Learning Event 2018 - GPD Turkey

Glass Performance Days 2018

March 07-09, 2018, Istanbul, Turkey

Case study from
New Istanbul Airport – Largest in Europe
Innovation Corner - Hall 11

Emissivity measurement along the value chain – Monitoring from deposition, tempering to window testing

Agenda

1. Company
2. Relevance and Materials of Conductive Coatings in Glass Industry
3. Characteristics and Requirements for Coatings
4. Metrology for Conductive Materials
   - Eddy Current Technology
   - Testing Setups
4. Opportunities Provided by Non-contact Eddy Current Testing
   - LowE Coating
   - Mirror Coating
   - Automotive Coating
   - Electrode Coating, e.g. Smart Glass or Solar Glass
5. Summary

Company – SURAGUS GmbH is German Metrology Specialist

Technology

- Eddy current-based testing solutions (SURAGUS)
- Other integrated metrology (OEM)

Location and Presence

- R&D and manufacturing in Germany (Dresden & Berlin)
- EddyCus systems are present on six continents
- Local representatives and service teams in Korea, China, Taiwan …

Ownership

- German privately owned LayTec & SURAGUS Group (> 80 employees, >2,100 systems worldwide)

Applications

- Quality assurance of functional thin-films

Relevance - Conductive Coatings on Glass Can Be Found in Various Glass Applications

Indirect Properties

- Architectural glass industry (emissivity)
- Mirrors (optical properties)

Electrical Properties

- Display and flat monitors
- PV/Solar
- LED/OLED Lightning & Smart-Glass
- Smart glass
- Deicing and heating applications

Photo : Michigan State University

SURAGUS Non-Contact Technology

How Eddy Current Works

I. A primary magnetic field is created when alternating current is injected into an induction coil

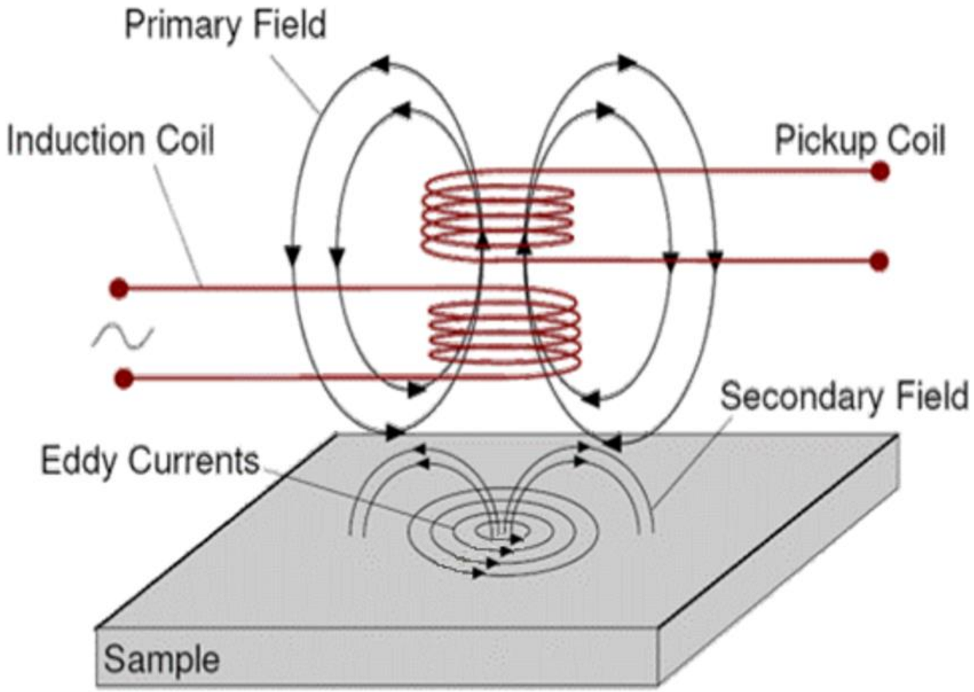
II. Eddy Currents are generated when the coil is placed over a conductive sample

