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SENTECH Erfolg durch Leistung

Large Area Mapping of Thickness, Haze, and Sheet Resistance of TCO Films on Glass

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• Motivation

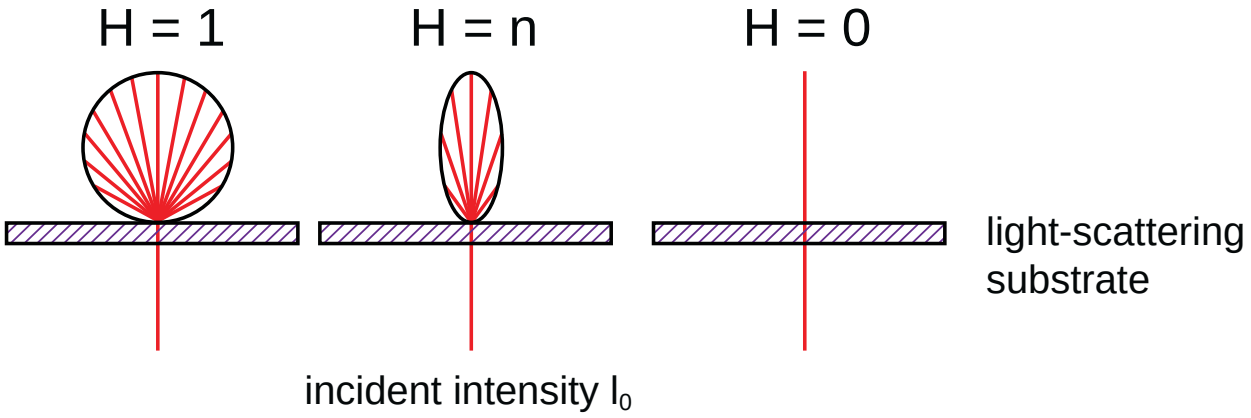
The measurement of thickness, Haze, and sheet resistance of TCO films on large glass sheets is mandatory for the qualification of existing deposition processes in terms of uniformity, for the development of new deposition technologies, and for quality control in the production process of thin film solar cells.

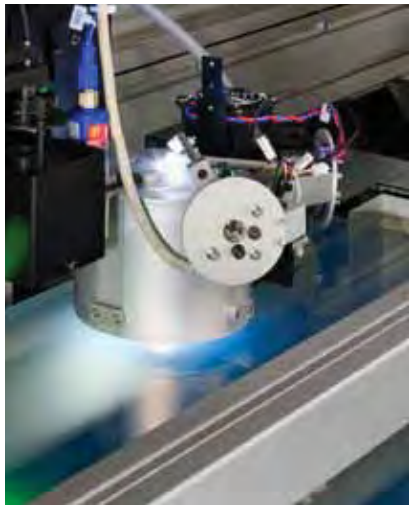
The parameter Haze describes the ability of a rough film to scatter light. Absolute value, uniformity, and spectral dependence of the Haze are essential film parameters for highly efficient solar cells. The measurement of the thickness uniformity of the TCO film is important for the conductivity and the optical appearance of the cell. The direct measurement of the sheet resistance uniformity is one point for the assessment of the electrical and optical properties of a module.

The **SenSol H** mapping system offers the ability to map these parameters on large areas in short time without nearly no edge exclusion.

• Haze measurement

Haze = $T_{scattered} / T_{total}$ $T = I_t / I_0$ (I_t transmitted intensity)

