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Estimation of Device Parameters for an Efficient Model Analysis in C-V Measurement for Al/Si/P-Si Heterostructure

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Abstract: C-V measurements provide a wealth of information about device and material characteristics. Capacitance versus (usually reverse) voltage, referred to as C-V, measurements can be used to study the most basic properties of semiconductor rectifying junctions. In addition to obtaining simple capacitance values at a given bias, which may be important for circuit simulation, the data can be manipulated to yield a number of other parameters such as the built-in potential, Vbi, the doping profile as a function of depth and the barrier height. This paper will present the principle of c-v measurement and c-v measurement of metal /porous silicon/silicon/metal (MISM) structure. To do the C-V measurement of (MISM) structure, metal –porous silicon contact must be needed. So metal-porous silicon contact (both ohomic and rectifying) are also being discussed.

Key Words: C-V Measurement, Metal-porous silicon, Semiconductor etc.

I. INTRODUCTION

Electrical properties of porous silicon layers need to be thoroughly studied for its use as active layer in various optoelectronic and sensing applications. To study the electrical properties of PS layer metal contact must be needed. In the present study we use Ag as a contact material on porous silicon /c-Si heterostructure. In this chapter we discuss about the ohmic and rectifying contact of metal- semiconductor junction and also observe the I-V characteristics of metal /porous silicon/silicon/metal (MISM) structure and lateral contact on substrate films.

For CV measurement (Capacitor versus voltage) measurement, two instrument settings are basically possible.

- a capacitor in series with a resistor.
- a capacitor in parallel with a resistor.

This implies that when the device exhibit a more complex CV circuit that what is anticipated with one of this setting, the capacitance will become a function of measurement frequency. Therefore, for device modeling, a frequency of 1 MHz is typically applied. This frequency is sufficiently high enough to achieve a good resolution with the capacitance meter (sufficient phase shift for the resolution of the instrument), but also sufficiently low to avoid second order effects (secondary capacitance, inductive influence etc.).Regarding the measurement principle itself, there are two different methods available.

The current/voltage method

The auto-balancing method.

II. BASIC MEASUREMENT PROCEDURE

At first chiller is on. The temperature range is in between (15-18) °c for 35 minutes. Switch on the main switch. After 10 minutes switch on the rotary pump. Then after 10 minutes switch on the pirani guage and select guage head, at that time close all vacuum valves. Combinational valve goes to the backing position when pressure crosses the point 0.05mbar. After 10 minutes switch on the diffusion pump (DP). DP takes about 30 minutes to reach the operating temperature. At that time we check the flow of cooling water. Remove the chamber admitting air. After 5 minutes load the filaments with the required material and fix the substrate on the work holder. After 30 minutes close the chamber air admittance valve and check the needle valve in close condition and backing valve and roughing valve to open slowly. Select GH-2 in Pirani gauge and wait until (around 15 minute) it shows to cross 0.05 mbar. Close the roughing valve and open the backing valve. Select GH-1 in Pirani gauge. Slowly open the high vacuum valve as the pressure starts rising in Pirani GH-2, reaches 1*10(-3) mbar. Switch on the Penning gauge to read high value in the chamber.

NOTE: **Clean the L-gasket sealing portion before placing the chamber and that no foreign materials are left on the base plate where the chamber L gasket sits.**

Select GH-2 in Pirani gauge. After 1 minute open the needle valve slowly and maintain the pressure in GH-2. Switch on the HT by selecting the HT rotary switch to HT position. Switch on the CB. After 2 minutes increase the variac control slowly and measure the primary current of HT on the primary meter. Set the current to 0.8 amp. Do not allow backing pressure. Needle valve can control the pressure in the chamber. Glow discharge time depends upon the type of substrate. For normal application 5 -7 minutes is sufficient. When HT cleaning is complete, then variac control is in position zero. Close the needle valve and open the high vacuum valve slowly getting the backing pressure from rising above 0.2 mbar. After 1

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minute switch on the Penning gauge and select GH-1. After attaining the required temperature (275°C) bring back the control to zero position. Switch off RH and CB1. Select Filament holder by selecting selector switch. Switch it on by selecting ht, rh, lt , rotary switch . Switch on the CB. Slowly turn off the variac control with the source shutter covered and observes the evaporation is just melting. Uncover the source by shutter control knob unless initial wearing of the filament is needed. When evaporation is complete shutter the source. Switch off the penning gauge. Close the high vacuum valve. Open the air admittance valve till air flow ceases and removes the chamber. Unload the work holder. Switch on the LT by selecting from the HT, RH, LT, Rotary switch. Switch on CB.
NOTE: **Prior to HT cleaning, select DP and RD position. Switch on the rotary drive speed control. Level the work holder rotating throughout the cleaning and evaporation cycles.**

