties of deep levels is needed for semiconductor technology, and from several points of view concerning fundamental questions of solid state physics [5].

Incorporation of atomic hydrogen into crystalline, polycrystalline or amorphous semiconductors causes significant changes in both electrical and optical properties of these materials. The principal interest of hydrogen in crystalline semiconductors occurs because of its ability to passivate the electrical activity of dangling or defective bonds [6]. Hydrogen forms complexes with impurities and has been used to suppress swirl defects in Float-Zone silicon. It can be introduced in semiconductors during crystal growth, by direct implantation, by exposing to a hydrogen containing plasma or by chemical reaction at the surface. In many cases its incorporation into crystalline semiconductors is unintentional and can cause changes in the electrically active dopant profiles in the near surface region. This is very undesirable situation in most cases since control of the switching and transmission characterstics of a device requires close control of the electric field in the active region near the surface. This property of deactivating both shallow and deep centers in the most technologically important semiconductors, Si,GaAs and virtually all the semiconductors have attracted wide interest.

Recently passivation of impurities (both shallow and deep) in semiconductors by atomic hydrogen has gained momentum, as these studies are further helpful in understanding the nature of the impurities. It is becoming increasingly well recognised that atomic hydrogen can be incorporated into silicon and other semiconductors during number of device processing and operation steps. The passivation of deep levels by atomic hydrogen is very effective and relatively stable (thermally) phenomenon. Temperatures in excess of 400°C are normally required to reactivate the deep levels after it has been passivated.

For characterisation of deep impurity levels in semiconductors, several techniques are available like Deep Level Transient Spectroscopy (DLTS) [7], Thermally stimulated capacitance (TSCAP), Admittance Spectroscopy, Photo Luminescence etc. DLTS the extensively used technique, has the following advantages:

1. It can distinguish majority and minority carrier traps.
2. It can determine the activation energy and capture cross-section of the traps.
3. It is sensitive, rapid and straight forward and
4. It is capable of detecting both radiative and non radiative recombination centers.

DLTS is basically a high frequency junction technique in which capacitance or current transients are generated by applying voltage or optical pulse (trap filling pulse) to the reverse biased depletion region of the device. For DLTS, a p-n or Schottky junction should be formed with the material to be characterised. This technique has undergone several modifications from time to time both in experiment and analysis. A brief compilation of this is given in chapter II .

In view of the importance of platinum as an efficient lifetime killer in silicon and also the existing controversial results, we have taken up a systematic study of the deep levels introduced by platinum in silicon. In addition hydrogenation of the platinum related levels in silicon will help to understand the passivation of these levels by atomic hydrogen. These can be accomplished by using the DLTS technique.

This thesis, therefore essentially contain the design and working aspects of an automated DLTS system and investigations carried on the deep levels of platinum and process induced deep levels in silicon.

This thesis is organized into five chapters and a brief summary of each chapter is given below.

Chapter I deals with the theoretical aspects of the deep levels in Si and their effect the device characteristics.

In chapter II, detailed experimental aspects dealing with the characterisation of the devices (diodes) and hence the semiconducting materials are discussed. The experimental techniques developed in the laboratory is explained. All the measurements made using the developed modules like voltage sources, data acquisition system, temperature measuring module, DLTS controller and computer interface to the above units are computerised.

Software has been developed to carryout the I-V,C-V and DLTS studies and is discussed thoroughly. Details (hardware and software) of the computer controlled automated DLTS system developed in the laboratory are presented in this chapter. Main modules of the DLTS system developed are

1. DLTS controller, to provide control signals to various modules of the system
2. Programmable bias pulse generator, for applying bias pulses to the test device
3. Data acquisition system, for digitising the transient capacitance signal at regular intervals of time
4. Baseline correction and signal amplifier circuits

5. Thermocouple signal conditioner and amplifier
6. Temperature measurement and control system and
7. Sample cryostat to carryout low temperature measurements

In chapter III, results on the platinum acceptor levels in n-type silicon are presented. Further, this chapter deals with the passivation of platinum acceptor levels by atomic hydrogen and their thermal reactivation.

Results on the identification of the process induced deep levels in aluminium deep diffused thyristor grade silicon are presented in chapter IV. Variation of the deep levels introduced depending on the experimental conditions like the ambients under which the diffusions are carried out and the codiffusing elements are discussed in this chapter.

Chapter V summarises the work done and the future plan of work.