

Comparison of Sensitivity in Contactless Measurement Techniques of Semiconductor Wafer Carrier Lifetime

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Abstract

This paper presents comparison of the measurement sensitivity among various contactless measurement techniques of semiconductor wafer carrier lifetimes using reflected microwaves, characterized by such detection units as rectangular waveguides, loop antenna, and strip lines.

Some contactless measurement techniques of minority carrier lifetimes of semiconductors have been proposed¹⁻⁷⁾ basing on a photo-conductive decay method using microwaves. These techniques are useful especially to evaluate a degree of crystalline perfection of silicon wafers for VLSI's. In such measurements, it is hard to measure lifetimes of silicon wafers having low resistivity and a short lifetime, since the change of the photo-conductance is negligible due to extremely few excess carriers excited compared with ones in thermal equilibrium. So, it is needed to consider about techniques to increase sensitivity for realizing the lifetime measurement of such wafers.

This paper presents comparison of the measurement sensitivity among various contactless measurement techniques using reflected microwaves, characterized by such detection units as rectangular waveguide^{2,3)}, loop antennas⁴⁾ and strip lines^{5,6)}. The sensitivity can be evaluated conventionally by the magnitude of the signal output voltage ΔV_0 including the information of the lifetime⁶⁾. ΔV_0 is drastically depended on coupling of the wafer with the electric or the electromagnetic field leaked from the detection units. So, ΔV_0 has been measured by the lifetime measurement circuits⁶⁾ as shown in the block diagram of Fig. 1, for the various detection units having the coupling structures as shown schematically in Fig. 2. The detection units in Fig. 2(a)-(c) are composed of a micro strip, a coplanar line and a slot line, with short end, respectively. These measurement techniques are based on the coupling of the wafer with the electric field leaked from the small pair electrodes placed in the parallel resonance position on the strip line⁶⁾. Figure 2(d) is a loop antenna type, in which the wafer couples with the electric field leaked from the narrow gap of the loop connected to the end of the coaxial cable⁴⁾. Figure 2(e) is a x-band rectangular waveguide type, in which the wafer couples with the electromagnetic field leaked from the aperture of the waveguide fringe^{2,3)}. The wafer used is 2 inch diameter, 125 Ω cm resistivity and about 60 μ s lifetime n-silicon wafer. The wafer is placed on the pair electrodes for the strip line types, on the gap for the loop antenna type and on the aperture

of the fringe for the waveguide type. The microwave used was 10 mW power and 1.5 GHz frequency, excepted for 10.5 GHz for the waveguide type. The conductance change of the wafer was induced by illuminating of the LED light pulse (λ :9500 Å, pulse width: 200 μ s, spot size: 2 mm ϕ). The measurement of ΔV_0 was performed under the same illumination conditions for each detection unit. The relative value of ΔV_0 measured are plotted in Fig.

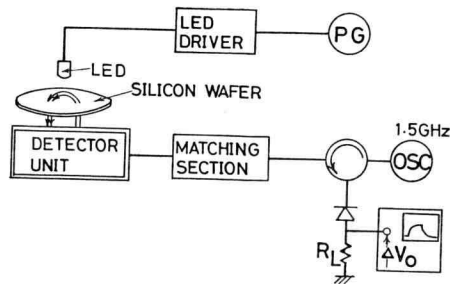


Fig. 1 Block diagram of the lifetime measurement circuit.

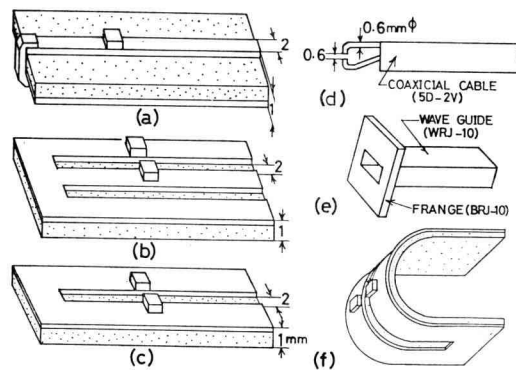


Fig. 2 Various detection units;

(a) micro strip line type, (b) coplanar line type, (c) slot line type, (d) loop antenna type, (e) rectangular waveguide type and (f) bended style slot line type.

