ON THE PROFILE OF INTERFACE STATES OBTAINED FROM CONDUCTANCE METHOD OF AL/SIO_2/P-SI STRUCTURES

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МОП структура Al/SiO_2/p-Si с окисным слоем, полученным термальным окислением, изготовлена на Si(100) p-типа. *C-V-f* и *G/ω-V*-f характеристики этих структур были исследованы при комнатной температуре в области частот 10кГц-1МГц. Частотную дисперсию C и G/w можно интерпретировать в величинах плотности поверхностных состояний N_{ss}. N_{ss} может следовать за сигналом и приводить к дополнительной емкости, особенно на низких частотах. Значения измеренных *C* и *G/ω* уменьшаются с увеличением частоты из-за непрерывного распределения плотности состояний на границе раздела. На зависимости *C-V* проявляются аномальные пики при прямом смещении из-за N_{ss}. Экспериментально найдено, что положения пиков в *C-V* соответствуют положительному напряжению, и пиковые значения емкости уменьшаются с увеличением частоты. Экспериментальные результаты показывают, что N_{ss} на границе раздела Si/SiO_2 имеют существенный эффект на *C-V* и *G/w-V* характеристиках МОП структур .

Al/SiO_2/p-Si (MIS) structures with thermal growth oxide layer have been fabricated on p-type Si(100). The *C-V-f* and *G/ω-V*-f characteristics of these structures have been investigated in the frequency range of 10 kHz-1 MHz at room temperature. The frequency dispersion in C and G/w can be interpreted in terms of the interface states density (N_{ss}). The N_{ss} can follow the ac signal and yield an excess capacitance especially at low frequencies. The values of measured *C* and *G/ω* decreases with increasing frequencies due to a continuous density distribution of interface states. The *C–V* plots exhibit anomalous peaks at forward bias due to the N_{ss}. It has been experimentally found that the peak positions in the *C-V* plot shift towards positive voltage and the peak value of the capacitance decreases with increasing frequency. Experimental results show that the N_{ss} at Si/SiO_2 interface have a significant effect on C-V and G/w-V characteristics of MIS structures.

INTRODUCTION

Due to technical importance of MIS structures in semiconductor technology, the semiconductor/insulator (Si/SiO_2) interface and defects on its neighborhood have been extensively studied in the past four decades [1-6]. The N_{ss} values of MIS structures are important parameters that affect their main electrical parameters [3]. When a voltage is applied across the MIS device, the combination of the insulator layer, depletion layer and the series resistance of the device will share applied voltage. The forward and reverse bias *C*-V-*f* and *G/ω-V-f* measurements give the important information about the energy distribution of the interface states of the MIS structure. The characterization of interface states in MIS structure has become a subject of very intensive research in the last decade, and a number of workers have suggested various ways of characterization [7,8]. In this study we investigate the effects of interface states, which cause non-ideal behavior on electrical characteristics of MIS structure and we report results of a systematic investigation on the frequency dependence of the electrical properties of MIS structure.

EXPERIMENTAL DETAIL

The Al/SiO_2/p-Si structures used in this study were fabricated using p-type Si(100) wafer with thickness of 280 Ω.m, 2" diameter and 8 Ω.cm resistivity. Firstly, Si wafer was degreased in organic solution of $CHClCCl_2$, CH_3COCH_3 and CH_3OH consecutively and then etched in a sequence of H_2SO_4 an H_2O_2, 20% HF, a solution of 6HNO_3: 1HF: 35H_2O, 20% HF and finally quenched in de-ionised water for a prolonged time. Immediately after surface cleaning, high purity (99.999 %) Al with a thickness of ~2000 Å was thermally evaporated onto the whole backside of Si wafer in vacuum system. The ohmic contacts were prepared by sintering the evaporated Al back contact at 750 ^{o}C for 60 minutes in flowing dry nitrogen ambient at rate of 2 litre/min. Rectifier contacts formed by evaporation of 2000 Å thick Al dots of ~1 mm diameter onto the Si wafer. The interfacial insulator layer thickness was estimated to be about 53 Å from high frequency (1MHz) measurement of the oxide capacitance in the strong accumulation region. The C-V and G/ω-V measurements were carried out in the frequency range of 10 kHz–1 MHz at , room temperature using a HP 4192A LF impedance mater.

RESULTS AND DISCUSSIONS

The values of the capacitance and conductance depend on a number of parameters, such as N_{ss} and the formation of insulator layer between metal and semiconductor. The effect of density of N_{ss} can be eliminated when the *C-V* and *G/ω-V* plots are obtained at sufficiently high frequency [9], since the interface states does not follow ac signal above this frequency. In this case, the series resistance seems the most important parameter, which causes the electrical characteristics of MIS structures to be non-ideal [6].