III. The characteristics of the Eddy Currents are determined by material characteristics

IV. The Eddy Currents generate a secondary magnetic field opposed towards the primary field

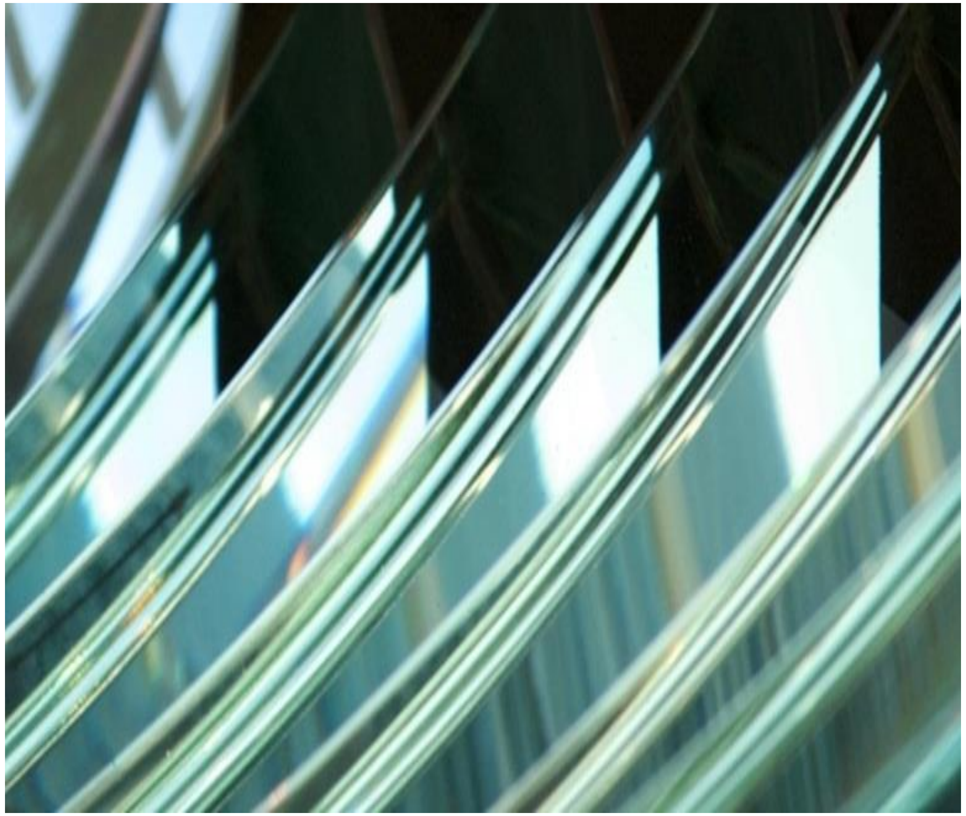
V. The impedance of the coil is affected by material differences that influence conductivity

VI. This influence is measured by a pick up coil



- + High sample rate
- + High sensitivity
- + Non-contact solutions
- – Limited to conductive materials

Monitoring of Layer Modification Processes



Capabilities of eddy current monitoring

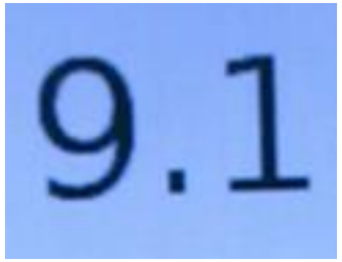
- Metal layer thickness measurement from 2 nm – 2 mm
- Sheet resistivity measurement from 0.1 mOhm/sq to 3,000 Ohm/sq
- Defectoscopy by imaging

Process monitoring

- Deposition (PVD, CVD, ...)
- Annealing/Tempering
- Others (Doping, Etching etc.)

