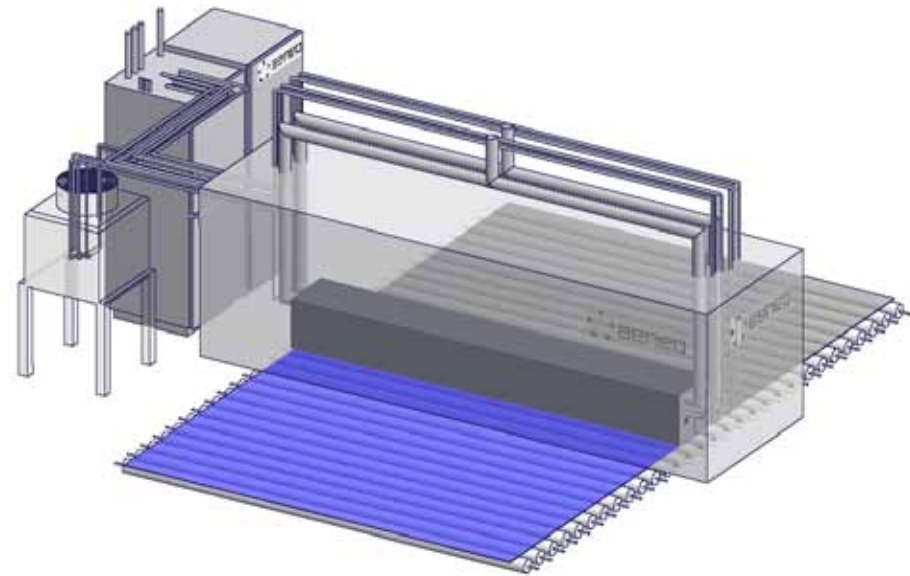


BENEQ

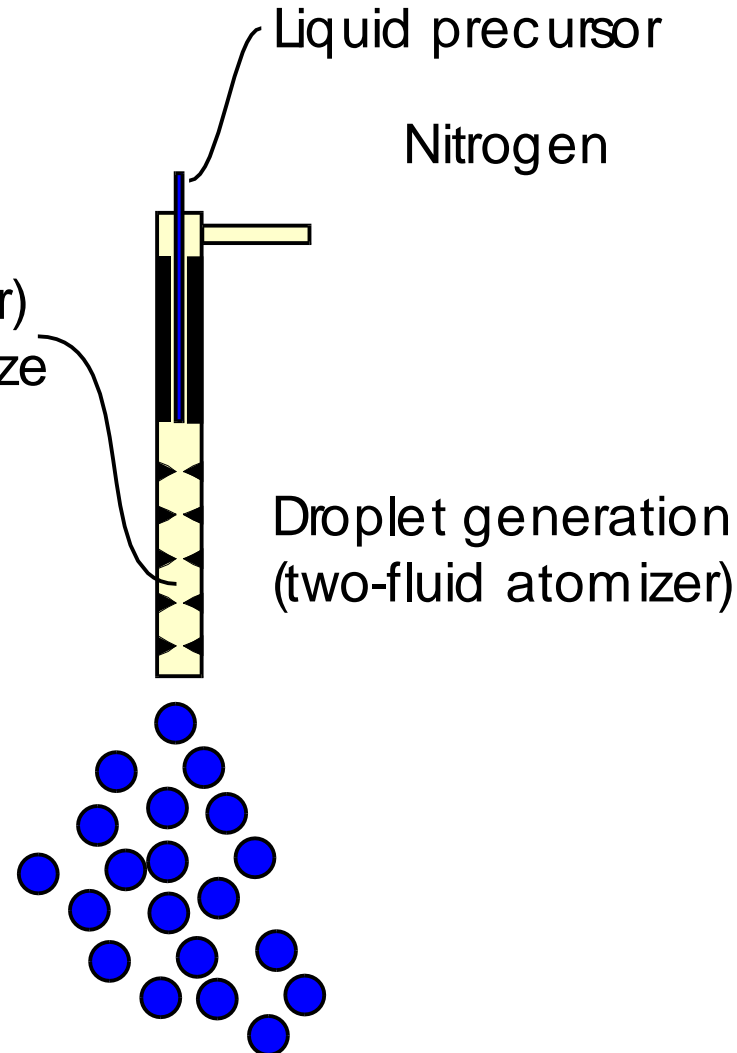
nAERO™

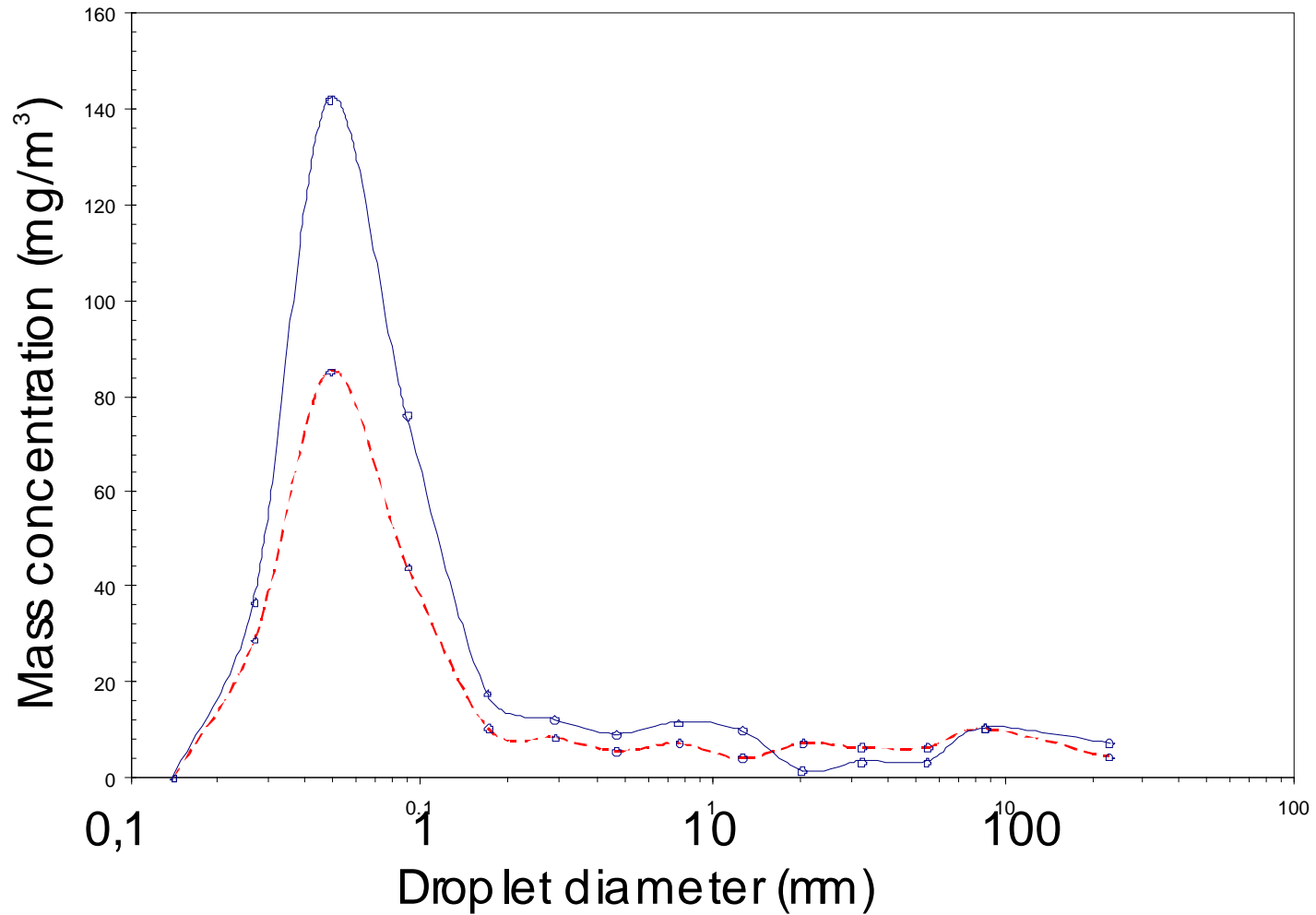
Turning Innovations into Success

- Developed for off- and on-line production of advanced coatings on glass.
- Deposition temperature 400 – 1000 ° C, typically 550 – 610 ° C.
- High coating growth rate.
- Based on the deposition of ultrafine droplets in a controlled atmosphere.
- Ultrafine = mean droplet diameter smaller than 1 micrometer.



