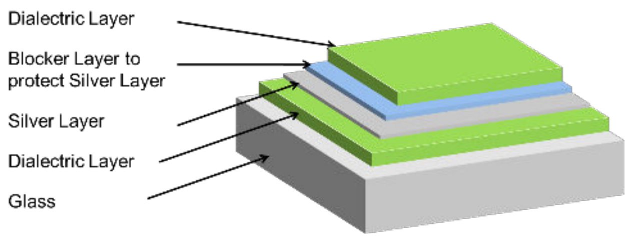
LOW-E GLASS

What is measured

Delcom sheet resistance meters are most often used to measure the active layer of Low-E glass. This includes both metal coatings such as Silver (Au) and Gold (Ag) and semiconductive coatings such as Indium Tin Oxide (ITO) and Fluorine-doped tin oxide (FTO).

Figure 1: Possible Low E Glass cross-section



Delcom sensors are used extensively in the Low-E industry because sheet resistance approximates emissivity.

Assuming wavelengths more than 3 micrometers (i.e $\lambda > 3$ µm) and a sufficiently low sheet resistance, we can say that normal emissivity approximates four times sheet resistance divided by the impedance of vacuum.

Figure 2: Equation for emissivity

$$\varepsilon_n \approx \alpha_{n,IR} = 1 - \rho_{n,IR} = 4 * \frac{R_\square}{Z_0}$$

Knowing that the impedance of vacuum is 377 Ohms, the formula can be further simplified resulting in the statement that emissivity approximates 0.0106 times sheet resistance.

Figure 3: Equation for emissivity as a function of sheet resistance

$$\varepsilon_n \approx 0.0106 * R_\square$$

Of course, each researcher/production manager has their own constant that they are comfortable with. Delcom software allows for users to designate their own constant and observe readings on the Delcom meter in units of emissivity.

Why measure with Delcom

It is important to note that because eddy current meters rely on a magnetic field to achieve their reading, they have a number of advantages over four-point probes to include:

- Reliably approximates emissivity
- Is non-destructive
- Reads through insulating layers
- Measures moving material
- Provides nearly instantaneous readings
- Provides real-time process inspection

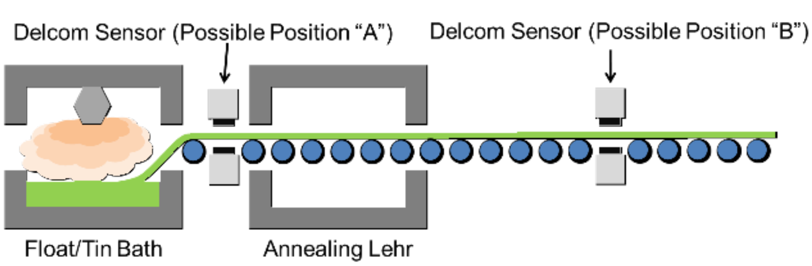
Employment strategies

Low-E glass manufacturing faces a number of challenges to include:

- Problems caused by curing, annealing, temperature change, and other processes changing the sheet resistance over the course of production that needs to be carefully monitored
- Cross-web consistency born of using multiple targets or other segmented deposition techniques

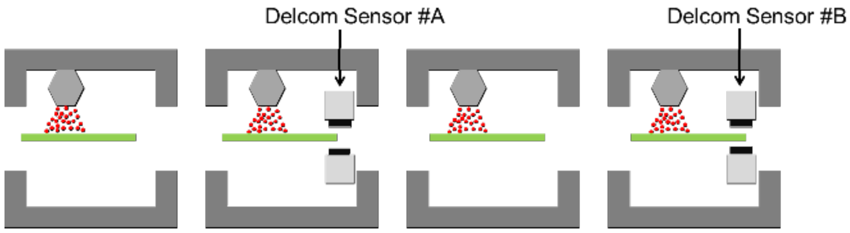
For those customers manufacturing Passive Low-E glass, a hard coat pyrolytic process of applying a tin oxide or silver layer (Chemical Vapor Deposition when performed in vacuum) is employed. In such a process, a Delcom sensor can be deployed before or after annealing. Regardless of placement, efforts must be made to shield the sensor from the high radiant heat of the glass and equipment. In addition to shielding, the cooling line option might be needed to ensure the Delcom sensor does not overheat.

Figure 4: Possible sensor locations for hard coating process



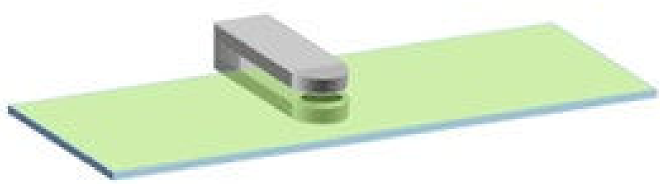
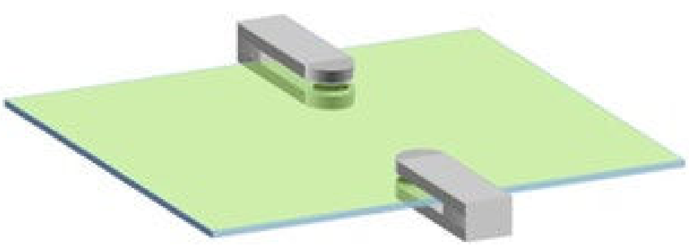
For those producing solar control Low-e and passive Low-E glass, an off-line soft coating process is often used. This process occurs after the glass ribbon has been cut into stock sheets, occurs at room temperature under vacuum, and employes Magnetron Sputter Vacuum Deposition (MSVD) to apply a thin transparent coating of tin oxide or silver. If a Soft Coat manufacturing process is being employed, any Delcom vacuum-ready sensor can be employed in nearly any location.

