Solar Selective Absorber

Coating Methods – Plasma Processes

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Selective Absorber

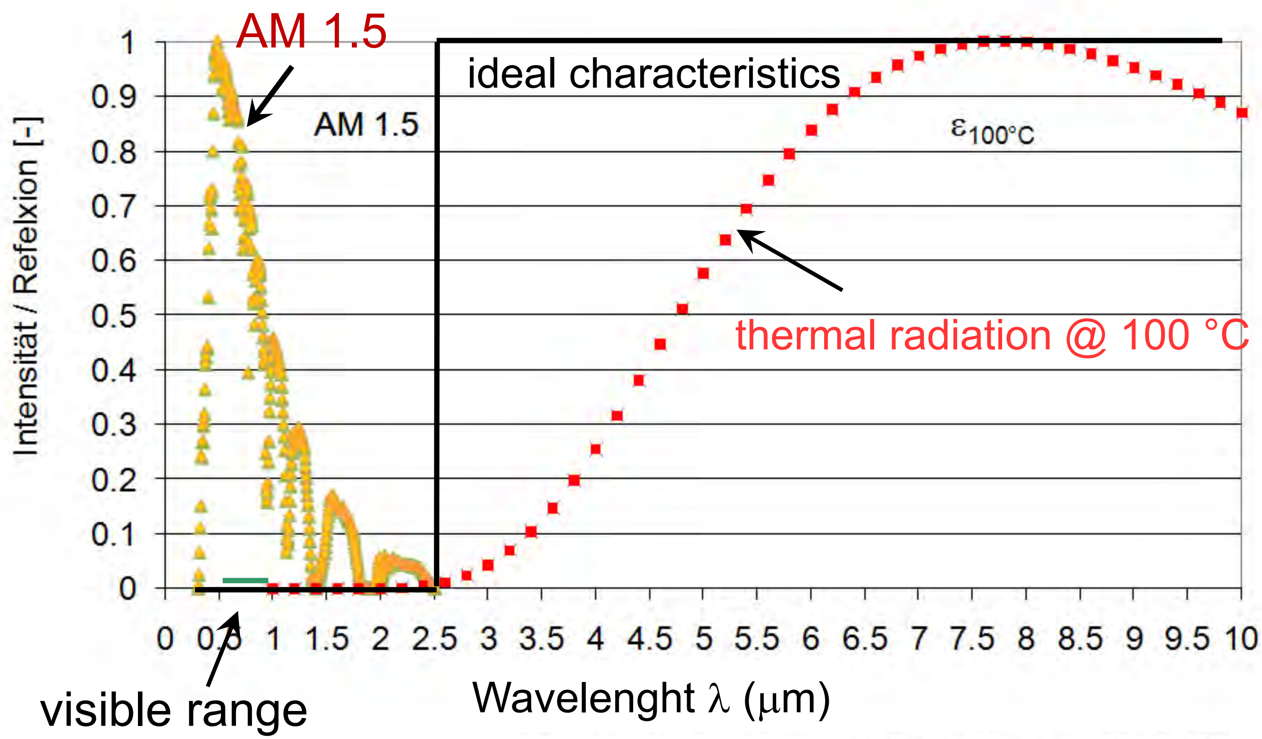
- **Optical properties of a selective absorber**

Optical properties of solar selective absorbers $\left(\underline{\alpha_{AM1.5}} / \underline{\varepsilon_{T°C}}\right)$

Wien's displacement law:

$$\lambda_{\max} = \frac{2897{,}8\,\mu\mathrm{m}\cdot\mathrm{K}}{T}$$

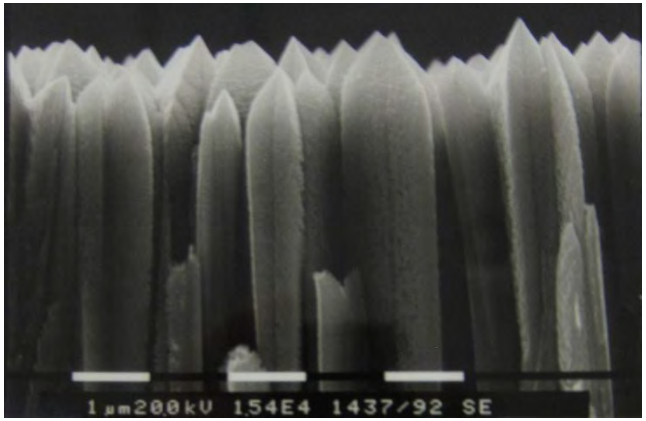
Temperature T (°C)	Wavelength λ_{max} (µm)
200	6.1
250	5.55
300	5.05
500	3.75
600	3.33



Thermodynamics: 2. Law $\quad \varepsilon(\lambda, T) = \alpha(\lambda, T)$

- **Design types of selective absorber**

  - Intrinsic selective material
  - Surface texture / geometrical structure
  - Semiconductor-Metal Combination
  - Multilayers
  - Metal-Dielectric
  - Solar-transmitting / Blackbody-like