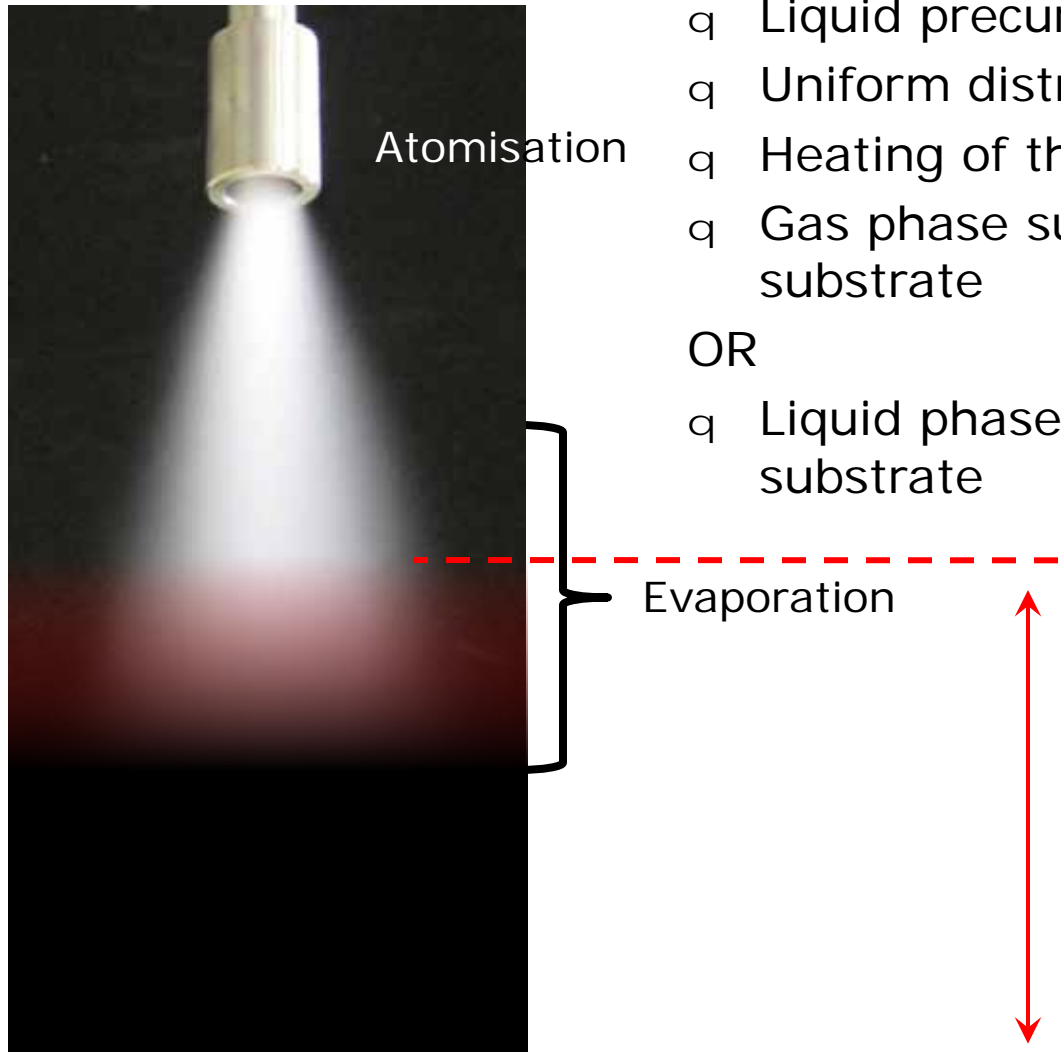
Droplet modification
(choked-flow atomizer)
- decreases droplet size
- narrows droplet size
distribution





Property	0,5 μm droplet	100 μm droplet (mist)
Mean thermal velocity [cm/s]	5	0,0004
Gravitational settling velocity at 1 atm [cm/s]	0.0001	25
Evaporation time [s, water, 100% RH]	0.01	>1000
Speed for impaction [m/s]	100	<1
Specific surface area [water, cm^2/g]	40,000	50