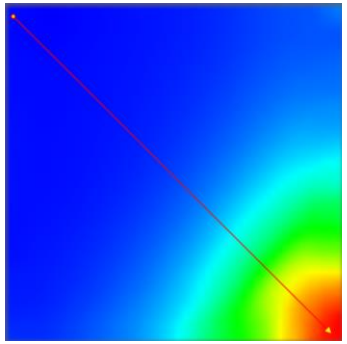
Introducing Four General Testing Setups

Portable testing

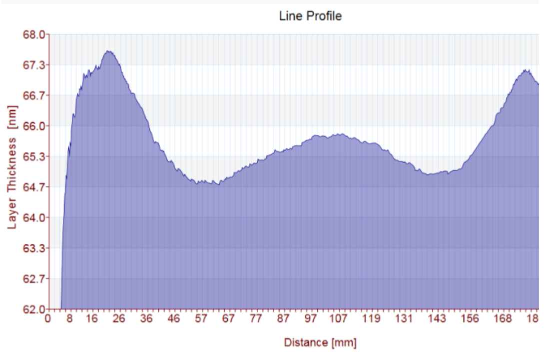


Non-contact single point measurement

Non-contact imaging solutions



Inline / tool integrated



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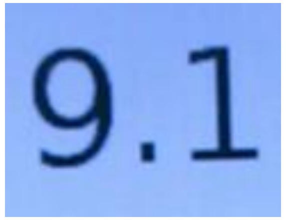
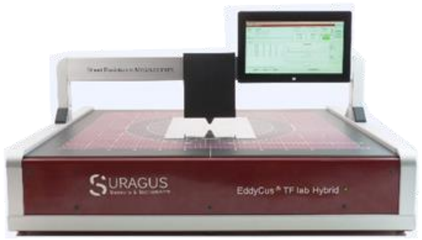
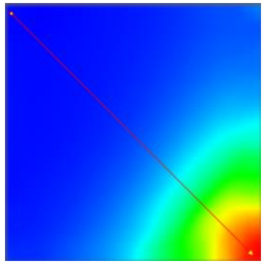


Non-contact single point measurement



2.35	1.73	1.84	1.89	1.79	2.01	3.48
1.68	1.13	1.20	1.23	1.17	1.19	1.95
1.62	1.14	1.21	1.25	1.15	1.16	1.94
1.65	1.17	1.26	1.35	1.20	1.21	1.94
1.71	1.14	1.21	1.24	1.16	1.19	1.99
1.76	1.14	1.19	1.20	1.15	1.22	2.14
4.20	2.01	2.13	2.00	1.96	2.34	4.24

Non-contact imaging solutions



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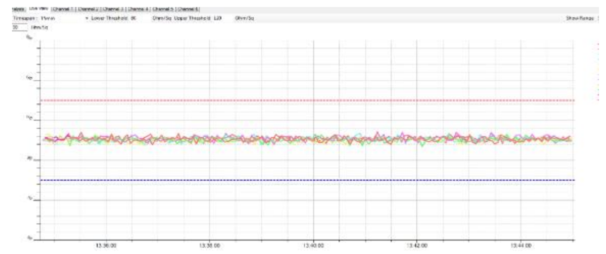


Architectural Glass – LowE Coatings

Process Characterization

- Ag Deposition
- Tempering
- Final inspection (even in building inspection)

Environment

- In-vacuo and ex-vacuo solutions

Setups

- In-vacuo after each Silver deposition enable the precise process control of each individual silver layer
- QA traversing system with optical and electrical sensor (eg. Zeiss)
- Portable