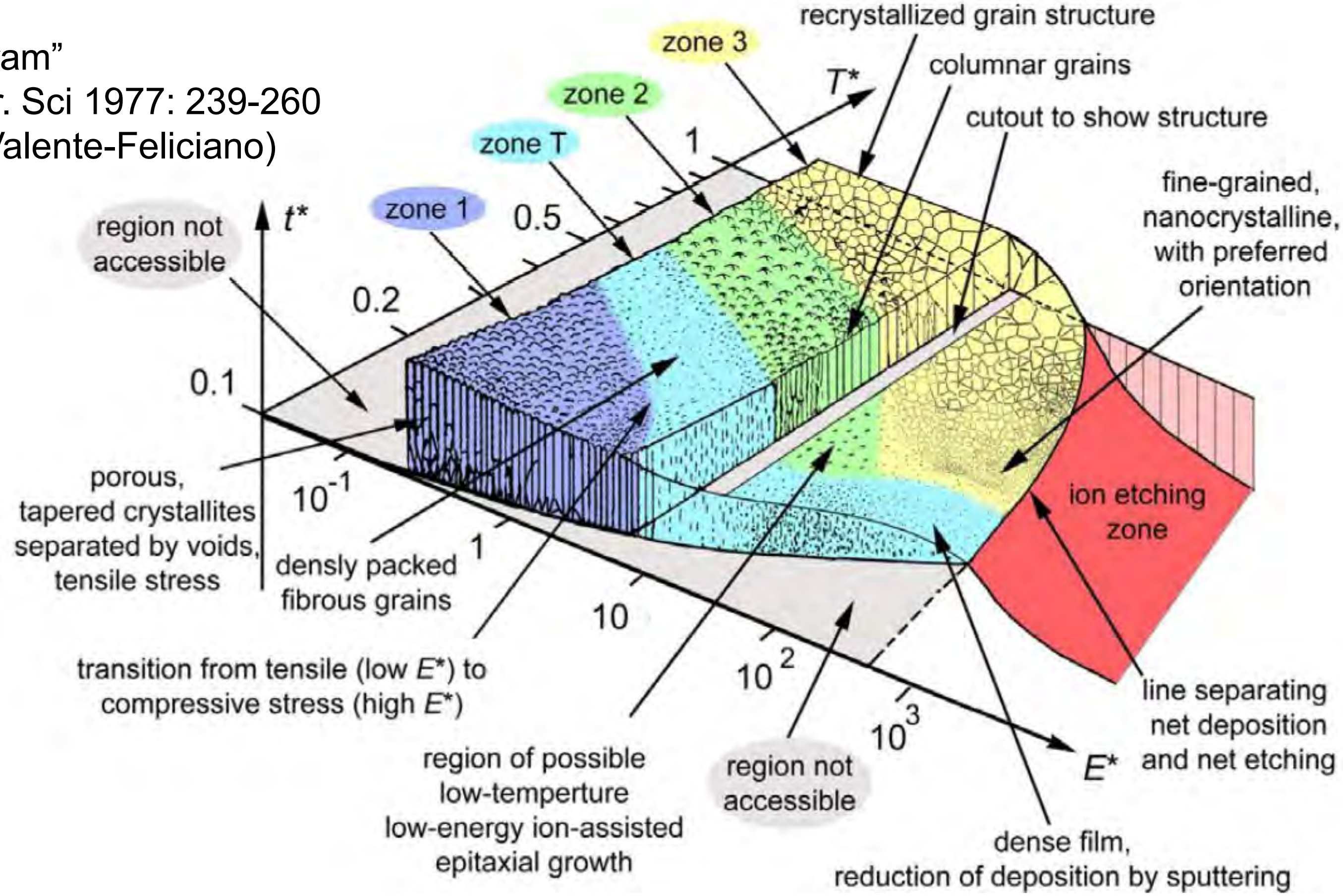


Nb on Si

Structural absorber with transition wavelength λ = 1 μm

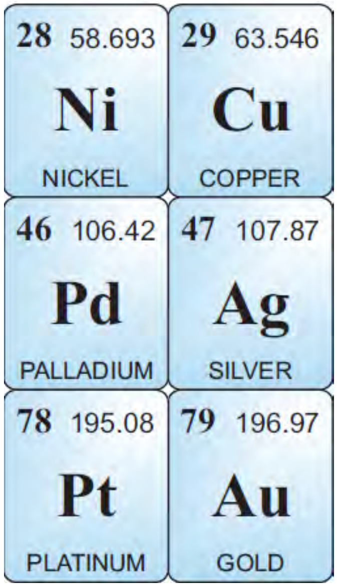
Structural absorber - morphology

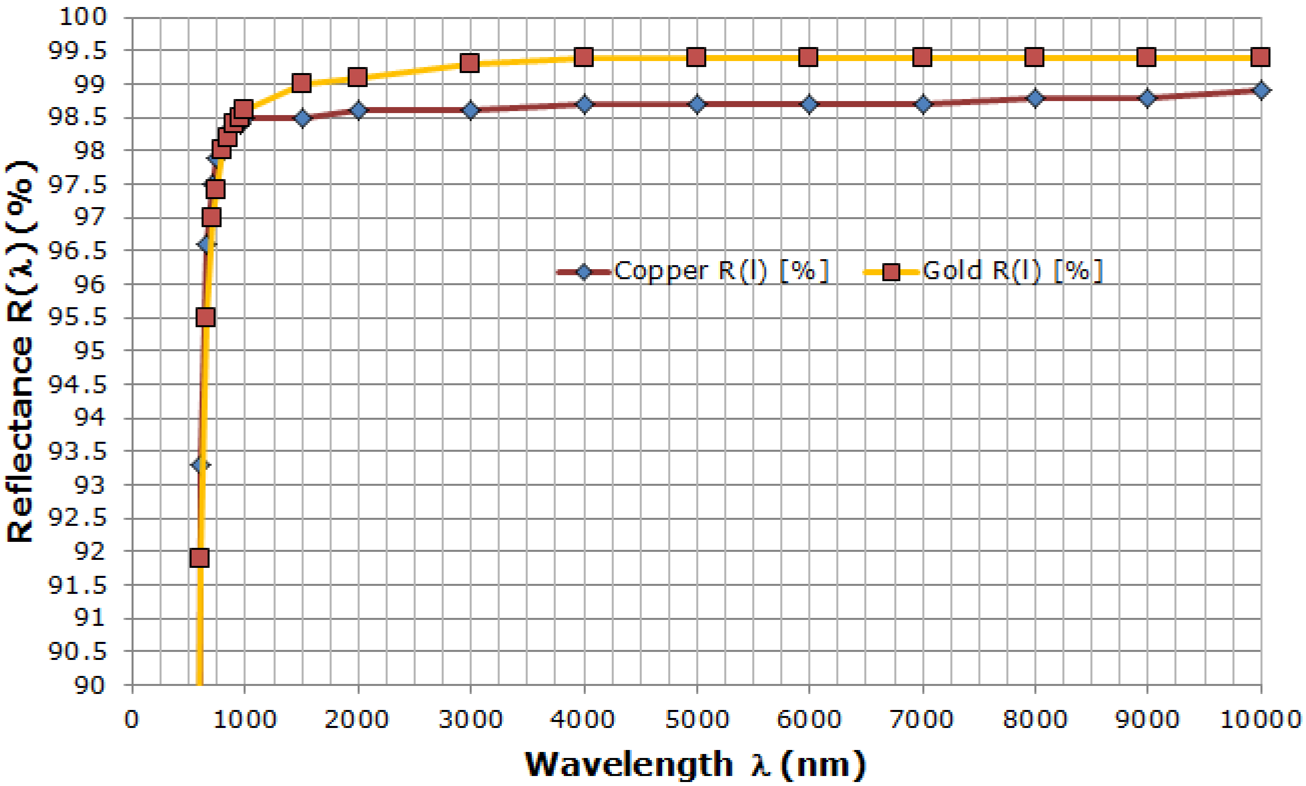
"Thronton-Diagram"
Ann. Rev. Mater. Sci 1977: 239-260
(Graph: A. -M. Valente-Feliciano)



