B-3-2 Contactless Measurement of Semiconductor Mobility, Conductivity and Carrier concentration

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Introduction In order to measure electrical properties of the semiconductor wafers, the ohmic contacts are usually necessary in the conventional methods. These contacts would introduce other damages as well as surface contamination to cause the difficulty in characterization of the wafers, especially wafers for LSI and a-Si film. Therefore, it can be said that the method of the contactless measurement of the properties is the best way for the characterization, if possible. However, there have been few studies reported about this contactless measuring method.[1)∿3)] Moreover, there has been no report about the contactless method to measure the conductivity σ, the mobility μ and the carrier concentration n, simultaneously. We propose a noble contactless measuring method of μ as well as σ (so that n), and show experimentally the usefulness of our method.

Principle A RF magnetic field produced by a driving coil which is placed over the wafer induces the eddy current I_e in the wafer as shown in Fig.1. The eddy current is proportional to σ and the wafer thickness t. If t is known, σ is measured by detecting the eddy current by a pick-up coil which is placed under the wafer in parallel with the driving coil.[2)] The eddy current* produces radial Hall voltage in the applied DC magnetic field. This Hall voltage has the relation, $V_H = k\mu B V_1$; where k is the constant value decided by the structure of the system, B the DC magnetic flux density and V_1 the driving coil voltage. Using this relation the relative value of μ can be derived by V_H, B, and V_1. V_H is detected by capacitive coupling between the concentric plate electrodes and the wafer. In this case, the sign of V_H expresses the conduction type of the semiconductor. From σ and μ values, n is calculated.

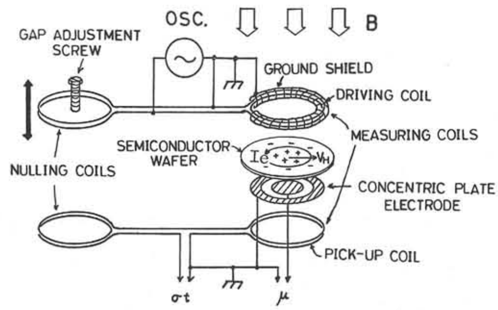

Fig.1 Detector Unit

* A Reverse version in which radial RF current is flown by using circular electrodes, has been proposed by G.L. Miller for measuring μ.[4)] On the contrary, our method uses a principle to measure Hall voltage induced by this eddy current, so that we can measure σ simultaneously.

Experiments and Results A Semiconductor wafer is just put on the electrodes as shown in Fig.1. By adjusting the coupling between nulling coils, the voltage in the pick-up coil induced by the RF magnetic field is compensated. It has been observed in preliminary experiment that the bigger diameter of the coils and the electrode, and the higher frequency of the driving magnetic field are required to obtain the larger output signal. We decided to use 18 mm diameter electrode and coils, considering the case to measure 1 inch wafer. We also decided to use 6MHz as the driving frequency to avoid the ambiguity due to the skin effect, considering that the maximum σ of the wafer is about $10(\Omega\cdot cm)^{-1}$. Figs.2 and 3 show experimental results. The output voltage of σt and μ are plotted respectively versus the results by the van der Pauw method. It is clearly shown that these σt and μ output are proportional to the results of Pauw method. Thus, one can know σt and μ values of the wafer by comparing the outputs of the sample whose σt and μ values are known. Carrier concentration calculated by σ/μ is plotted in Fig.4. In our system, the measurement has been accurately performed over the range $0.3\sim 10(\Omega\cdot cm)^{-1}$ in conductivity for the wafers of t=200μm, above $200cm^2/V\cdot s$ in mobility and $1\times 10^{15} \sim 1\times 10^{17}cm^{-3}$ in carrier concentration of Si. The discrepancies between the data obtained by our method and by Pauw method over $\sigma t=1\ \Omega^{-1}$ is considered due to the skin effect.

Conclusion In this study, the validity of this contactless method without any contamination and/or any destruction is demonstrated. It can be said that this method proposed here is useful in wafers for LSI as well as for regular semiconductor studies. Other experimental examples will be presented at the session.

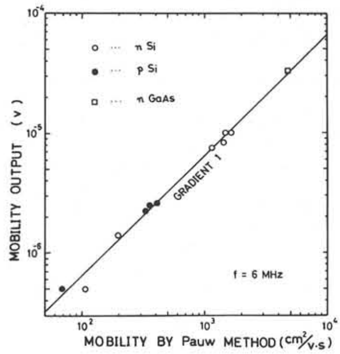

Fig.2

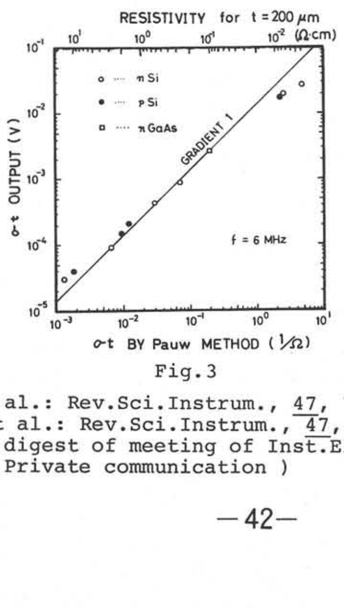

Fig.3

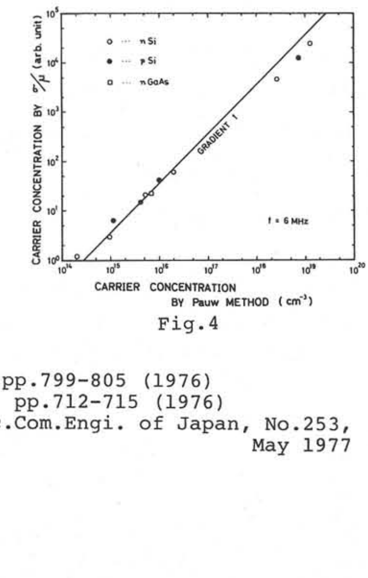

Fig.4

References

1) G.L. Miller et al.: Rev.Sci.Instrum., 47, 7, pp.799-805 (1976)
2) J.D. Crowley et al.: Rev.Sci.Instrum., 47, 6, pp.712-715 (1976)
3) T. Oohara: The digest of meeting of Inst.Elec.Com.Engi. of Japan, No.253, May 1977
4) G.L. Miller (Private communication)