III. EXPERIMENTAL DATA & DISCUSSION

Metallization of Al on Si substrate by Thermal Evaporation. Metallization unit: HIND HI VAC BC 300. Pressure achieved: 0.001 mbar (Pirani gauge). Thickness of Al: 350 Å.
In this work the metal (Al 99.999%) deposition on both of the c-Si surface and on porous Silicon surface is done by thermal evaporation .The contacts on C-Si surface are very good contacts with low contact resistance. But the Al contacts on porous Silicon surface are failed in continuity test in most of the time. This problem may be due to the rough surface of prepared PS samples. So nickel was coated on PS layer by electro less plating method.

IV. RESULT OF C-V MEASUREMENT

The CV measurements were made and are plotted in figure as graph of C verses voltage. During Capacitance measurements, the voltage is varied from -1.5 volt to 1.5 volt and frequency (1 KHz, 100 KHz, 1 MHz) and different capacitance versus voltage is measured with changing frequency. The DC level was also varied (100mV, 500mV and 1V) and readings were taken.

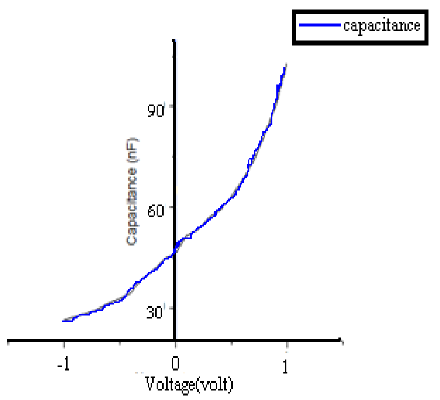

Fig. 1: C-V Characteristics at 1V DC Bias and frequency of 1 kHz.

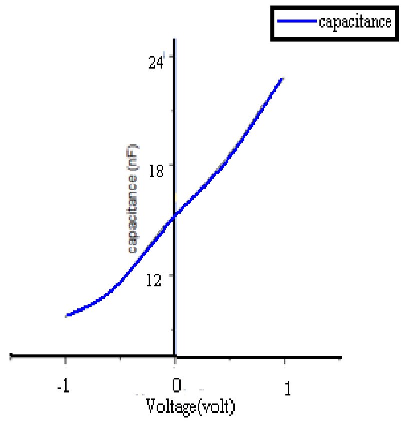

Fig. 2: C-V Characteristics at 1V DC Bias and frequency of 100 kHz.

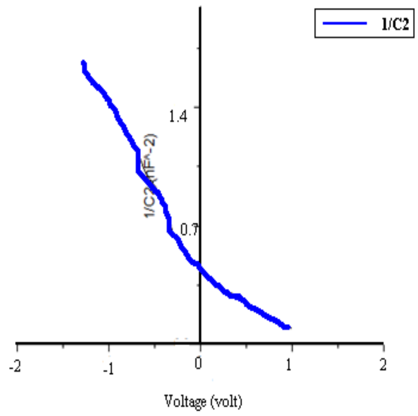

Fig. 3: Characteristics of 1/C2 vs voltage

V. DISCUSSION

The C-V characteristics of the fabricated device reveal that when there is an increase in voltage in the AL/P-Si region, then there is an increase in the capacitance. On the other hand, when there is a decrease in voltage then the capacitance decreases. This can be interpreted from the increase or decrease of the depletion width formed between the junction. From Fig 1, 2 and 3 it has been seen that the behavior remains the same at all tested frequencies (1 KHz, 100 KHz). The Characteristic of $1/C^2$ vs. voltage shows that an almost straight line. So, the depletion layer and barrier height are constant, and carrier concentration is also having a constant value. According to the capacitance-voltage measurements, the capacitance, the built-in potential, the width of the depletion layer and the carriers' concentration are equal to $0.47 nF/cm^2$, 1.25V, 0.22 µm, and $3.35x10^{16}$ cm^{-3} respectively.

VI. CONCLUSION

In this paper a cost effective simple etching technique is discussed which eliminates the disadvantages associated with the expensive anodization technique. The C-V characteristics of the PS sample show the behavior of an abrupt junction where the capacitance is found to be dependent on depletion width with change in bias voltage.

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The carrier concentration was calculated to be $3.35x10^{16}$ cm^{-3}. The depletion width is calculated which is 0.22µm. Further study is required for viewing the application of the device as a high energy density capacitor as the capacitance is expected to increase with enhancement of pore size.

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