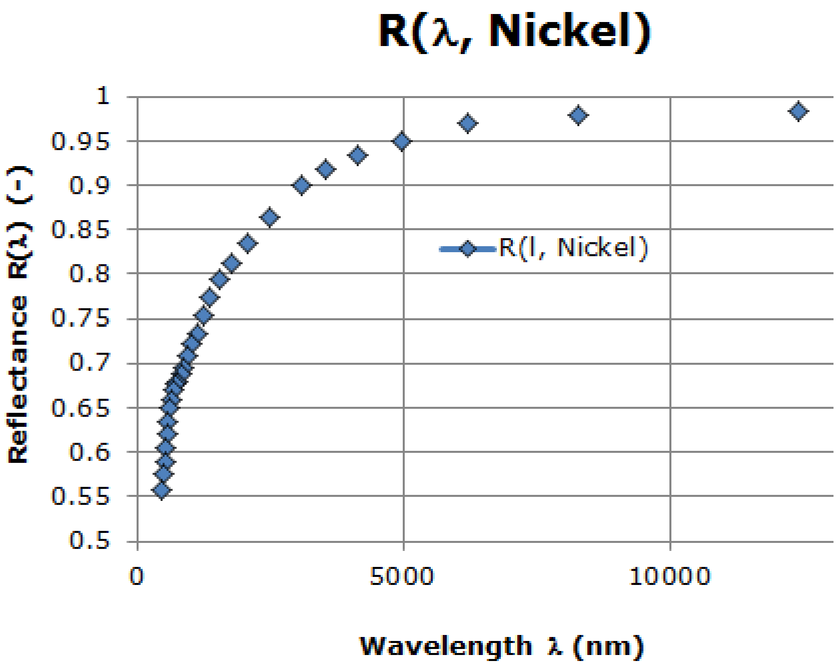
"Physical (parameters) processes establishing structural zones" – film morphology.

