COMPARATIVE STUDY ON EMITTER SHEET RESISTIVITY MEASUREMENTS FOR INLINE QUALITY CONTROL

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ABSTRACT

With increasing degree of automation and throughput in latest crystalline Si solar cell manufacturing lines a quality control (QC) directly incorporated in the corresponding process equipment is of rising interest. The dominant QC parameter for the phosphorus diffusion step is the emitter sheet resistance normally measured based on manually drawn samples. In contrast, our aim was to develop and test measurement methods which can be directly incorporated in high volume diffusion equipment.

Two contactless approaches have been studied, the Eddy Current technique and a newly developed system based on SPV (Surface-Photo-Voltage) probing. As reference measurement technique a four point probe FPP was used.

As result it could be clearly shown that the novel SPV approach already included in a new 30MW cell line lead to the same accuracy as an off-line FPP whereas the Eddy current technique can not be applied.

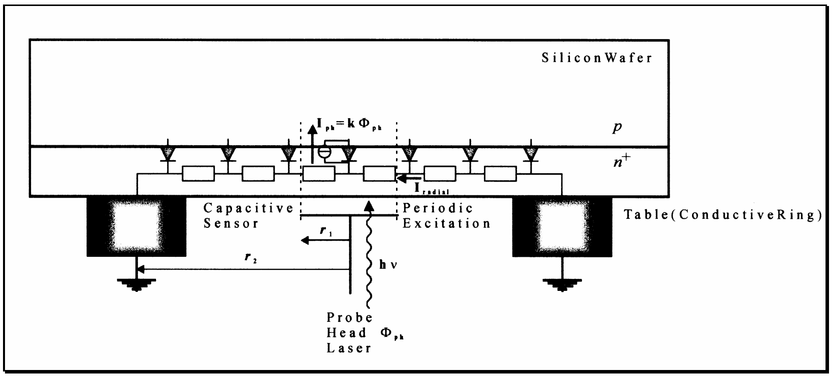

Fig. 1: Measurement principle of the developed SPV set-up for sheet resistance measurements

1. MEASUREMENT

In the underlying study two contactless measurement techniques were applied to study the emitter sheet resistance r_s after the phosphorus emitter diffusion: the Eddy current method and a novel SPV technique. As a reference four point probe (FPP) measurements were undertaken which request a direct contact between probe head and silicon wafer sample. There are several reasons to rely on contactless approaches within an inline quality control system:

- lower probability of contaminating the silicon wafer by metal probes
- Stress free measurements reduce the chance of wafer breakage (especially appropriate for thin substrates)
- Potential of measurements on uneven surfaces
- Less maintenance due to no wear-out of the contact probes
- Reduced effort for the incorporation in automation systems

The basic idea to use Eddy current measurements for sheet resistance evaluation was the alteration of the measurement signal due to the highly doped n-type layer on the surface as compared to specimen without diffusion.

The basic principle of eddy current and SPV measurements used for semiconducting samples is described elsewhere [1-3].

The principle of the developed SPV technique for r_s measurements is shown in Fig. 1. Different sheet resistances lead to a variation in the surface photovoltage which can be detected by a capacitive probing at the outer metal ring of the system (see also Fig. 2).

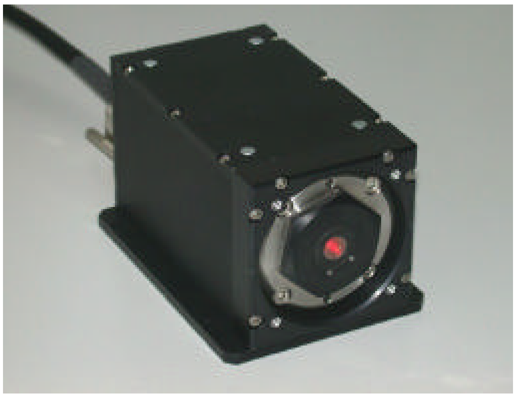

Fig. 2: Photograph of the SPV measurement head

In a first step all three measurement techniques were compared on almost identical wafers with very low sheet resistivity variation.

In a next phase the influence of bulk resistivity was tested and finally the accuracy compared to a standard off-line FPP technique was demonstrated.

2. RESULTS

For a first comparison of the used measurement techniques FPP (contacting device as reference), Eddy Current (contactless) and SPV (contactless) a set of 10 multi- and mono-crystalline Si wafers with only slightly varying emitter diffusion (40-45W/sqr) were used (Fig. 3).

In order to compare both contactless techniques, samples with varying emitter diffusion and bulk resistivities were prepared. In order to investigate the influence of crystal structure multi- as well as mono-crystalline samples underwent the same diffusion step and were subsequently measured.

The results show a very good agreement of SPV and FPP measurements. On the other hand Eddy Current results couldn’t be correlated with the sheet resistance values.