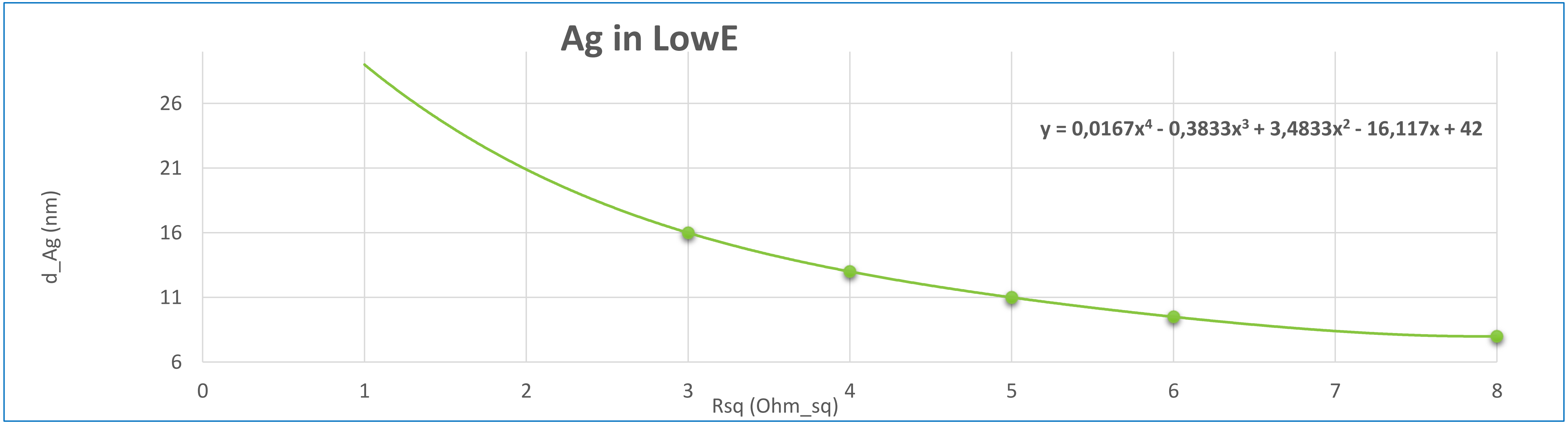
Measurements

- Silver thickness, emissivity, sheet resistance

Silver Thickness and Sheet Resistance

- Numerical calculations show that the thickness correlates with the sheet resistance and may be written as

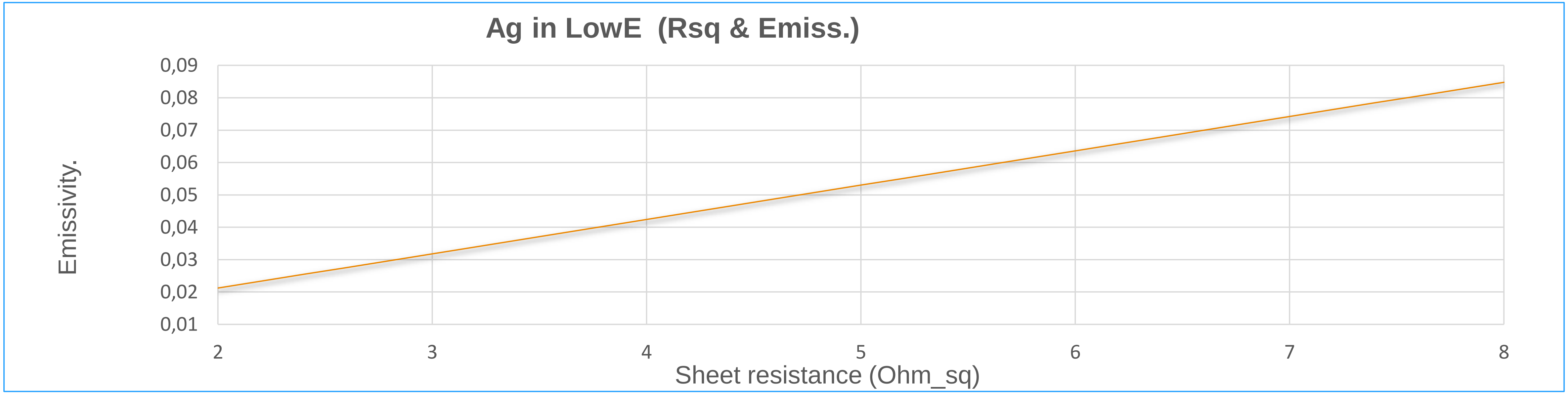
$$t = 0.0167 \text{ x } SR^4 - 0.3833 \text{ x } SR^3 + 3.4833 \text{ x } SR^2 - 16.117 \text{ x } SR + 42$$



Emissivity and Sheet Resistance

- Numerical calculations show that the emissivity e does depend on sheet resistance and may be written as

$e = 4e_0 R_\square c = 0.1\, R_\square / 3\pi$ or $\mathbf{e = 0.0106\, R_\square}$ where $R_\square$ is giving in $\Omega/\square$



Ref: J. Szczyrbowski and A. Dietrich, Evaluation and control of the optical and thermal properties of low-emissivity coatings, SPIE Vol 302 (1988)

Emissivity and Sheet Resistance

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$e = 4e_0 R_\square c$ = 0.1 $R_\square$ / 3π or **e = 0.0106 $\boldsymbol{R_\square}$** where $R_\square$ is giving in Ω/□