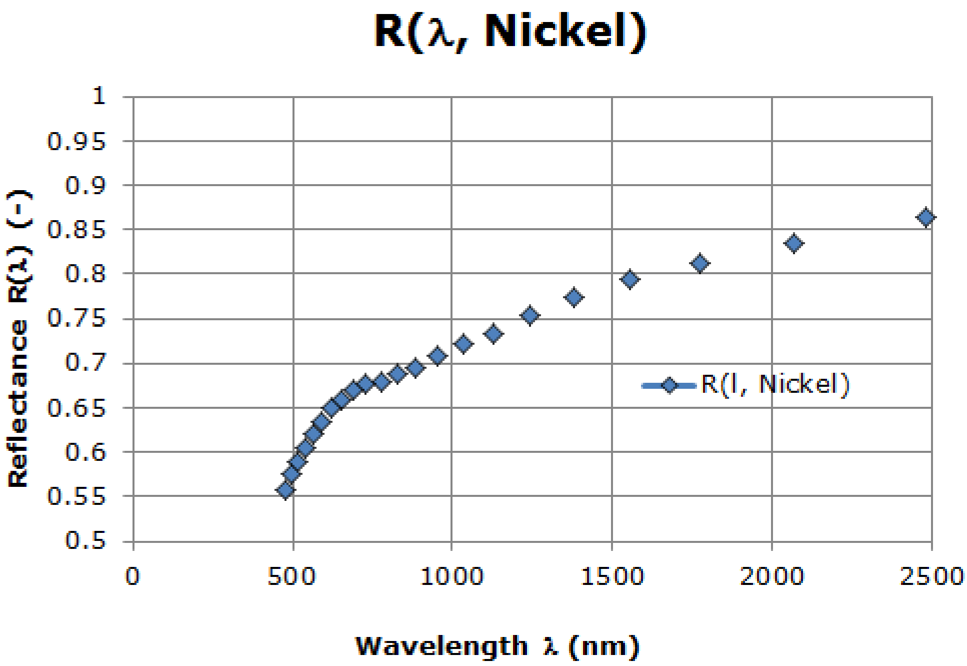
- **Substrates for "combined" absorbers**