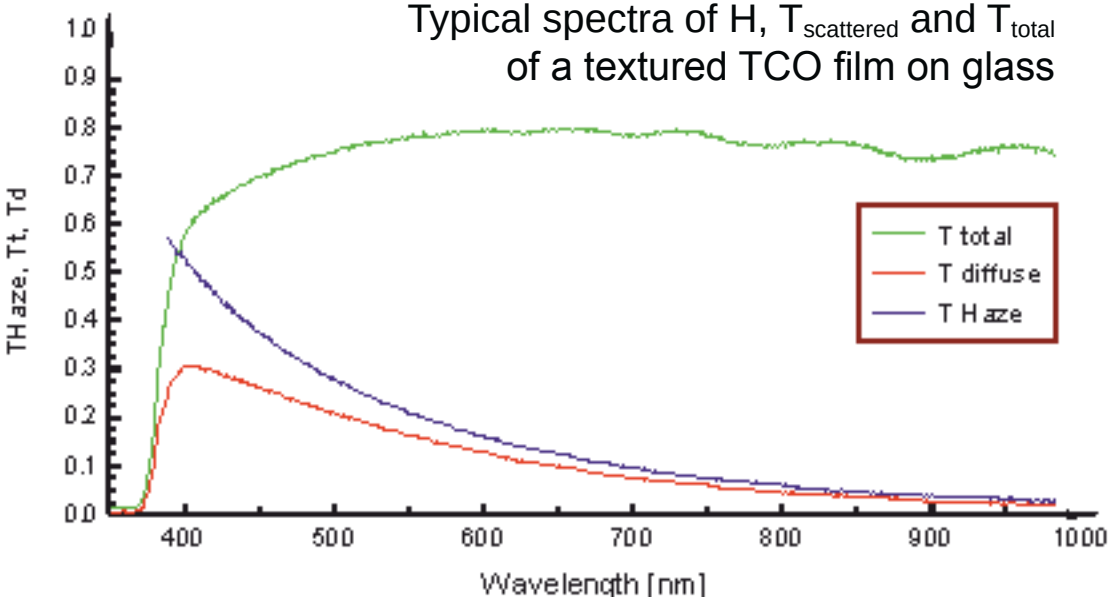




Principle:

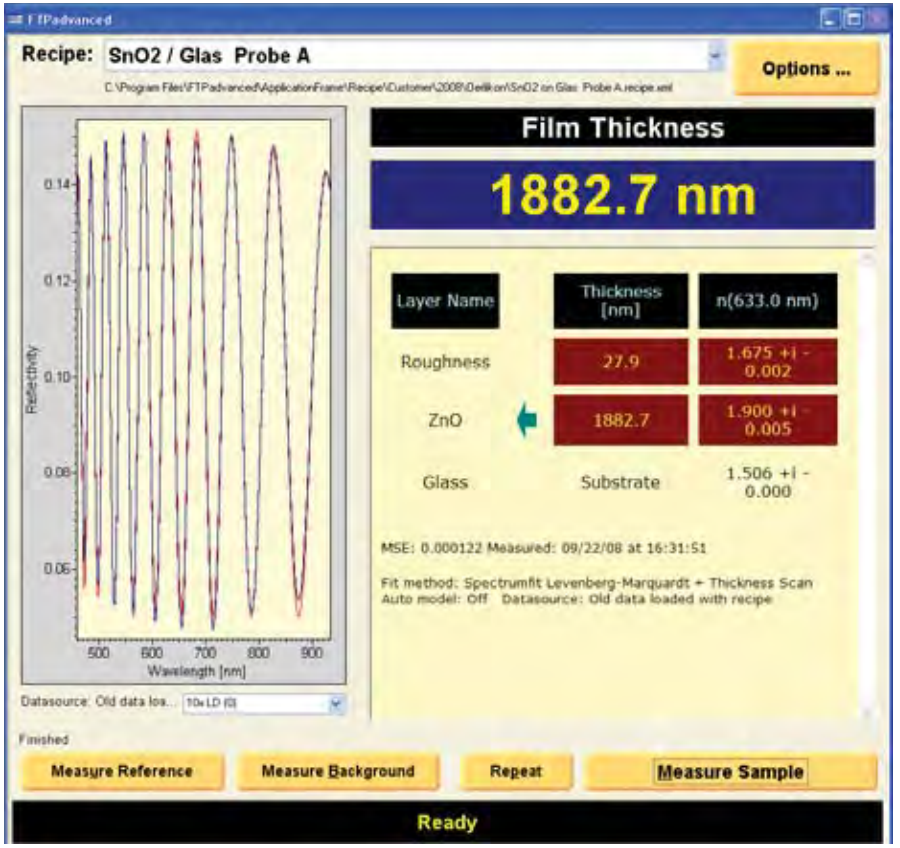
Light is transmitted through a substrate with a light-scattering film on top. The total transmitted intensity and the scattered intensity are measured using an integrating sphere. The light path can also be converted using diffuse illumination and the measurement of light transmitted into a small solid angle.