- The industry adds typically some “safety markup” when applying this formula for QA and Process control. Often this formula is used **e = 0.0109 $\boldsymbol{R_\square}$**
- This formula is valid for thin layer metal layers in the nm range
- This formula is in depended on the type of LowE. Oxide layers in-between metal layers affect the optical performance not the emissivity
- This formula requires that the top side encapsulation is thinner than 200 nm which is typically true

Customized Tempering Processes

Materials

- Metal coatings (LowE-Ag)

Process Characterization

- Tempering

Setups

- Portable
- Inline fix sensor
- QA traversing system

Measurements

- Emissivity / Sheet resistanace

Customized Tempering Processes

- Tempering processes significantly change the emissivity
- Different types of LowE react differently towards tempering
- Tempering effect can be used to
  - Assess tempering homogeneity
  - Optimization of silver thickness considering tempering performance or even adapting tempering performance (idea)

	Glass 1		Glass 2	
	A	B	D	C
	non-tempered	Tempered	non-tempered	tempered
Segment 1	0.023	0.009	0.039	0.024
Segment 2	0.018	0.016	0.033	0.018
Segment 3	0.019	0.019	0.048	0.037
Segment 4	0.022	0.015	0.051	0.030
average	0.021	0.015	0.043	0.027
TNO	0.021	0.015	0.040	0.022
SRUAGUS				
TF Portable Ohm/sq	1.81	1.40	3.74	1.90
Emissivity TF portable	0.019	0.015	0.039	0.020

Mirror coatings

Materials

- Metals (Ag, Cu, Al + combinations)

Process Characterization

- Deposition

Environment

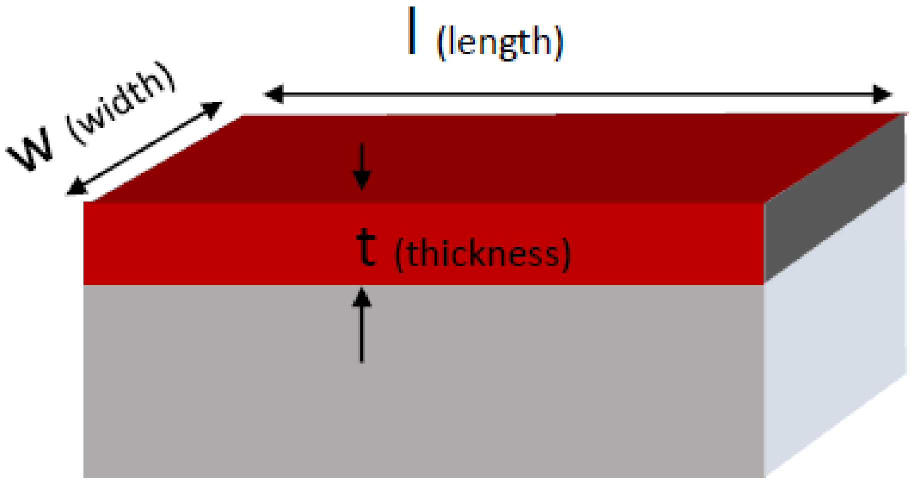
- In-vacuo and ex-vacuo solutions

Setups

- Inline
- QA traversing system

Measurements

- Thickness, metal area weight



Sheet resistance $R_{\square}$ or R_S is derived by assuming that the film width equals the film length (w = l)

$$R = \frac{\rho}{t} \cdot \frac{l}{w} \equiv R_S \frac{l}{w}$$

The unit of R is Ω
The unit of R_S is Ω (Ω/□ is typically used in order to distinguish between resistance)

