Neutron activation analysis is used to study the process of Cu gettering in a silicon wafer in which differently doped and disordered regions are present. The results show a strong preference of the copper atoms to be concentrated in the n+(p+) and in the n+ regions. The effectivity of the gettering process can be increased by thermal growth of the defects present in the boron implanted layers.

Introduction

Small quantities of metals can degrade the lifetime of charge carriers in the active device regions in silicon integrated circuits.

Metal contamination can occur during the process steps, starting with the silicon ingot fabrication through all device fabrication steps such as wafering, polishing, oxidation, epitaxy, ion implantation, etc. All these steps have to be carried out under extremely clean and metal free conditions. Nevertheless a low degree of metal contamination remains at the end of the process, which may result in malfunctioning of devices or circuits.

The functioning of silicon devices can be degraded by metals in two ways:

a. The first one is that metals or complexes of metals with point defects or dope atoms form discrete levels in the energy gap. Such levels cause unwanted thermal generation or recombination of charge carriers. These levels contribute to the leakage current of reversely biased pn-junctions.

Suppose we have a silicon slice which contains 1 ppb (1 ng/g) Au atoms, in other words $7 \times 10^{12}$ Au atoms per cm$^3$. One of the levels of Au lies 0.02 eV from the middle of the energy gap. Capture cross sections for electrons and holes for this level are $\sigma_e = 4 \times 10^{-16}$ cm$^2$ and $\sigma_h = 1 \times 10^{-15}$ cm$^2$. Using the Shockley-Read-Hall theory it can be calculated that due to thermal generation these gold levels can give a leakage current of about 70 nA/cm$^2$ for a 10 µm thick depletion layer of a reversely biased junction at room temperature. The corresponding generation lifetime is only 15 µs. This leakage current value is much too high for most devices and circuits. Levels of only 100 pA/cm$^2$ at room temperature are acceptable.

This example shows that small amounts of metals can cause relatively large leakage currents and low generation lifetimes of charge carriers.

b. The second way in which metals may interfere with device functioning is by precipitation. Metals tend to precipitate on defects or at interfaces during cooling at the end of a heat treatment. Such precipitates which might have a size of only 10 nm may cause failure of the devices.

An example of the signal output of a charge coupled device in which local current spikes are generated due to metal precipitation can be seen in figures IA and
1B. Figure 1A has only uniform leakage current generation due to the presence of well distributed deep centers. Figure 1B shows a similar device with local current spikes originating from metal precipitates.

A well known method to remove metals from the device area towards harmless places of the slice is called "gettering".

The gettering process removes in-solution metals, removes metals from lattice defects, dissolves metal precipitates and may also dissolve crystal defects. Dissolution of the metals is accompanied by a process of metal diffusion to a sink zone that is conveniently placed outside the space charge regions of the active devices, e.g. in a diffused isolation region lying between the active devices, or in the backside of the wafer.

The sink zone consists of either a highly doped region (phosphorus gettering) in which the solubility of metals is greatly enhanced or of a highly disordered region (ion implantation, polysilicon) in which metals precipitate on the lattice defects, or it is also possible that a region is both highly doped and disordered as can be the case with highly phosphorus doped layers.

One particular problem in estimating the effectiveness of the gettering process is that the concentrations of the metals are extremely low. Classical chemical detection methods fail. Some backscattering experiments have been carried out with Au and Cu at concentration levels exceeding the levels commonly found in wafers with devices. Results of such analyses have to be looked upon with caution.

Neutron activation analysis, however, is a method which has the capability to measure metal concentrations to a ng/g level and even lower. It is possible to use NAA for measuring the metal content in different areas of a slice after a thermal anneal. In this paper we shall show that the effectiveness of metal gettering by different doped or disordered regions can be measured at realistic levels of metal contamination.