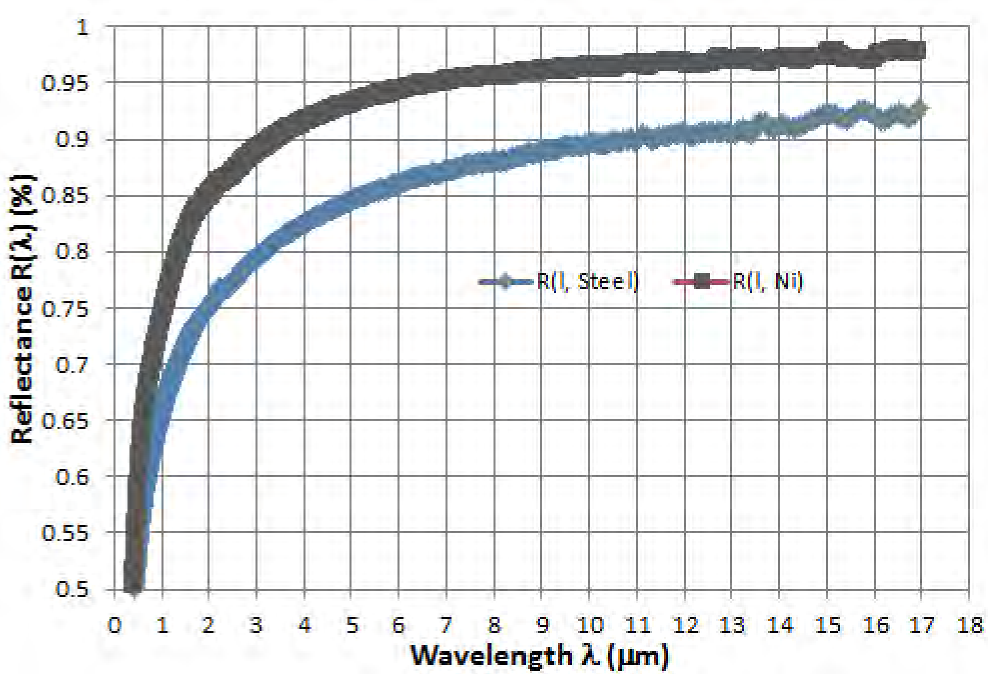


- **Substrates for "combined" absorber tubes**

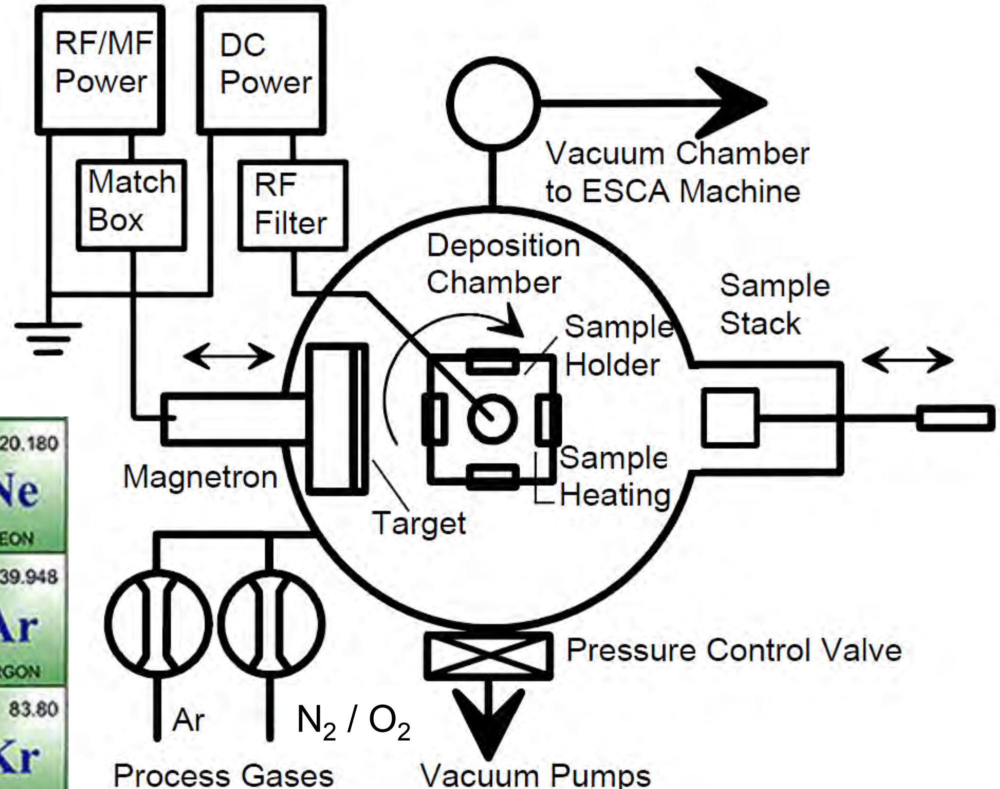


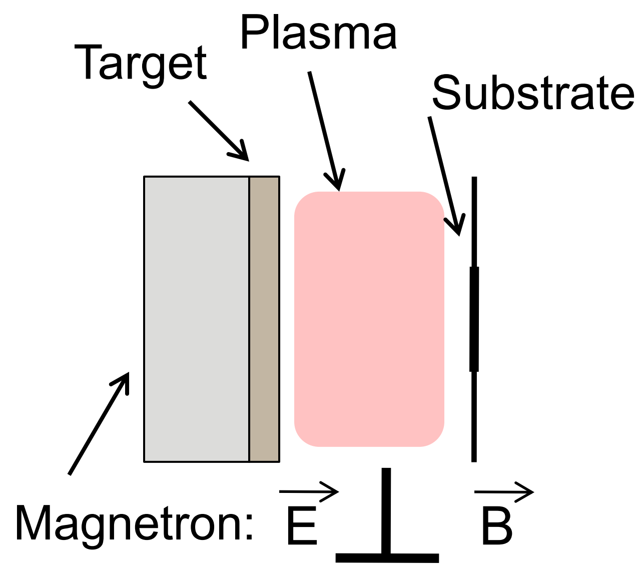


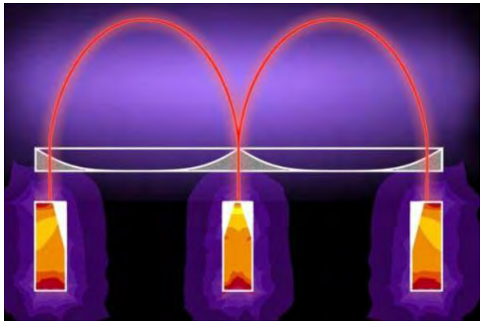
- **Substrates for “combined” absorber tubes**