The density of interface states (N_{ss}) can be derived from Hill-Coleman method [10]. According to this method, the density of interface states can be calculated by using the following equation:

$$N_{ss} = \frac{2}{qA} \frac{(G_m/\omega)_{\max}}{((G_m/\omega)_{\max} C_{ox})^2 + (1 - C_m/C_{ox})^2)} \qquad (1)$$

where, A is the area of the diode, ω is the angular frequency, $(G_m/\omega)_{\max}$ is the maximum measured conductance value. C_{ox} is the capacitance of insulator layer in strong accumulation region and C_m is the capacitance value, which corresponding to the $(G_m/\omega)_{\max}$ value. In order words, in the high frequency, the N_{ss} cannot follow the ac signal and consequently do not contribute appreciably to the MIS capacitance. This situation may be different at low and intermediate frequencies, depending on the relaxation time and of N_{ss} and the frequency of the ac signal [3]. As a result we can say that in the low frequencies N_{ss} can follow the ac signal and yield an excess capacitance, which depends on the frequency, but in the high frequency limit (f ≥ 500 kHz), the interface states cannot follow the ac signal. This makes the contribution of interface state capacitance to the total capacitance negligibly small [9]. The N_{ss} calculated from Eq. (1) as a function of frequencies are shown in Fig. 1 (a). As seen in Fig. 1 (a), The N_{ss} values decrease with decreasing frequencies. On the other hand, the values of N_{ss} was estimated using the combination of low-frequency (C_{LF}) and high frequency (C_{HF}) method to the following equation [9]:

$$N_{ss} = 1/qA \left[\left(\frac{1}{C_{LF}} - \frac{1}{C_{ox}} \right)^{-1} - \left(\frac{1}{C_{HF}} - \frac{1}{C_{ox}} \right)^{-1} \right] \qquad (2)$$

where C_{LF} is the lowest value of the low frequency (1 kHz) capacitance, C_{HF} is the high frequency (500 kHz) capacitance at voltage corresponding to C_{LF}, C_{ox} is the accumulation insulator layer capacitance, and A is the capacitance area. The results are presented in Fig. 1 (b). The values of N_{ss} are of order 10^{12} eV^{-1} cm^{-2} which are closer to the values of obtained I-V measurements.

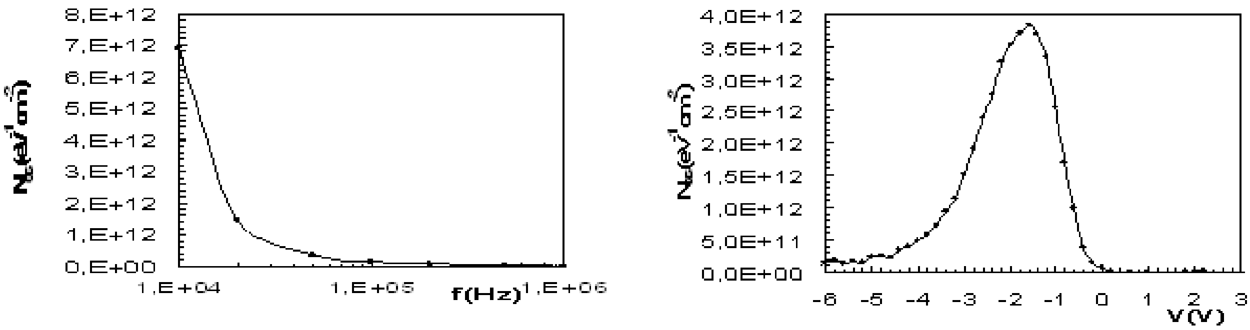

Fig. 1 (a) The N_{ss} vs Logf (b) N_{ss} vs V obtained from the Hill-Coleman and C_{LF}-C_{HF} method, respectively, of the Al/SiO_2/p-Si MIS structure at room temperature.

CONCLUSION

The *C-V* and *G/ω-V* characteristics of the Al/SiO_2/p-Si MIS structure were measured in the frequency range of 10 kHz-1 MHz at room temperature. The peak values of *C-V* at forward bias have been found to be strongly dependent on the values of interface state density (N_{ss}). The experimental results confirmed that both the measured *C* and *G/ω* varies with applied voltage and frequency, and decreases with increasing frequency especially in depletion and accumulation region due to a continuous distribution of N_{ss} at Si/SiO_2 interface. Also, it can be explained that the N_{ss} can follow the ac signal and yield an excess capacitance and conductance, which depends on the relaxation time of N_{ss} and frequency of the applied ac signal. The experimentally *C-V* and *G/ω-V* characteristics confirm that N_{ss} is important parameter that strongly influence the electric parameters in MIS structure.

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