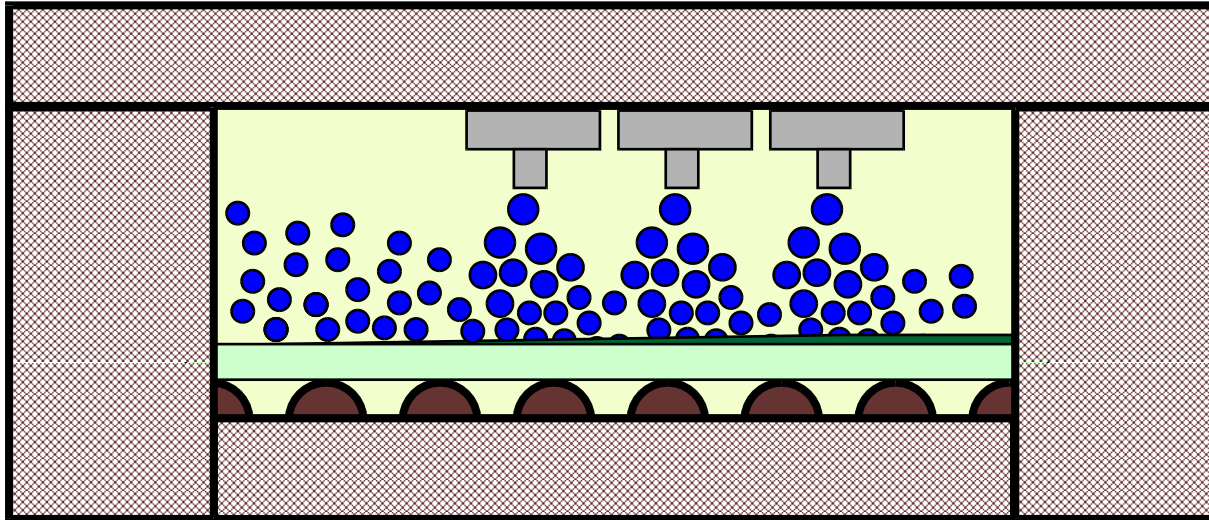
William C. Hinds, Aerosol Technology – Properties, Behavior; and Measurement of Airborne Particles, 2.ed., John Wiley&Sons, Inc., New York, 1999



- q Liquid precursor + atomisation gas
- q Uniform distribution of the aerosol
- q Heating of the aerosol
- q Gas phase surface reaction on the substrate

