Non-Destructive Surface States Density Measurement by Pulse Photoconductivity Method – Takahiro Ono

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Abstract

We have devised a method for measuring interface state density of semiconductor devices by applying PPCM (Pulse Photoconductivity Method) [1] which is a nondestructive and noncontact photoconductivity measurement method. In this paper, we report the measurement principle of the interface state density measurement and the measurement result of the interface state density of the N type Si substrate on which the oxide film is formed.

Background

The interface state of a semiconductor device affects device characteristics. Because of miniaturization of the device, the influence of the interface state becomes obvious, and the evaluation of the interface state becomes important. In the current interface state density evaluation method, since it is necessary to measure after the manufacturing process of the device is completed, a simplified structure / simplified measurement method is desired.

Principle

We describe the interface state density measurement principle of non-destructive and noncontact Si substrate using PPCM (Pulse Photoconductivity Method) [1]. FIG1 is a principle view of the interface state measurement, and FIG2 is a diagram of the interface state measurement device. By bringing the probe close to the Si substrate and performing pulse voltage application and pulsed light irradiation in a noncontact manner, carriers captured at the interface level of the band gap are excited and move into the oxide film. The voltage signal due to carrier movement at this time is observed. FIG3 shows an example of a voltage signal when an N type Si wafer is measured. The interface state density can be calculated by calculating the excited carrier density from the interface state by the following equation using the peak voltage ΔV of the observed signal.

$$Q_{it} = C_f \Delta V \tag{1}$$

$$D_{it} = \frac{Q_{it}}{q \times S \times \Delta E} \tag{2}$$

Q_{it} [C] is the amount of charge excited from the interface state. C_f [F] is the cable capacity of the measurement system. ΔV [V] is the peak voltage of the measurement signal. D_{it} [cm^{-2} eV^{-1}] . q [C] is the elementary charge. S [cm^2] is the electrode area. ΔE [eV] is the resolution of the interface state density measurement.

In the case of measuring the interface state density of a specific energy in the band gap in order to obtain the energy distribution of the interface state density, the energy of the pulsed light is adjusted. At this time, the energy of the irradiated light is the sum of the following energy.

1: 3.1 eV (energy difference between the lower end of the SiO_2 conduction band and the lower end of the Si conduction band)

2: Energy corresponding to band bend of silicon when voltage is applied.

3: Energy difference from the lower end of the silicon conduction band to the energy region to be measured.

Experimental method and result

In this experiment, the interface state density of the N type Si substrate (100) on which the oxide film was formed was measured. As shown in FIG4, the energy resolution of the interface state density of this measurement is 0.224 eV. FIG5 shows measurement results of the interface state density in this experiment, and each number in the graph indicates the result of the energy region corresponding to the number in FIG4.

Summary

We have devised a non-destructive and non-contact interface state density measurement method applying PPCM. In the conventional measurement method, a device structure is necessary, and since it is a contact measurement, it is difficult to evaluate the interface in the manufacturing process of the device. In this method, the device structure is unnecessary for measurement and it is non-destructive · non-contact measurement. Therefore, it is considered that this method can evaluate the interface in the manufacturing process.

Reference

[1] Y. Nishi, *et al.*, ***The International Symposium on Semiconductor Manufacturing***, PC-P-064, Tokyo, Japan, (2010)

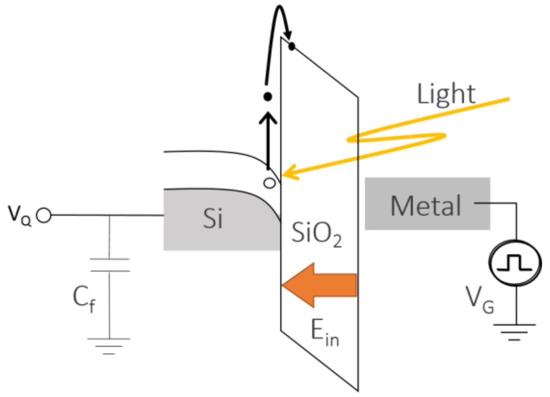

FIG 1 principle view of the interface state measurement

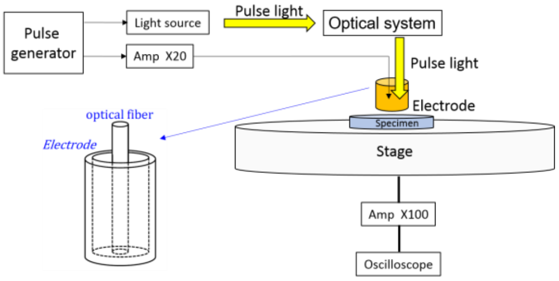

FIG 2 diagram of the interface state measurement device

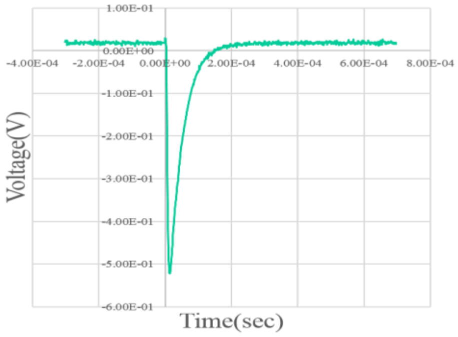

FIG 3 example of a voltage signal

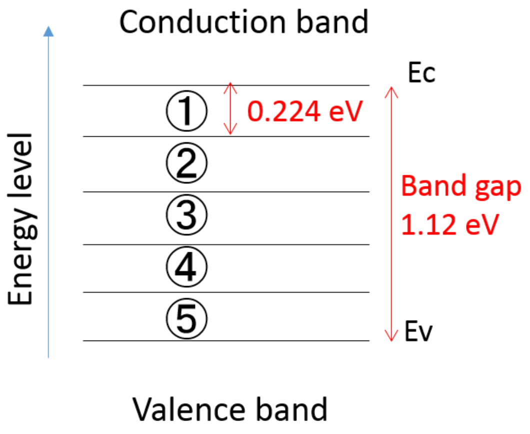

FIG 4 example of a voltage signal

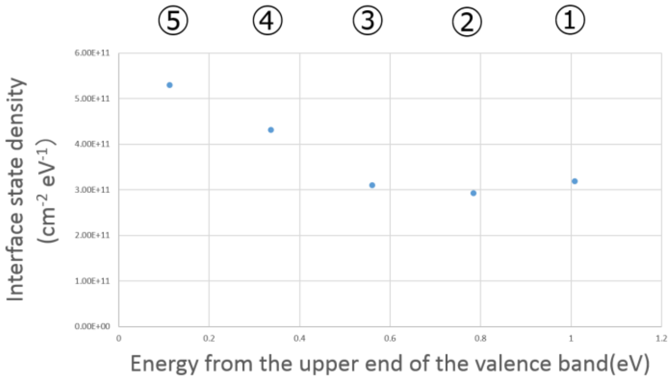

FIG 5 measurement results of the interface state density