Typical spectra of H, $T_{scattered}$ and T_{total} of a textured TCO film on glass



• Thickness measurement

$$R(\lambda) = R_{ref}\,(I_m - I_d)\,/\,(I_{ref} - I_d)$$

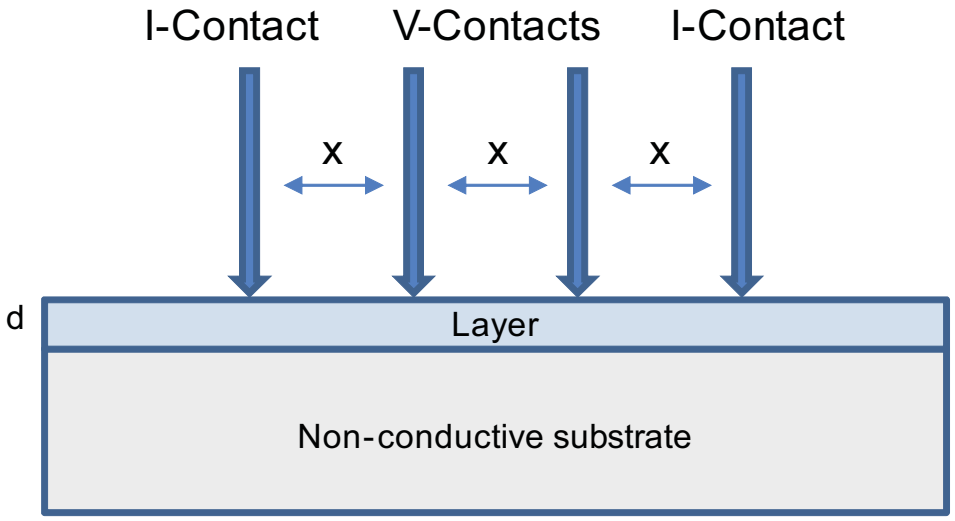


Principle:

The reflectance of the sample is measured as function of the wavelength.

An optical model describing the layer structure of the sample is used to fit the calcuated reflectance to the measured reflectance. The mean square error of the deviation is used as figure of merit to characterize the goodness of the fit. Film thickness and optical constants can be determined.

• Sheet resistance measurement



4-Point probe head

Weak traces on TCO film

$$R_S = k * V / I = \rho / d$$

k: geometrical factor ($\pi / \ln 2$), ρ: resistivity
V: voltage, I: current

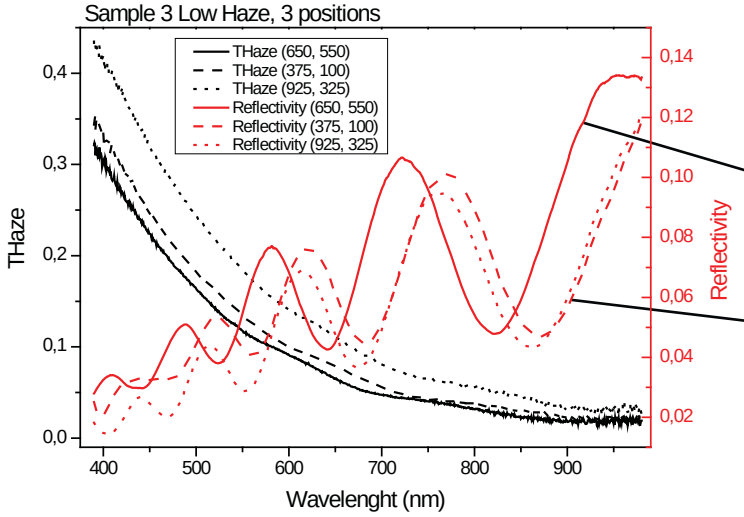
Principle:

The 4-point probe head is mechanically brought in contact with the TCO film by applying a small and constant load. The potential drop is measured during the current flow through the outer contact tips. All tips must be in stable contact with the sample surface. The film damage created by the tips can be minimized by optimizing the load pressure.

