Effect of Wafer Height and Bow on Eddy Current Sheet Resistance Measurements

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Abstract

Sheet resistance (Rs) measurements are critical to compound semiconductor manufacturing. Current processes are inducing increasing amounts of bow in wafers. The standard eddy current determined Rs measurement is sensitive to this bow, as well as height differences between the calibration wafer and the actual wafer of interest. We illustrate what the influence is and how to compensate for it to avoid detuning an epi reactor for artificial reasons.

INTRODUCTION

Sheet resistance (Rs) measurements, primarily non-contact eddy current (EC) based, are critical to compound semiconductor manufacturing, particularly the epi used in the manufacture of HBT and HEMT devices [1]. Even modern EC systems use the fundamental techniques of the pioneers at Bell Labs, Miller et.al.[2]. The EC system uses induction to determine the sheet resistance of a sample under test. Current manufacturing processes are inducing increasing amounts of bow in wafers. The standard Rs measurement is sensitive to this bow. The measurement is also sensitive to height differences between the calibration wafer and the actual wafer of interest. This is a significant result for both single coil (typically used for flat panel applications) and double coil (typically used for wafers) eddy current systems. We illustrate what the effect is for both types of systems and how to compensate for it to avoid detuning an epi reactor (either MBE or MOCVD) for artificial reasons.

SINGLE COIL EC SYSTEMS

Single coil EC systems are typically used in flat panel applications where conductive materials are deposited upon glass substrates. In such applications, the thicknesses of the substrates vary and so EC measurement systems are typically a single coil head. This head is mounted such that the height may vary to accommodate test samples of various thicknesses. While there are systems with automation to maintain a steady distance between test sample and sensor head, many R&D systems are manual and so the height from the sample might be less controlled (Fig. 1). The system might be calibrated at one spacing and readings taken at another.

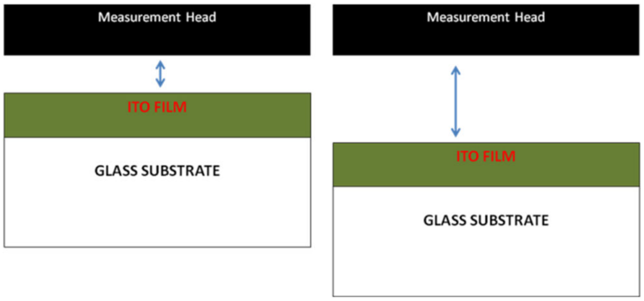

Figure 1. Example of two possible sample-head positions in a manual single coil EC system. A difference from probe-sample spacing compared to the calibration sample introduces error.

By examination of known samples, it is shown that a single coil eddy current system has a region of roughly linear response to height differences. The linear region is shown to be $\pm$ 250 microns from the baseline calibration region. The linear response is determined to be 0.77% deviation from actual values for each micron of height difference (Fig. 2).

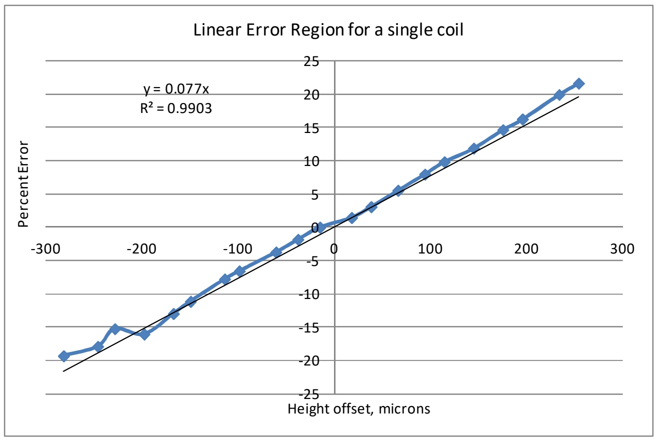

Figure 2. Influence of height difference on accuracy of single coil eddy current system. The error is 0.77% for each micron of height difference.