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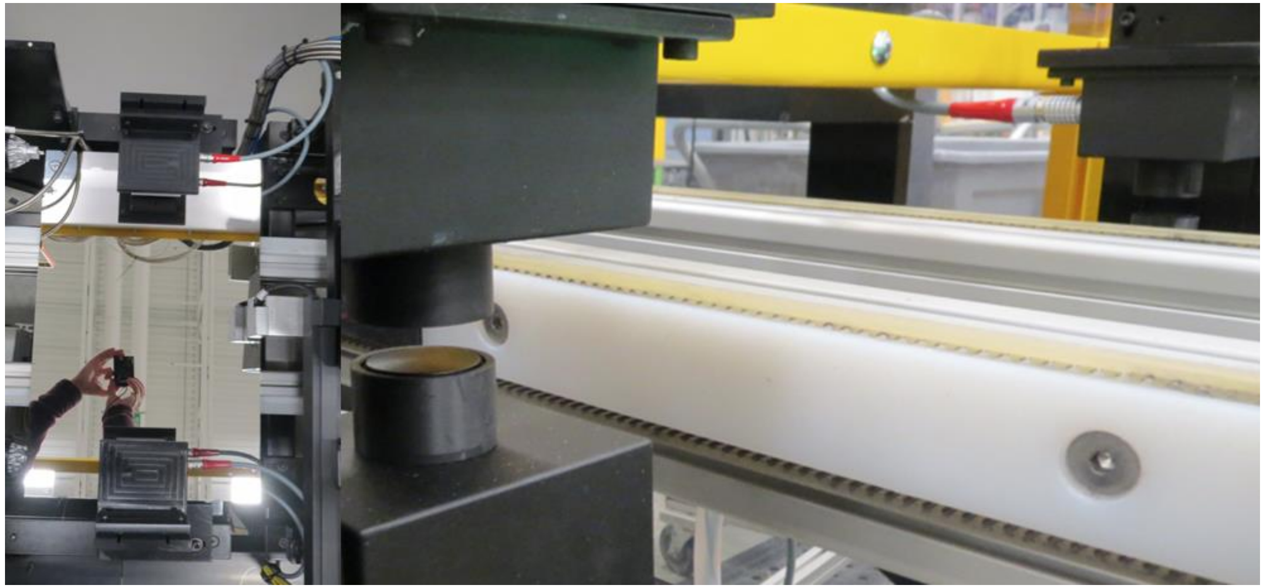


Automotive Glass Testing

- Deicing
- LowE
- Hidden layer testing

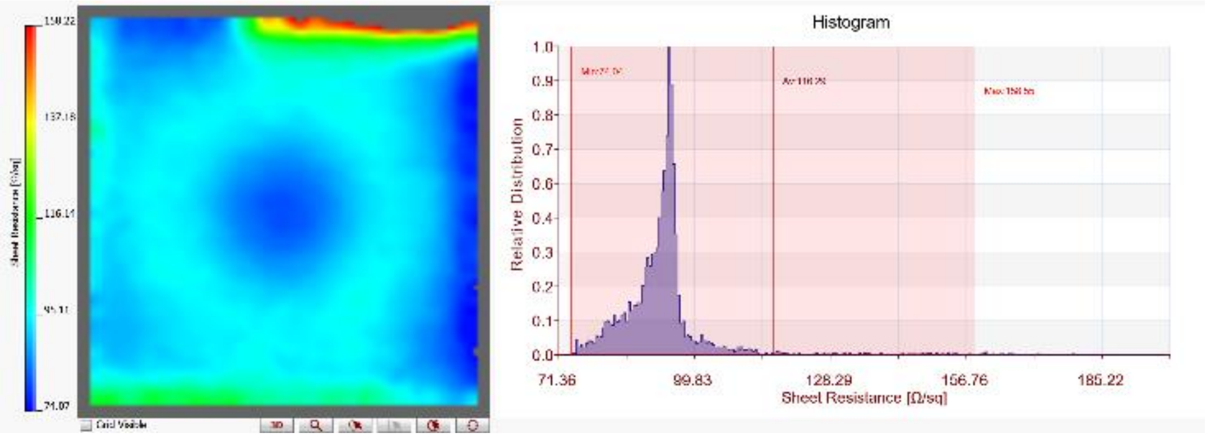
Electrode Characterization, e.g. Smart Glass or Solar Glass

