Characterization of Heavy Metal Contamination by Capacitance-Frequency Method

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A capacitance-frequency (C-f) method[1)] is applied to characterize heavy metal contamination. As is well known, heavy metal impurity is very harmful to the device performance and one of the most probable candidates for the device degradation of VLSI devices. Therefore, both detecting and controlling heavy metal contamination are very important. In this study, the characterization of generation lifetime, interface traps, and bulk traps based on the C-f measurement is carried out. The validity of this method is assured with the use of Cu-doped and Au-doped samples.

Figures 1 shows the frequency dependence of the capacitance-voltage (C-V) characteristics of Cu-doped MOS diode. The frequency dependencies of normalized capacitance at the inversion condition of Cu-doped and reference samples are shown in Fig. 2. The C-f curve of the reference sample is independent of the measuring frequency. On the other hand, the C-V curves of the Cu-doped sample reveal the so-called low-frequency C-V curve at the lower frequency than 10 kHz. As is well known, the low-frequency C-V characteristics is occurred when the generation of the minority carriers are able to keep up with the measuring frequency under the inversion condition. Namely, the shorter the generation lifetime is, the higher the frequency at which the low-frequency C-V characteristics occur is. It is clear from Fig. 2 that the generation lifetime of the Cu-doped sample is extremely shortened compared with that of the reference sample. Thus, it was ascertained that the generation lifetime could be characterized by using the C-f method.

Figures 3 shows the frequency dependence of the C-V characteristics of Au-doped MOS diode at 900 °C. In Fig. 3, there is a kink near V_G=-2V in C-V curve measured under the very low frequency. The kink of the C-V curve of the 900 °C Au-doped sample is due to carrier generation through the bulk traps located at E_C-0.55 eV which keep up with the measuring frequency. It is found from this result that the relative high density of the bulk traps can be estimated from the low frequency C-V curves. As for the characterization of the interface trap density, high-low frequency C-V techniques[2,3)] based on frequency dependence of C-V curves are convenient tools and are employed in this study.

Figure 4 shows the C-f curves of Au-doped and reference samples. The normalized inversion capacitance of the 900 °C Au-doped sample is lower than those of the other samples. This is because that the Au-related bulk traps act as a donor killer and carrier density is decreased. Also, it is clear from Fig. 4 that the generation lifetime is shortened with a increase of the density of gold impurity that is increased at the elevated temperature.

In summary, we have applied a capacitance-frequency method to estimate the heavy metal contamination in silicon crystals. In this method, both frequency dependence of C-V curves and C-f characteristics are utilized to characterize generation lifetime, interface traps, and bulk traps. The experimental results have revealed that this method is promising tool and is potentially applicable to fast wafer-level inspection.

Reference

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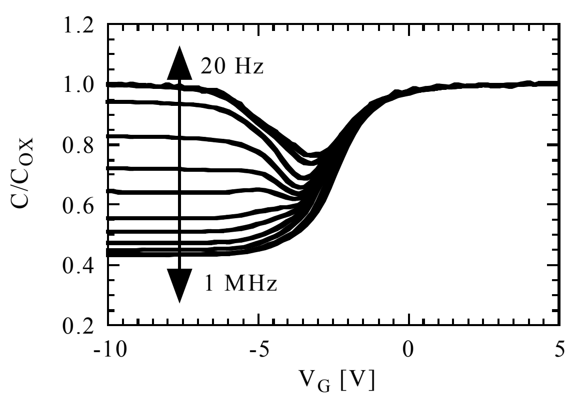

Fig. 1 Frequency dependence of C-V curve of Cu-doped MOS diode.

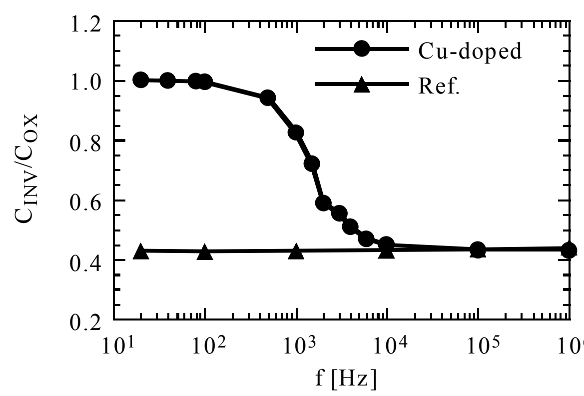

Fig. 2 Capacitance-frequency curves of Cu-doped and reference MOS diodes.

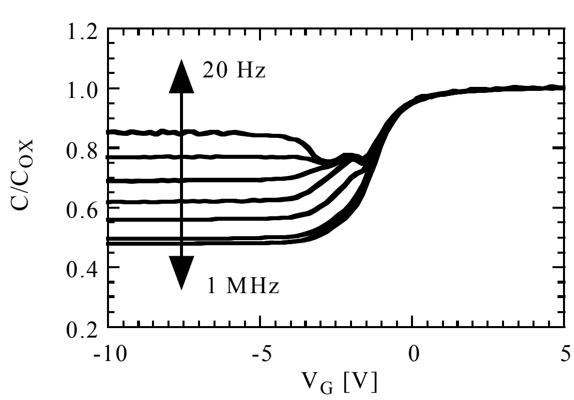

Fig. 3 Frequency dependence of C-V curve of 900 °C Au-doped MOS diode.

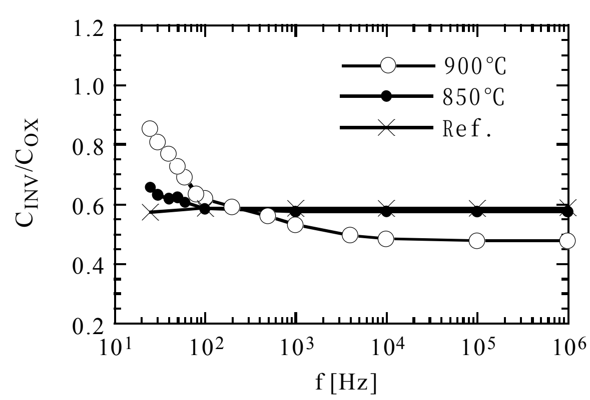

Fig. 4 Capacitance-frequency curves of Au-doped and reference MOS diodes