- **Plasma process for absorber preparation**







www.angstromsciences.com

<u>Reactive Magnetron Sputtering</u>

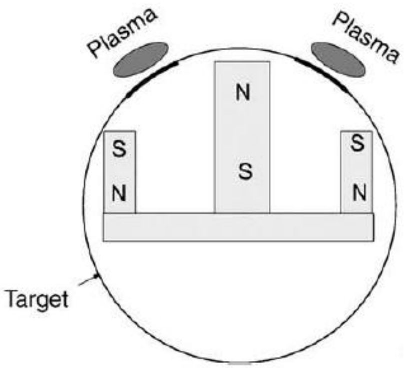
Target Materials: Cr, W, Ti, … Ag, Au, …Nitrides …)

Process Gases: noble gases / reactive gases

Selective Absorber

- **Plasma Process Technology Components**

  Magnetron Technology – planar / circular



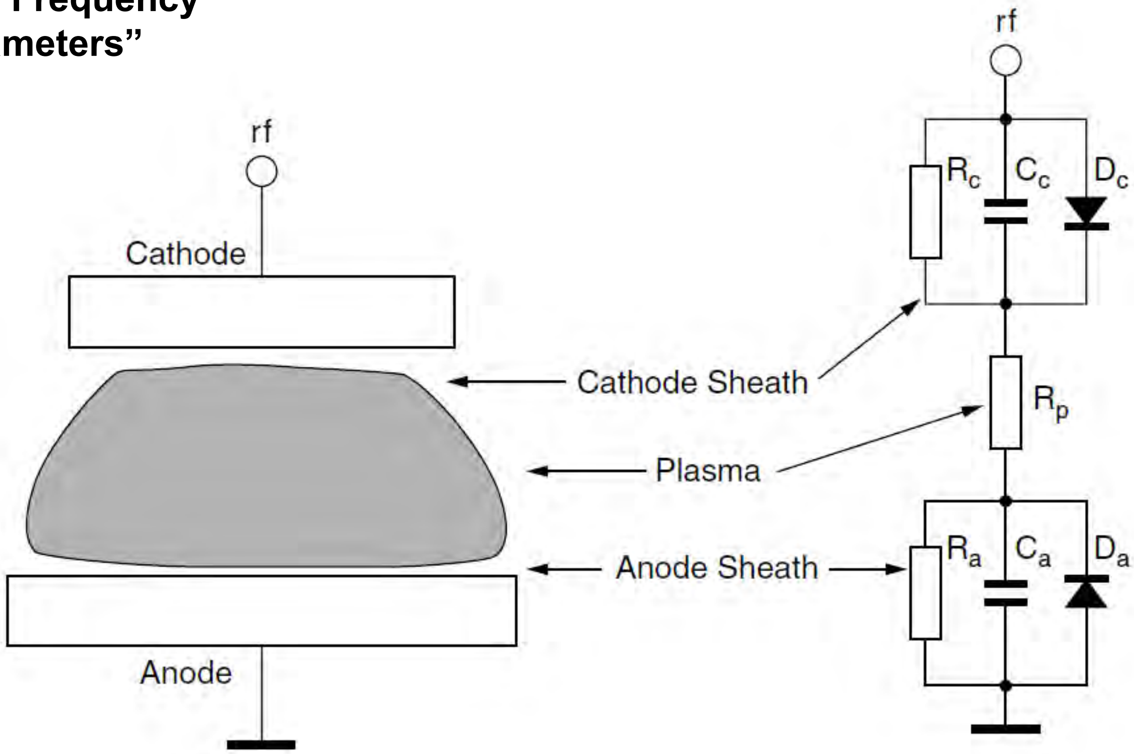
D. Depla et al.
Plasma Deposition Processes

http://www.vonardenne.biz

Magnetron Technology:
- **http://www.vonardenne.biz**
- **http://www.angstromsciences.com**