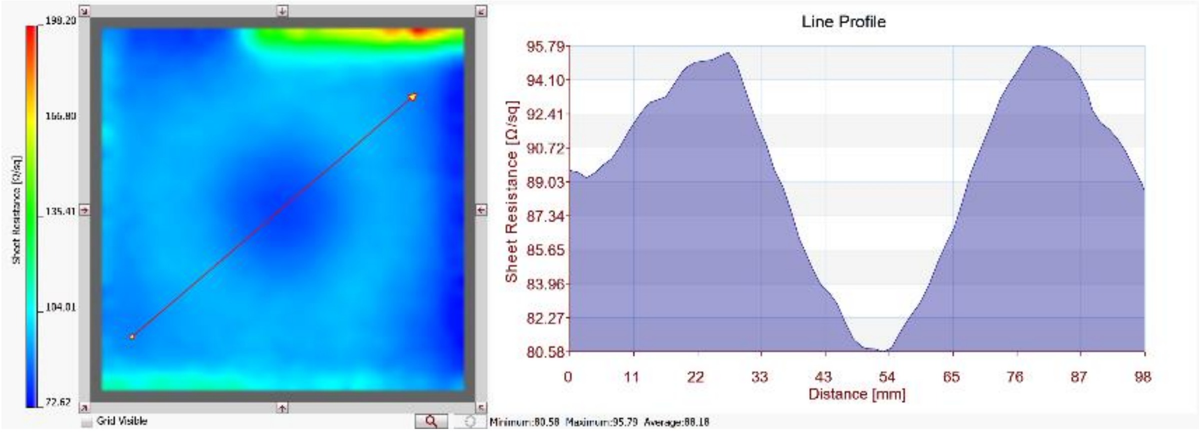
Processes

- Depositing
- Doping
- Annealing

Aim

- Homogenous electrode function
- Meeting sweet spot transparency and sheet resistance





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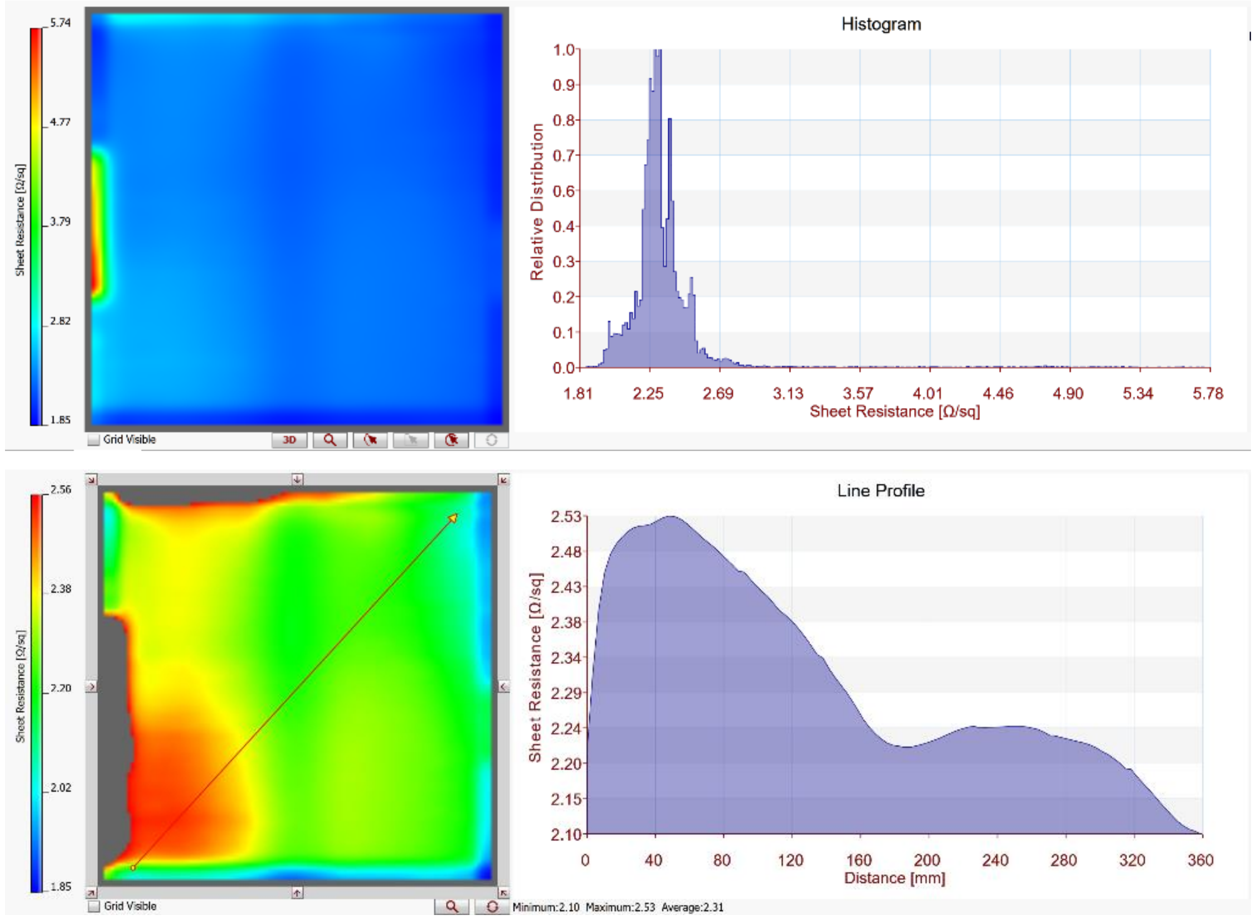