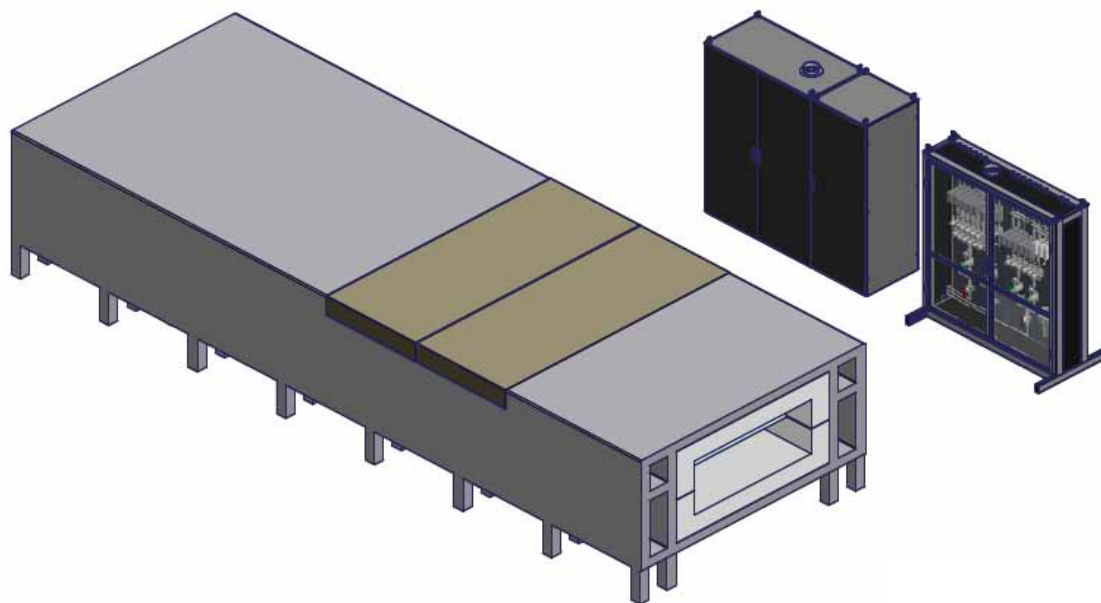
OR

- q Liquid phase surface reaction on the substrate



- Droplet residence time short due to small droplet size
- Both impaction and diffusion generate deposition – high growth rate
- Controlled oxygen-deficient atmosphere – non-stoichiometric coatings

Precursor materials	Mono-butyl-tin-chloride (MBTC) Trifluoroacetic acid (TFA) Methyl alcohol (MeOH)
Precursor composition (wt-%)	MBTC : TFA : MeOH 50 : 25 : 25
Precursor feed rate	50 – 150 ml/m ²
Atomizing gas feed rate	0.5 – 2 Nm ³ /m ²
Glass temperature	550 – 610 °C