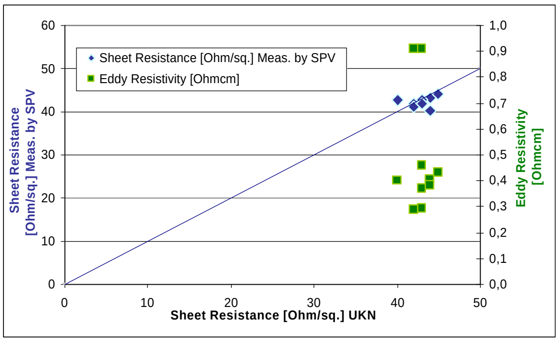

Fig. 3: Eddy current resistivity and sheet resistance values, measured by SPV, compared with four-point sheet resistance values (UKN)

For a better understanding of previous results a set of Cz mono-crystalline wafers with different bulk resistivity and identical n-type emitter diffusion was processed and measured.

It is clearly visible (Fig. 4) that Eddy resistivity has a broad variation with varying bulk resistivity.

The reason is obviously the deep penetration of the Eddy current into the bulk material, which severely affects the measurement signal. The surface sensitivity is to low for the Eddy Current signal.

The SPV on the other hand shows stable results and a good correlation with FPP data.

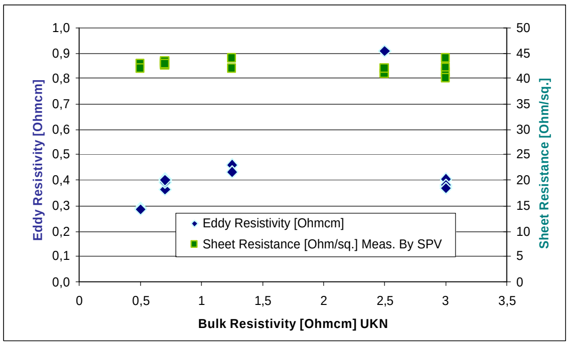

Fig. 4: Sheet resistance measured by SPV and Eddy current resistivity compared with four-point sheet resistance values (UKN) on Cz wafers with varying bulk resistivity.

It is obvious that the Eddy current technique clearly failed exhibiting r_s largely scattering from sample to sample whereas the SPV method lead to excellent agreement with the FPP reference measurement. In order to further study the misleading Eddy current results analysis of Cz samples with varying bulk resistivity but identical n-type emitter diffusion were undertaken and are depicted in Fig. 4. Due to the high penetration depth of the Eddy current into the silicon bulk the variations of the bulk resistivity severely affects the obtained measurement signals. The surface sensitivity is to low to give reliable r_s values.

In order to examine the accuracy of the SPV measuring technique, a sensitivity study for different samples with varying sheet resistances was carried out (Fig. 5). It clearly indicates that the novel sheet resistance measurement technique leads to reliable results with an accuracy of 5% for different emitter resistivities used for industrial type solar cells (screen printed devices typically 45Ω/sqr. and buried contact solar cells 90Ω/sqr.).

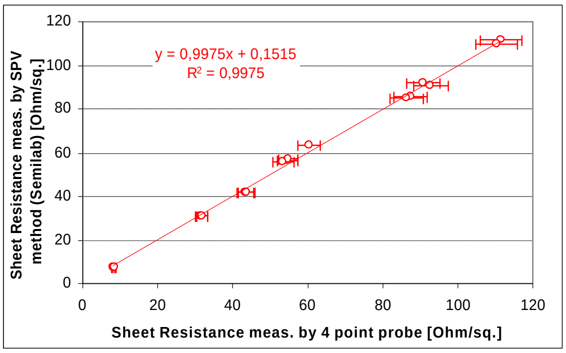

Fig. 5: Sensitivity analysis of the SPV system using diffused multi Si wafers with different emitter sheet resistances.

3. SUMMARY

Our study clearly indicates that the novel emitter sheet resistance measurement system based on SPV technique is a reliable instrument for contactless quality control of the emitter diffusion in a crystalline silicon manufacturing line.

Fig. 6: Photograph of the SPV measurement system for in-line characterization of mc-Si wafers after P-diffusion

On the other hand a measurement duration of below one second obtained with the new in-line apparatus is a prerequisite for its incorporation directly in unloading section of either a conveyor belt based diffusion furnace or a batch type $POCl_3$ system. First three SPV sheet resistance measurement apparatus (Fig. 6) were already included as quality control instruments after the diffusion section of a new 30MW production line in Germany. The results show that SPV measurement of the sheet resistance is an excellent tool for in-line diffusion control.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Zoth et al., J. Appl. Phys. 67, 6764 - 6771, 1990

[2] M. Miyazaki et al., Japan. J. Appl. Phys. 34, 409-413

[3] K.S. Choe et al., J. Crystal Growth 97, 622, 1989