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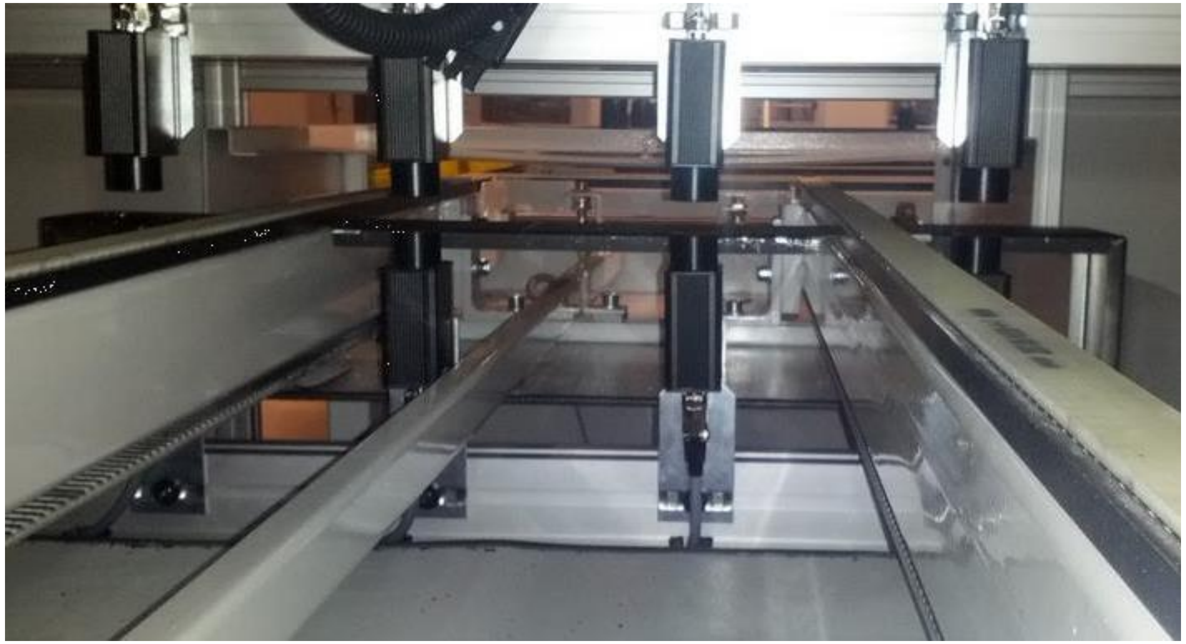

SURAGUS inline testing installation at solar manufacturer, Germany

Summary

- Conductive coatings matter in glass industry
  - Architectural glass with LowE coatings – emissivity testing
  - Mirrors – thickness / reflection testing
  - Solar & smart glass – sheet resistance testing
- Eddy Current Testing is **Non-contact, High Speed and Enables High Resolution Solutions**
- Eddy Current Testing Enables **Inline, Imaging, Single Point and Portable Testing**
- Measurements for **Deposition & Tempering Processes + Final Inspection**
- Measurement Characteristic are **Sheet Resistance, Emissivity and Layer Thickness**
- Insights and **Benefits** in Characterization of LowE, Mirror and Transparent Electrode Layers
  - Emissivity testing and Process Control for LowE coatings
  - Optimizing tempering processes
  - Ensuring the electrical coverage and performance of transparent electrodes for smart glass and deicing application
  - Measurement of hidden conductive layers for automotive glass application

Thank you for your attention!

For questions and requests please feel free to contact us…or see us at SURAGUS booth

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