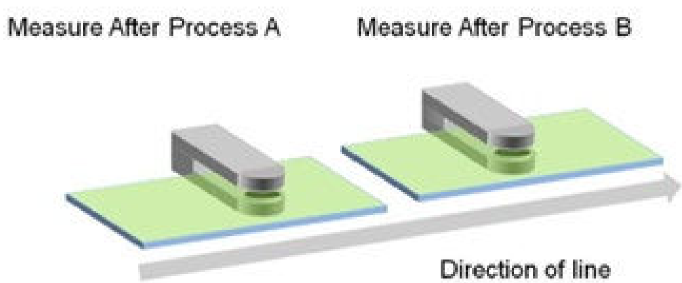
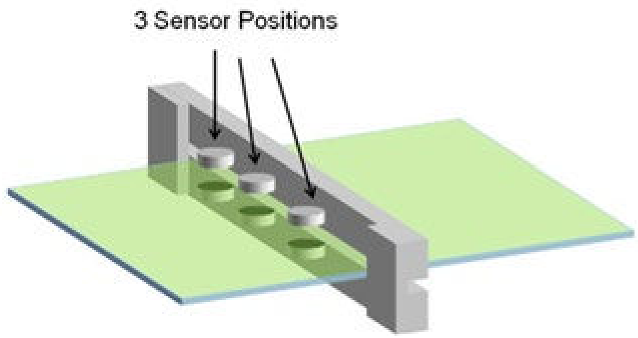
Figure 5: In-situ monitoring for a soft coating process (including possible positions for Delcom Sensors):



Cross-web & downstream monitoring

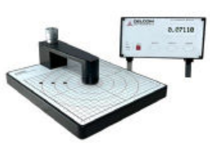
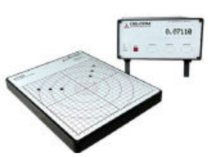
In general, Delcom sensor deployment strategies can include one or more of the following deployment tactics.

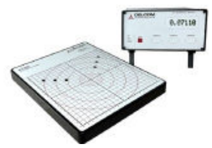
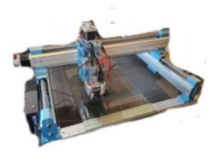
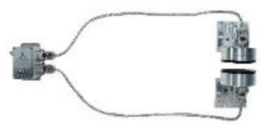
Deployment Strategy	Image	Advantages
Single sensor single spot		• Most cost-effective option on the market • One single fixed-point • Achieve instantaneous process feedback
Two sensors monitoring cross-web		• Monitor cross-web uniformity

Two sensors monitoring downstream		• Monitor downstream consistency
Multi-channel monitoring cross-web		• Monitor cross-web uniformity • Movable sensor positions • Add sensor positions at a later time

Recommended sensors

Delcom recommends the following sensors based on the user's material, stage of development, and application.

Use case	Image	Recommended Sensor	Use case
Benchtop		RD200	• For material up to 12 mm thick • For materials up to 200 mm x 200 mm
Benchtop		RS200	• For material more than 12 mm thick • For materials up to 200 mm x 200 mm
Benchtop		RD450	• For material up to 12 mm thick • For materials up to 450 mm x 450 mm

Benchtop		RS450	• For material more than 12 mm thick • For materials up to 450 mm x 450 mm
Benchtop		RM400	• Automatic mapping • For material up to 400 mm x 400 mm
Inline		30C9	• Most cost-effective inline solution • 300 mm reach and 9 mm gap
Inline		OEM	• Variable position, gap, and spot size • Customer decides where and how to mount
Inline		Inline	• Monitor cross-web uniformity • Variable position, gap, and spot size • Add channels anytime

Recommended sensor range

Delcom sensors measure sheet resistance in Ohms/square, therefore ranges of our instruments stated in terms of emissivity require multiplication by the user's preferred constant. Below are Delcom sensor ranges restated in units of emissivity assuming a constant of 0.0106.

Figure 6: Delcom sensors are available in the following ranges

Range Name	Min Sheet Resistance in ohms/square	Max Sheet Resistance in ohms/square	Min Emissivity	Max Emissivity
x10	5	100000	0.053	1060
x1	0.5	10000	0.0053	106
÷10	0.05	1000	0.00053	10.6
÷100	0.005	100	0.000053	1.06

Low E Glass products typically have a target sheet resistance of between 1 and 8 ohms/square. Therefore, the recommended instrument range for this application is "x1".