3 to compare with the sensitivity among various detection units. As is known from the figure, the sensitivity of the group of the strip lines are high compared with the others. This reason is mainly in the convergence of the electric field due to using the parallel resonance and a narrow waveguide. However, even in these techniques, the wafer does not strongly couple only with the field at the resonance position but also with other positions on the strip line, though its coupling is weak. This spurious coupling may make the field induced at the resonance position weak, so that the sensitivity decreases. To decrease this spurious coupling, the above three strip line type detection units were bent in the bended style as shown in Fig. 2(f), as an example. Figure 4 shows the electric field distribution along the line comparing the above flat style. As expected, the field at the skirt region in the bended style is more weak than in the flat style, so that the field at the peak becomes

stronger. ΔV_0 measured for the bended styles of three strip lines mentioned in the above is shown by \circ in Fig. 3. We can recognize that the sensitivity of each bended style is higher compared with ones of the flat styles.

The output voltage ΔV_0 strongly depends on the distance from the detection units to the wafer. Figure 5 shows experimental results of ΔV_0 versus the distance. ΔV_0 decreases

DETECTION UNITS	RELATIVE SENSITIVITY
SLOT LINE	15 20
MICRO STRIP LINE	15 20
COPLANAR LINE	15 20
LOOP ANTENNA	10
WAVE GUIDE	5

\circ : BENDED STYLE

Fig. 3 Comparison of the sensitivity for the various detection units.

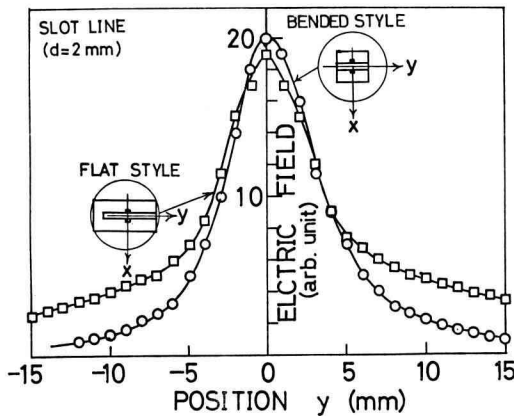


Fig. 4 Comparison of electric field distributions along the line, between the bended and flat style.

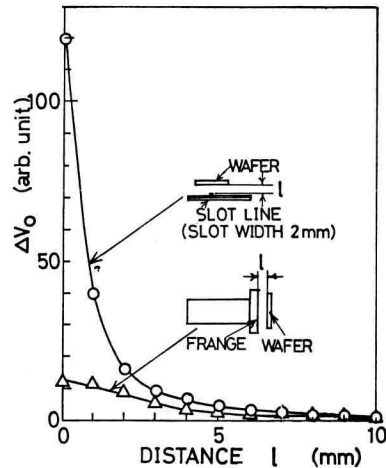


Fig. 5 ΔV_0 versus the distance from the detection units to the wafer.

drastically in the slot line type as the wafer goes far off. On the other hand, it decreases gradually in the rectangular waveguide type. However, it should be noted that the sensitivity of the slot line type is still yet high even when the wafer is placed more apart. We can conclude as follows; the sensitivity is high in the detection units using such strip lines as the micro, coplanar and slot lines, especially the bended style slot line have the higher sensitivity. The author would like to thank to Prof. S. Furukawa of Tokyo Institute of Technology and Mr. K.Ogiso with Kamakura Research Lab. of Mitsubishi Electric Co. Ltd. for the supports of the experimental instruments.

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