INPUT

- MBTC, TFA, MeOH
- N₂, O₂, H₂O

OUTPUT

- HCl, Cl₂, HF, H₂O, CO₂, N₂

Gas scrubber is required to neutralize the process products

INPUT under layer

- SiH_4 , C_2H_4 , CO_2
- N_2

INPUT Low-e / TCO

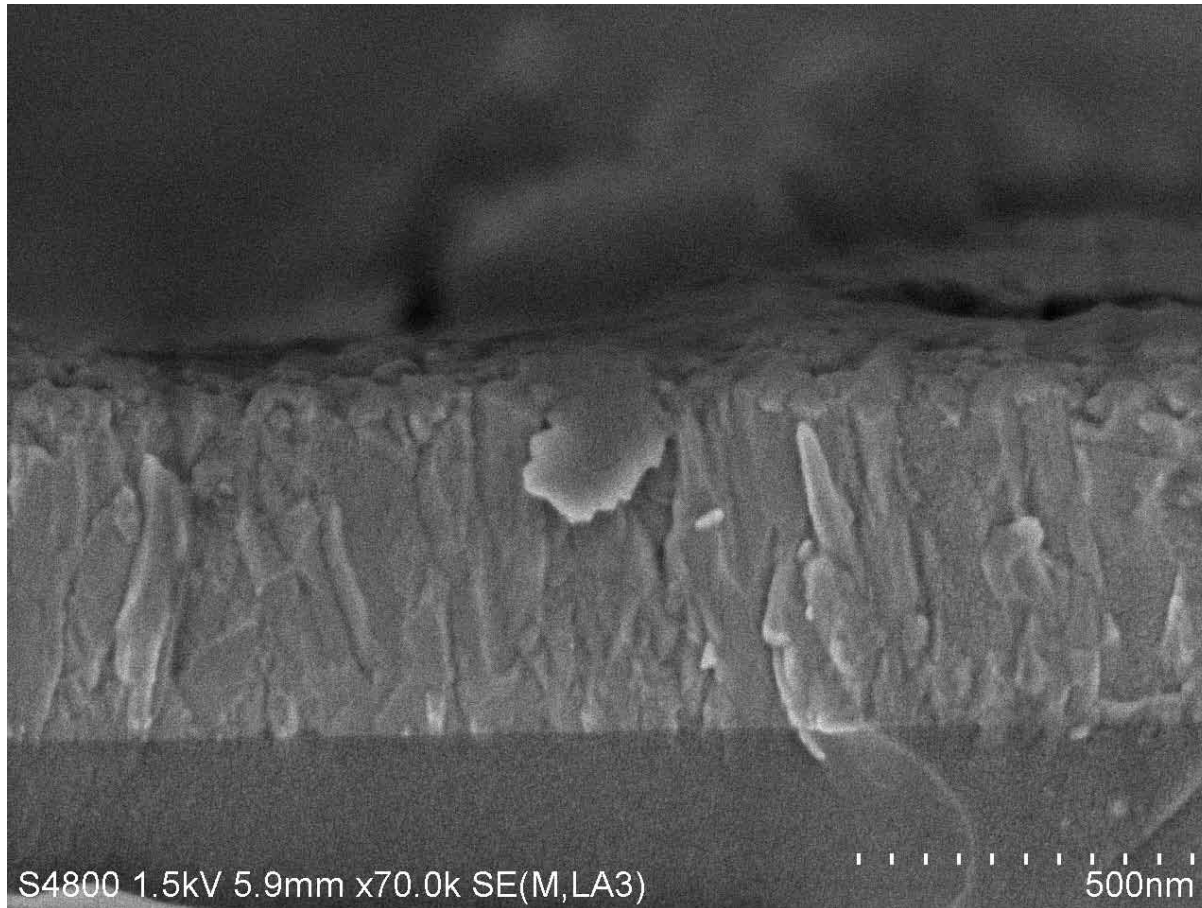
- MBTC, TFA, MeOH
- N_2 , O_2 , H_2O

q SiO_x under layer

- ü Thickness 70 nm
- ü Refractive index $n = 1.7-1.8$
- ü Suppresses colour interference in reflected light
- ü Serves as Na diffusion-blocking interlayer

q Low-e / TCO coating

- ü SnO_2/F
- ü Thickness 320 -500 nm
- ü Refractive index $n = 2$
- ü Emissivity 0.1 - 0.15
- ü Sheet resistance 0.08 - 15 $\Omega/$



SEM image of a $\text{SnO}_2:\text{F}$ layer made with nAERO™.

Emissivity measurement	Mk3 Emissiometer (Optical Sensors, Sweden)
Square resistance measurement	Keithley 2400 General Purpose SourceMeter with Alessi CPS-05 contact probe station
Measured emissivity []	0.09 – 0.17
Measured sheet resistance [W/ŷ]	7 – 15
Measured haze [%]	< 0.5 (low-e) 10-20 (TCO)
Measured Transimission T visible [%] T solar [%]	> 80 > 67

- § Beneq proprietary aerosol coating process is similar to conventional CVD coating process but offers several benefits:
- √ Beneq nAERO low-e coating is a pyrolytic SnO₂/F hard coating like in CVD
 - √ nAERO coating can be done between tin bath and lehr
 - Ø Easy access, easy maintenance
 - Ø Independent module, no risk to tin bath
 - Ø Lower investment level
 - √ Liquid raw materials are used directly in the process chamber
 - Ø No need to complex evaporation and gas distribution lines
 - Ø No condensation problems in the vapour lines
 - Ø Homogeneous material distribution due to true liquid solution, no need for mixing of gases and vapours

- § Beneq proprietary nAERO vs conventional CVD :
 - ✓ Fast process
 - Ø Low carrier gas consumption
 - ✓ Economical
 - Ø High efficiency process due to high growth rate

- § Beneq proprietary nAERO vs conventional vacuum sputtering :
 - ✓ Sputtering is always off-line process
 - ✓ Soft coating vs pyrolytic hard coating with nAERO
 - Ø Soft coating is sensitive to handling
 - Ø Soft coating is sensitive to humidity → shelf life issue
 - ✓ Sputtering requires high investment level
 - ✓ Sputtering offers still superior quality low-e glass

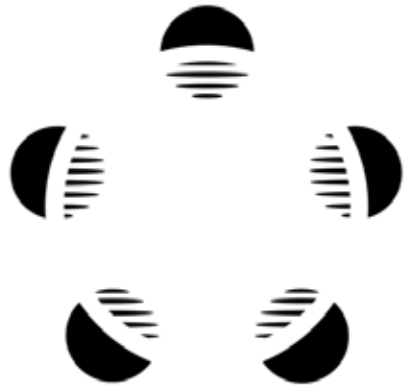
- **FCS 4000F, FCS 2000** - glass coating system for float glass and off-line applications
- Material, SnO₂:F
- < 15ohms/square at about 500 nm
- About 80% transmission
- Haze e.g. 10%, haze can be controlled for up to 20%
- FCS 2000 off-line, throughput up to 5m/min
- Coating cost competitive with atmospheric pressure CVD based TCO
- Proprietary and patented by Beneq



FSC 2000 off-line system
(1.4 m wide line)

Other nAERO Applications

- § nCLEAN - self cleaning surfaces
- § AR coating



BENEQ

*Equipment and Technology
for
Functional Surfaces*

Thank You!