• Thickness map

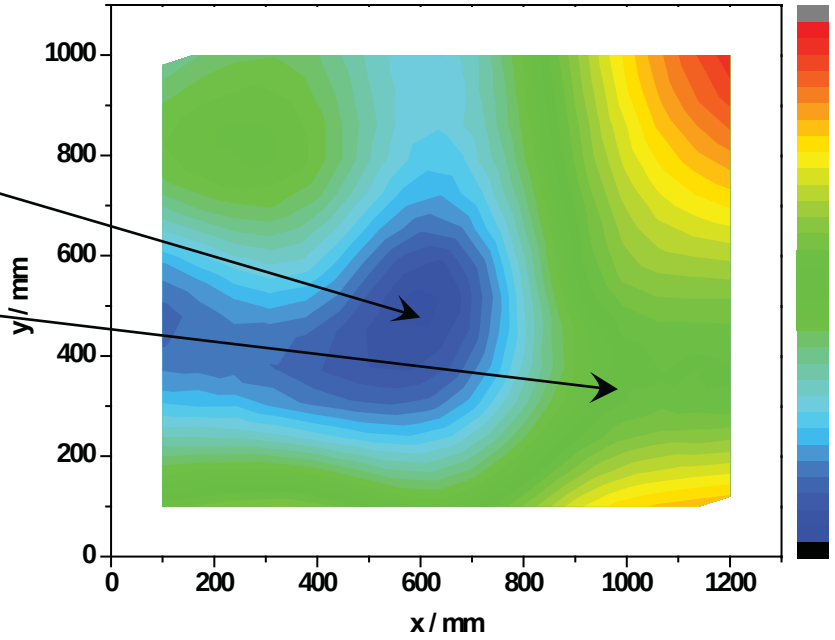
SenSol H
1,100 x 1,300 mm^2 mapping area

Thickness reproducibility < 0.1nm



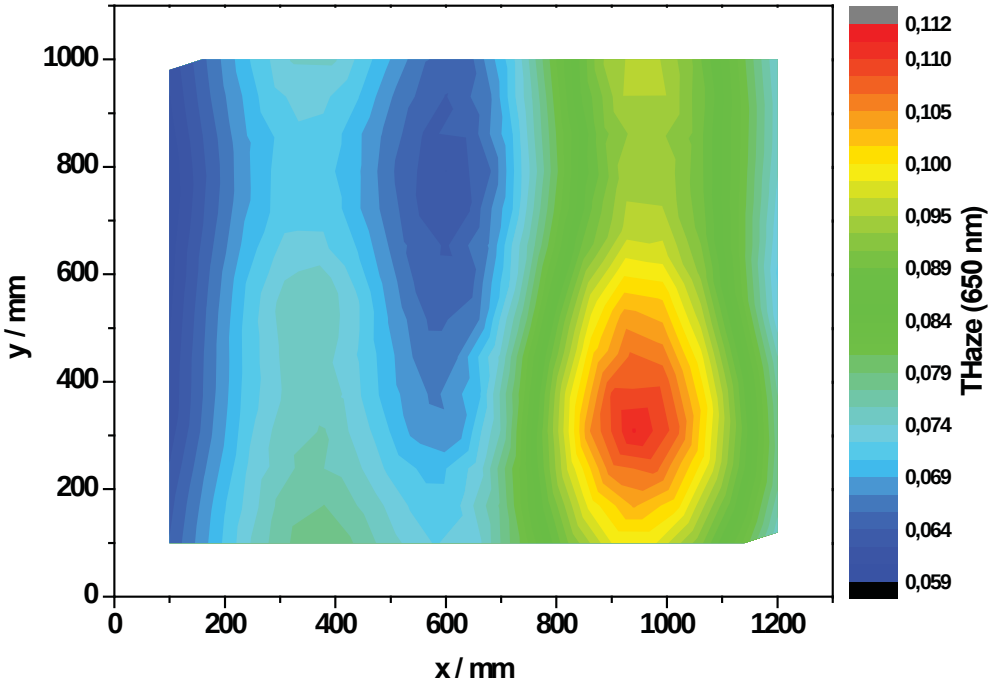
Correlation between film thickness and measured reflectivity curves

