

DOPING EFFECT FROM PT ATOM IN SILICON STRUCTURE AND TREATMENT BY ROENTGEN RADIATION FLASH EXPOSURE

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Abstract

In the present, semiconductor device has big change by using high technology to improve performance and push the limit of device to support with new product to support demand of human. One of the device we are still using in our life is power semiconductor, this can support many kind of work such as satellite, power electronics and automobile. The technique in this paper will focus by using the characteristics of Pt in silicon structure for high speed and treatment with flash Roentgen radiation exposure. In principle, Pt atom can generate trapping center in silicon structure and help for increase switching time for semiconductor base on silicon substrate. However, Pt has not only good property for device but still has damage in structure is generate cluster in silicon structure that make Pt atom not really help to improve performance completely. The another goal of this paper will using flash Roentgen radiation exposure help to treatment and destroy cluster from Pt atom in silicon structure.

Keywords: Pt atom, Roentgen radiation, C-V characteristics, Power device

Introduction

The most of power device using P-i-N structure, this structure consist of p and n layer with middle region has much lower concentrate. Intrinsic layer in the middle to p and n should

has high purity but it quite hard and very expensive to use substrate with high purity that will has cost for fabrication very high. However, we can use n- silicon for substrate

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and power device structure usual $p^+n^+n^+$ (Brorsson, 2011).

The reason to use power device in many product because significant advantages for switching time. The switching time for specific work is most important due to relate with human life. The example of switching time is X-ray machine, if power bottom slowly response it will be happen to user because will expose over dose and impact to life (Gregory and Gwyn, 1974).

Ion implantation is one of technique use for doping atom with high energy and short time more than thermal doping. This technique can control the concentration of atom for doped in semiconductor material by calculate time and energy. However, ion implantation can generate defects in substrate because high energy and atom size as well. After doping process will follow by RTP (rapid thermal process), this technique can push doping atom deep to substrate.

RTP usual in manufacturing of semiconductor device by head substrate with high temperature around 1,000-1,200°C just few second (De Keyser and Donald, 1999). This process should careful about wafer temperature brought down by slowly due to wafer structure has effect if temperature down quickly such as dislocations and wafer break. RTA (rapid thermal annealing) is the process in RTP using for treatment damage from ion implantation. This technique quite different from furnace annealing (FA) because time for RTA just few minute. In principle, FA can reduce damage from several process from device fabrication but cannot destroy big cluster in substrate structure (Barbarini *et al.*, 2010).

Radiation technique use for change characteristics of semiconductor for long time such as electron exposure (Sobhan, 2013), photon (Rosenfeld, 2011), neutron (Schwarze and Frasca, 1990) and Roentgen (Vavilov, 1977). Radiation can change the properties of material by generate trapping, defects and treatment. Generally, high radiation always use for trapping semiconductor structure to improve switching time of device but it can

generate unpredicted defects that will change device cannot use full performance.

In this paper, we will investigate to use radiation for treatment and improve performance of semiconductor device base on silicon substrate after pass several process. Roentgen radiation will use for study in this experiment with flash exposure on device after fabrication.

Material and Methods

The simulation and fabrication of power device base on silicon substrate and the process using CMOS technology. The device were fabricated using n-type silicon single crystal surface orientation, thickness 600 μm and 135 $\Omega\cdot\text{cm}$ resistivity. The wafer was cleaned with an ultra-sonic and washed to remove organic contaminants. The diode process module consists of (1) the deposition of oxide covered substrate, the dry-etching of active area, (2) the implantation of phosphorus at energy of 135 kV and dose of $1 \times 10^{16} \text{ cm}^{-2}$ for ohmic contact on backside wafer, (3) the implantation of boron at same energy, (4) dose on front side wafer, where the implantation was followed by a thermal annealing at 1,050°C for 60 min, resulting in a junction depth of about 1 μm and (5) the Al metal-deposition, 10 μm thick, on both front and backsides (Srithanachai *et al.*, 2012). After that the wafer was continued into sawing process. Finally, the assembling chip on prototype circuit board (PCB) was made before finishing connection, which is shown in Figure 1 (Ueamanapong *et al.*, 2012).