DOUBLE COIL EC SYSTEMS

Double coil (or double headed) EC systems find use in wafer based measurements. The systems tend to have fixed gaps, limiting measurement to below a certain thickness. This limitation is offset by a more precise measurement due to a more uniform magnetic field. However just as the single coil is affected by height/spacing differences, so is the double coil. The influence is not as great, as we will show. For this application we will use a wafer with bow as the illustration (Figure 3).

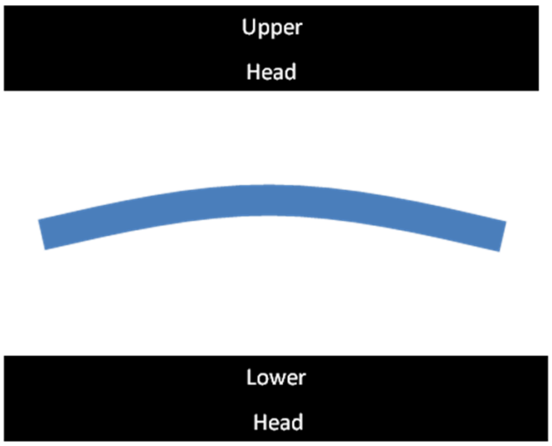

Figure 3. Exaggerated schematic of a bowed wafer between EC coils. The center is closer to the upper coil and so will register as a higher conductance and hence a lower sheet resistance.

In a similar way as for the single coil head, one may compare known standards as a function of spacing, or of height difference, to determine the influence of height difference on accuracy (Fig. 4). Here we repeat the single head results and plot on the same scale for comparison purposes.

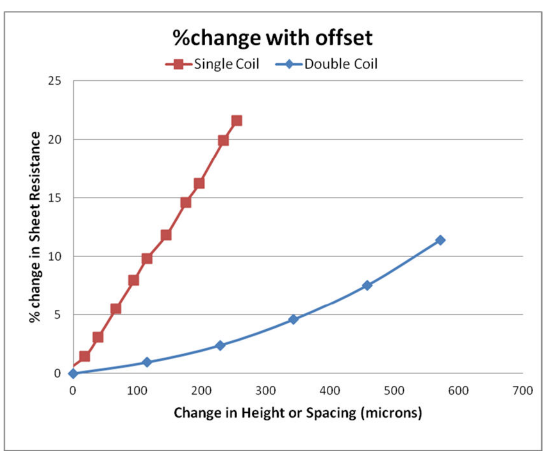

Figure 4. Influence of height difference on accuracy of double coil eddy current systems. We contrast with the single coil and see that the double coil has much less sensitivity to height differences.

The correction for the double coil system is best expressed as a quadratic fit of

$$0.000028x^2 + 0.004063x,$$

where x is the deviation from the calibration position.

CONCLUSIONS

Eddy current measurements for sheet resistance are extremely valuable for epi process tuning. However, it is critical to understand the influence of sample height and bow on these standard measurements to avoid detuning an acceptable reactor. As we have detailed above, with knowledge of the bow, or height difference, one may compensate the Rs value to determine the true readings. This correction could be automated by use of a position sensor in tandem with the EC measurement. Neglecting this correction might lead one to detune a reactor that might be working well. In summary, the effect of wafer thickness on the measured Rs is demonstrated, and a correction scheme for such data is given.

ACKNOWLEDGEMENTS

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REFERENCES

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[2] G. Miller, D. Robinson, J. Wiley, Rev. Sci Instrum., Vol. 47, No. 7, (1976).

ACRONYMS

EC: Eddy Current
HBT: Heterojunction Bipolar Transistor
HEMT: High Electron Mobility Transistor
MBE: Molecular Beam Epitaxy
MOCVD: Metal-Organic Chemical Vapor Deposition
PHEMT: Pseudomorphic High Electron Mobility Transistor
Rs: Sheet resistance