Thickness uniformity of TCO film on glass

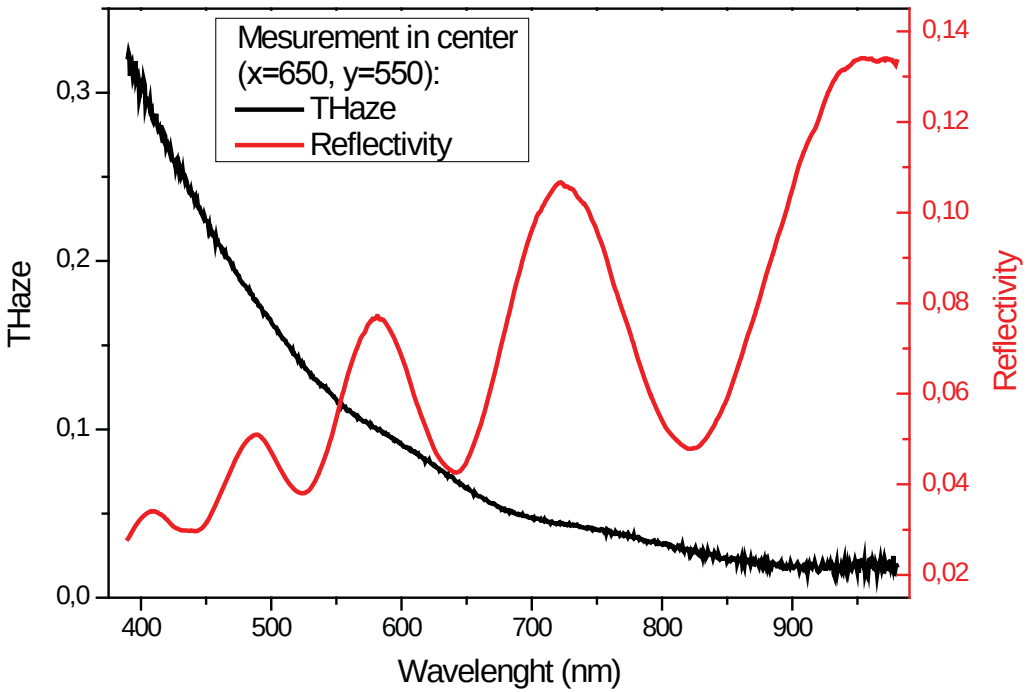


• Low Haze map

Haze uniformity at 650 nm wavelength



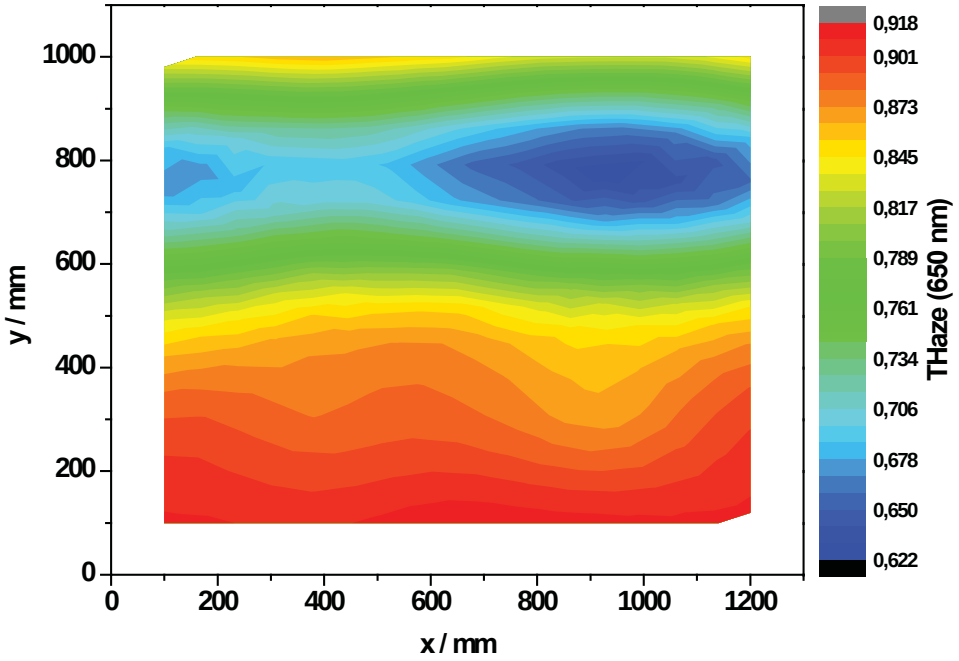
Spectroscopic measurement



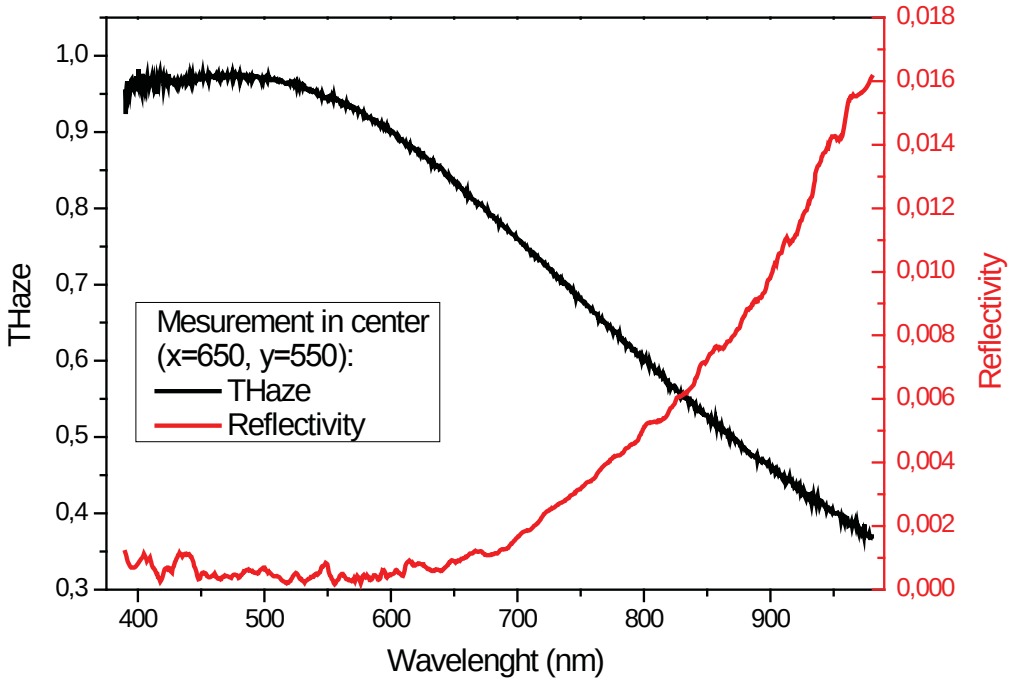
Haze reproducibility < 0.01

• High Haze map