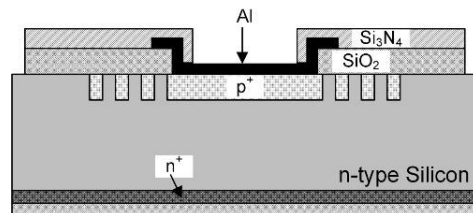


Figure 1. Power device structure for simulation and fabrication

The device after fabrication will measure electrical properties by using Agilent B1500A Semiconductor Device Analyzer and probing on the wafer by Cascade Microtech M150 probe station. The measurement can sweep current and voltage to support for I-V and C-V characteristics analysis.

The diode will expose by Roentgen radiation with 70 keV by flash expose 2 sec for 35 times. However, diode characteristics will measure before and after to compare the influent of radiation.

Results and Discussions

P-N junction diode is the most fundamental and the simple of electronics devices. The current in P-N junction diode is due to carrier recombination or generation somewhere within the P-N diode structure. Recombination is the effects under forward bias and occurred within the quasi-neutral regions, depletion region or at the metal semiconductor Ohmic contact. The reverse bias occurrence generates current due to the light will further increase the current (Ohkubo *et al.*, 2008; Poret *et al.*, 2009). The ideal diode equation is one of most basic equation in semiconductor and working through the derivation provides a solid background to the understanding of many semiconductors. The derivation of the ideal diode equation is covered in many textbooks and show ideal forward current characteristics in Figure 1.

The diode equation gives an expression for the current through a diode as function of voltage. The ideal diode law show below:

$$I = I_0(\exp(qV/kT)-1)$$

where I is the current, I_0 is the dark saturation current, V is the apply voltage, q is the absolute value of electron charge, k is the Boltzmann's constant and T is the absolute temperature (Plataniotis and Vinetsanopoulos, 2012).

The simulation of ion implantations with high energy 135 keV show in Figure 3. From the picture show Pt atom diffuse in silicon structure around 0.14 μm before annealing.

After annealing Pt atom will deposit to silicon structure and deep around 3-5 μm .

Pt atom has high concentration close to surface around $5 \times 10^4 \text{ atom/cm}^3$ and 200 atom/cm^3 at range 0.14 μm from surface. Although, Pt atom can create trapping center in silicon band but it still has cluster that make resistance of device different from idea case from Figure 2. Series resistance is major impact from defects and cluster in silicon structure.

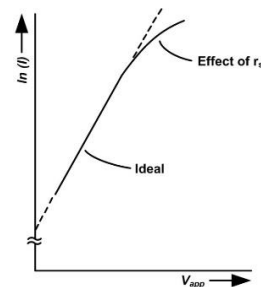


Figure 2. Ideal forward bias of diode

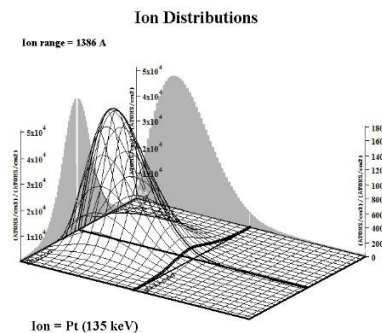


Figure 3. Pt doping range in silicon substrate before annealing

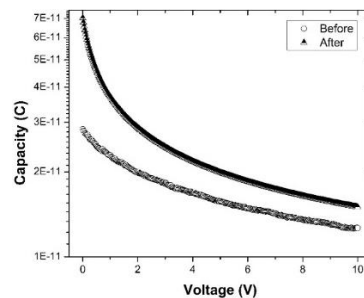


Figure 4. Capacitance-voltage between before and after expose

Figure 4. shows C-V characteristics of diode after exposed show significant high around 2 times at 0 V by before show 3×10^{-11} and after 7×10^{-11} F. We know that the capacitance is mean ability to storage electric charge, after expose the device has good properties by capacitance increase 2 times. The radiation may destroy cluster from fabrication process and decrease the number of defects.

Conclusions

From the simulation of Pt doped in silicon structure by using ion implantation may has defects in device substrate due to high energy for atom doping. The radiation exposure by flash may help to reduce some of the defects and destroy cluster from several process in device fabrication. The capacitance of flash exposure increase 2 times before expose that mean radiation exposure can use for treatment and we will analysis more detail of impact from flash radiation expose in term of concentration, current-voltage and compare with long time exposure in next paper.

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