ON THE PROFILE OF TEMPERATURE DEPENDENT INTERFACE STATE IN Al/SiO$_2$/p-Si (MIS) SCHOTTKY DIODES

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The temperature dependence of capacitance–voltage (C–V) and conductance–voltage (G/w–V) characteristics of metal–insulator–semiconductor (Al/SiO$_2$/p-Si) Schottky barrier di odes (SBDs) was investigated by considering interface state effect in the temperature range of 80–400 K. The C–V and (G/w–V) characteristics confirm that the interface state density (Nss) of the diode is important parameters that strongly influence the electric parameters of MIS structures. The crossing of the G/w–V curves appears as an abnormality compared to the conventional behavior of ideal Schottky diode.

INTRODUCTION

In fabrication of electronic devices such as metal–insulator–semiconductor (MIS) and metal–oxide–semiconductor (MOS) structures, the surface stability of semiconductors plays a very important role. The electrical characteristics of these devices are influenced by various non-idealities such as the interface states (N_{ss}) and interfacial interface layer [1–4]. The semiconductor crystal surfaces are usually covered with thin layer of native oxide and organic contaminants in the laboratory environment [5,6]. The formation of an insulator layer on Si by traditional ways of oxidation or deposition cannot completely passivate the active dangling bonds at the semiconductor surface. In this study, to achieve a better understanding the effects of Nss on the C–V and G/w–V characteristics the admittance measurements carried out in the wide range of temperatures (80-400 K) at 1MHz.

EXPERIMENTAL DETAIL

The Al/SiO$_2$/p-Si structures were fabricated using p-type Si(100) wafer with thickness of 280 μm, 2" diameter and 8 Ω.cm resistivity. Firstly, Si wafer was degreased in organic solution of $CHCICCI_2$, 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$_2$O, 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 pump system. The ohmic contacts were prepared by sintering the evaporated Al back contact at 650 ^{o}C for 30 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. The interfacial insulator layer thickness was estimated to be about 53 Å from high frequency (1MHz) measurement of the oxide Cm 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 analyzer (5 Hz-13 MHz) and a test signal 40 mV$_{rms}$

RESULTS AND DISCUSSION

The C-V-T and G/w-V-T characteristics of MIS Shottky diodes were measured in the temperature range of 80–400 K. According to Hill–Coleman [7], the density of interface states is given by

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

where A is the area of the diode, w is the angular frequency, C$_m$ and (G$_m$/w)max are the measured capacitance and conductance which correspond to peak values, respectively, and Cox is the capacitance of insulator layer. The values of various parameters for Al/SiO$_2$/p-Si Schottky MIS diodes determined from C–V and G/w–V characteristics in the temperature range of 80–400 K are given in Table 1.

Fig. 1(a) shows the C–V-T characteristics of the Al/SiO$_2$/p-Si Schottky barrier diodes. As seen in Fig. 1(a), the values of capacitance give a peak in each temperature, shifting to reverse bias region with increasing temperature. The presence of the capacitance peak in the forward C–V plot is investigated by a number of experimental results on metal–insulator–semiconductor (MIS) Schottky diodes [8-10]. Such a behavior is mainly attributed to the molecular restructuring and reordering of the Nss. The crossing of the G/w- V (Fig.1b) curves appears at forward bias showing an abnormal behavior when seen with respect to the conventional behavior of ideal Schottky diode. This behavior is attributed to no carrier freezing out which is non-negligible only at low temperature [11-13].

Table 1

The values of various parameters for Al/SiO$_2$/p-Si(100) Schottky MIS diodes.

T(K)	C(F)	G/w(F)	N_{ss}(eV^{-1}cm^{-2})
80	3,92x10^{-9}	1,08x10^{-9}	1,74x10^{12}
200	3,99x10^{-9}	1,05x10^{-9}	1,70 x10^{12}
300	3,33x10^{-9}	6,11x10^{-10}	9,85 x10^{11}
320	3,31x10^{-9}	4,77x10^{-10}	7,69 x10^{11}
340	3,18x10^{-9}	5,25x10^{-10}	8,46 x10^{11}
360	3,16x10^{-9}	6,77x10^{-10}	1,09 x10^{12}
380	3,13x10^{-9}	7,13x10^{-10}	1,15 x10^{12}
400	3,12x10^{-9}	8,22x10^{-10}	1,32 x10^{12}

CONCLUSION

The forward and reverse bias C-V-T) and G/w-V-T characteristics of the Al/SiO$_2$/p-Si (SBDs) were measured in the temperature range of 80–400 K. The effects Nss of the sample on C and G/w characteristics are investigated. It is found that both C and G/w were quite sensitive to temperature, especially at relatively high temperature, and the Nss shows a U shape. This behavior is attributed to the thermal restructuring and reordering of the interface. The admittance measurements confirm that the Nss are important parameters that strongly influence the electric parameters.

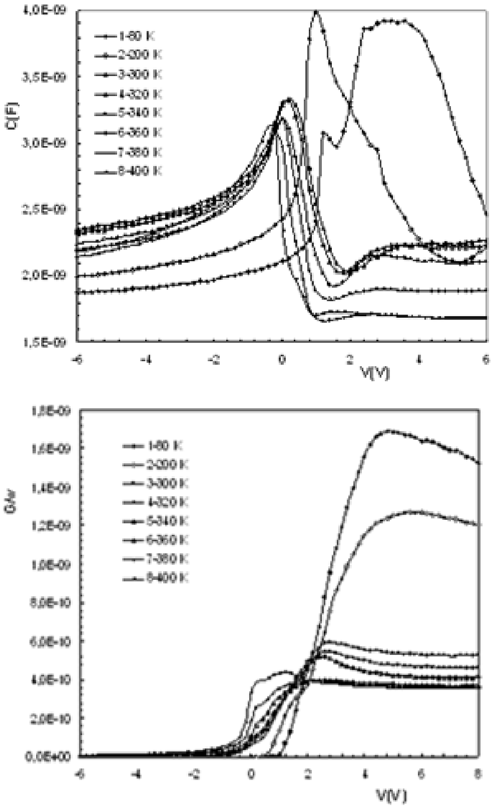

Fig. 1. The plots of C-V-T and G/w-V-T characteristics of the Al/SiO$_2$/p-Si SBDs, respectively.

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Received:10.02.2007