Haze uniformity at 650 nm wavelength



Spectroscopic measurement

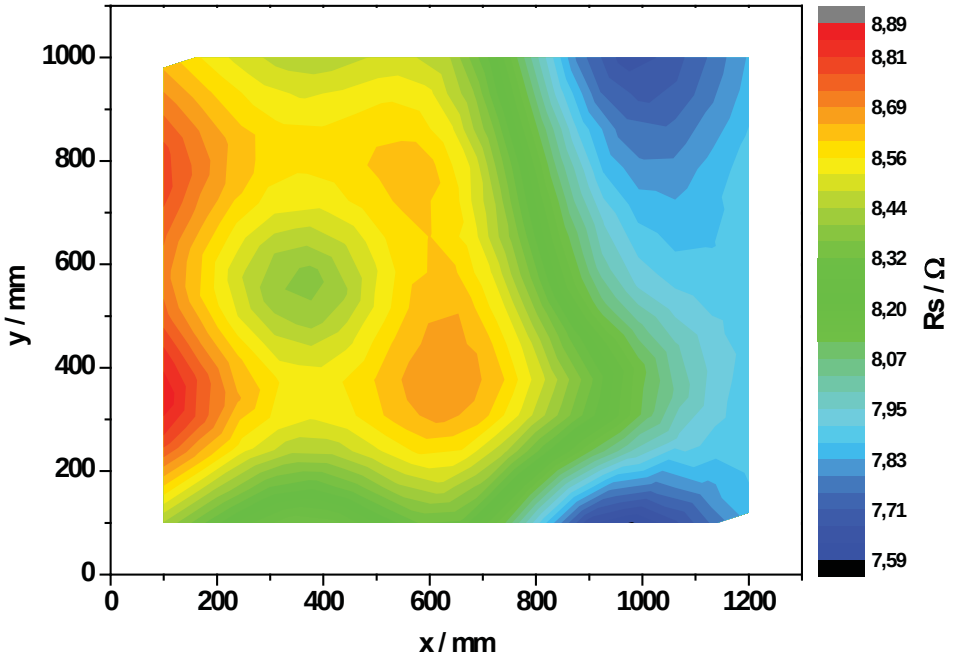


Haze reproducibility < 0.015

Thickness can not be measured

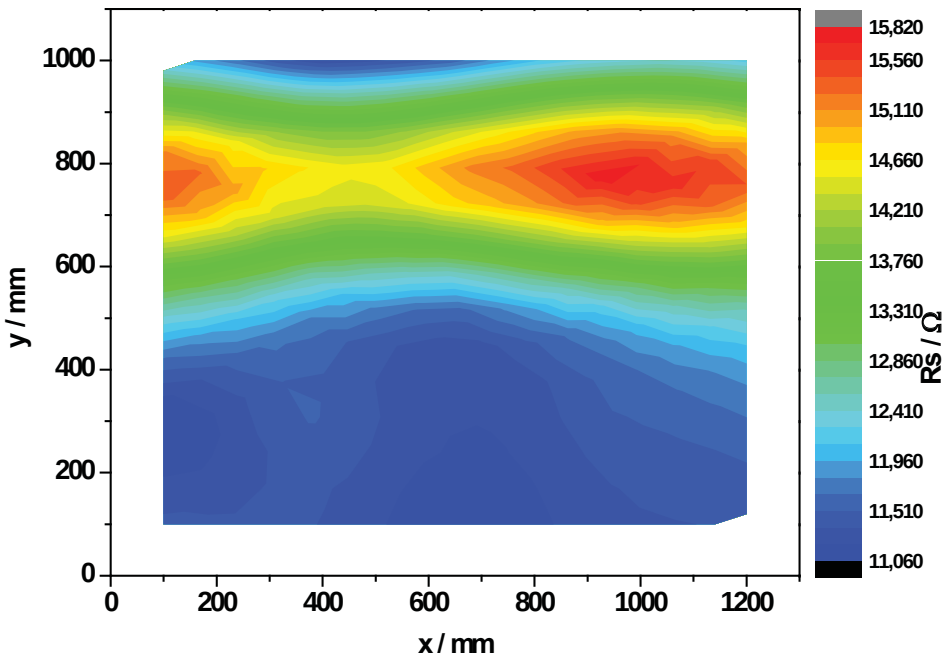
• Sheet resistance map

Low Haze



R_S reproducibility < 0.02 Ohm

High Haze



R_S reproducibility < 0.05 Ohm

Summary:

Thickness, haze, and sheet resistance of TCO films on large glass sheets can be measured using **SenSol** mapping platform. The reproducibility of the measurements is very high. Large roughness (high haze) destroys the capability to measure film thickness.