INFLUENCE OF X-RAY IRRADIATED ON JUNCTION DEPTH OF P-N DIODE

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Abstract: In this paper investigate the effect of X-ray irradiated on p-n diode. The change of electrical characteristics of diode can confirm by junction depth. Energy of irradiated are various in the range 40-70 keV at time of exposure 205 second. After irradiated by X-ray the electrical were changed, leakage current were decreased. The change of leakage current can analysis by junction depth, junction depth can be calculated by capacitance-voltage (C-V) characteristics. In junction depth of diode after irradiated the carrier concentration were little change.

Key Words: Junction depth/ Capacitance-voltage/ leakage current/ Irradiated

1. INTRODUCTION

Nowadays, semiconductors have to use in many work such as telecommunication [1], electronics [2], and medical [3]. Therefore, it will be to improve performance for support new technology in future. On the other hand, semiconductor device cannot support every work. When use device in radiation work, time to use is less because radiation have high energy. The degradation of device characteristics by irradiation with keV particles has been studied for many decades and is well documented nowadays. Despite this long research effort, the quantitative description of the link between the introduced lattice defects and the observed device degradation is still incomplete and shows considerable deficiencies [4]. In the present paper an attempt is made to bridge part of this gap by a combined effort to characterize with a selection of complementary analysis techniques the electrical characteristics of the introduced lattice damage and to correlate these fundamental defect properties with the observed diode characteristics. Since defects can be generated by ion implantation process or X-ray irradiation, etc, the induced defect will be confirmed by measurement of carrier concentration at junction depth. New results are presented on the impact of irradiation induced lattice damage on the carrier concentration. For the first time of results are presented to improve performance of diode [5].

2. EXPERIMENT

The process flow of shallow p-n junction diode is compatible with CMOS technology on Thai Microelectronics Center (TMEC).

![Fabrication process of p-n junction diode.](image-url)

The diode process module consists of (i) deposition of oxide covered substrate, (ii) dry-etching of active area,
(iii) implantation of phosphorus at energy of 120 kV and dose of $1 \times 10^{16}$ cm$^{-2}$ for ohmic contact on backside wafers, (iv) implantation of boron at same energy and dose on front side wafers (the implantation been followed by a thermal annealing at 1050 $^\circ$C for 60 min, resulting in a junction depth of about 1 μm) (v) Al metal-deposition, 10 μm thick, on front side and backside [6], the fabrication process shows in Fig. 1.

After its fabrication process show in Fig 2, the diode were irradiated by X-ray at room temperature for various energy of exposure.

The diodes were irradiated by X-ray for various energy and exposure dose, as shown in Table 1. The current-voltage (I-V) measurement was performed by the use of a HP4156B. The I-V characteristic results were measured on wafer with bias step of 0.025 V from reverse ($V_R$) to forward ($V_F$) voltage, in the range of -10 to +1 V. [7,8]

\[ I = I_0 \exp(qV/nkT) \]  

Here $I$ is the current, $q$ is the electron charge, $V$ the applied voltage, $T$ the absolute temperature, $k$ the Boltzmann constant, $n$ the ideality factor of p-n photodiode, and $I_0$ is the saturation current. From values of $V$ greater than $nkT/q$.

Fig. 4 shows the leakage current of p-n junction diode were irradiated by X-ray. As discuss in Fig. 4, the value of diode leakage current for before irradiation is dominated by Si bulk defect. Therefore, to evaluate the radiation degradation of the diode accurately, it has to exclude the influence of leakage current before irradiation. The change of $IR(\Delta IR)$ by the X-ray irradiation is estimated and shown in Fig. 4.

\[ C-V \] characteristics of the p-n diode before and after the X-ray irradiation are shown in Fig. 5, revealing an unchanged capacitance, originating from a radiation induced dopant deactivation in the Si layer.

3. RESULTS AND DISCUSSION

Fig. 3 shows the experimental semi-log forward and reverse-bias characteristics of the p-n photodiode. The diode parameters are determined from the I-V characteristics, which is usually described by the thermionic emission theory.

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I = I_0 \exp\left(qV/nkT\right) 
\]  

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4. CONCLUSION

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I-V characteristics were decreased at 70 keV of exposure. The effect of X-ray irradiated on I-V characteristics have many caused such as X-ray induced defect in bulk structure, carrier generation lifetime were increased and carrier concentration were changed. In this experiment, we investigated the carrier concentration of diode after irradiated by X-ray.

The capacitance of a reverse-biased junction, when considered as a parallel plate capacitor, is

\[ C = \frac{K_s \varepsilon_0 A}{W} \]  

(2)

The biases applied to the front side doping concentration calculate by eq. 3.

\[ N_D = \frac{2}{qK_s \varepsilon_0 d(1/C^2)dv} \]  

(3)

using the identity \( d(1/C^2)/dV = -(2/C^3) \) dC/dV. Note the area dependence in these expressions. Since the area appears as \( A^2 \), it is very important that the device area be precisely known for accurate doping profiling. From Eq. 4 we find the scr width dependence on capacitance as

\[ W = \frac{K_s \varepsilon_0 A}{C} \]  

(4)

Where \( N_D \) is the carrier concentration, \( A \) is the area of p-n junction, \( C \) is the capacitance, is the permittivity of vacuum, \( q \) is the electron charge and \( K_s \) is the permittivity of silicon. [8,9] These results can be concluded that change of leakage current at 40, 55 keV and 70 keV is decrease. Carrier concentration is one of the causes of the changes the electrical properties. From the results can be concluded that change of leakage current at 70 keV, is made this experiment more attractive.

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### 5. REFERRENCE