Coating Methods - RF excitation system

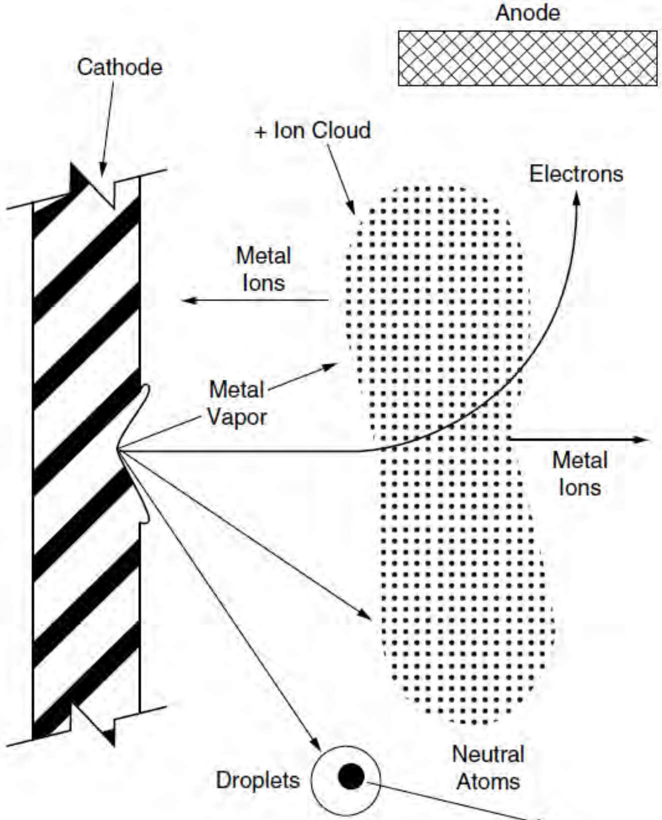
Plasma Ignition Frequency
Electrical “Parameters”



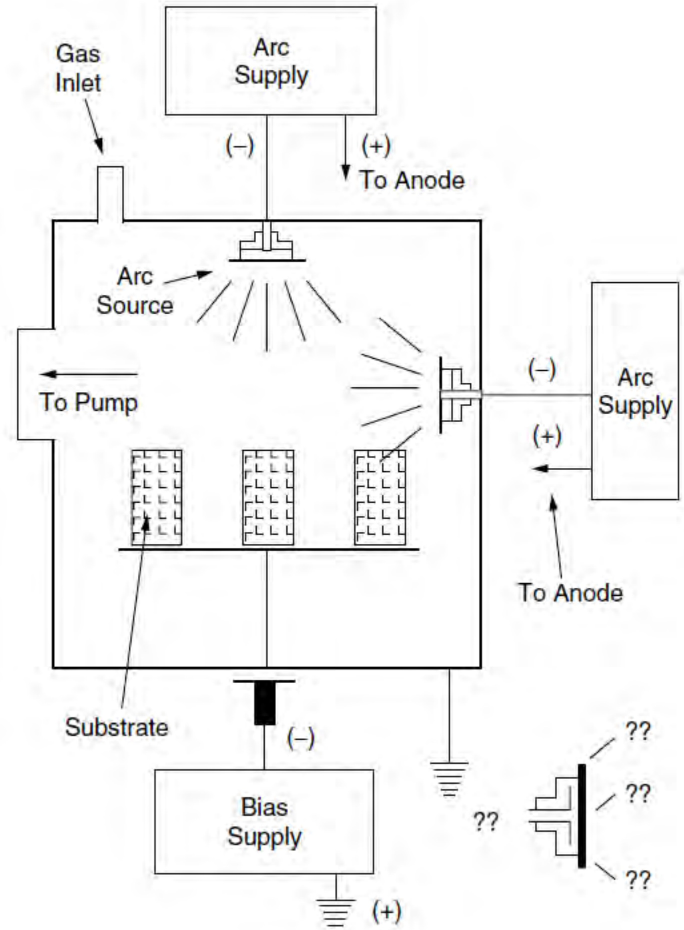
Lindas Pranevicius **- Coating Technology Handbook**

- **Coating Methods**

  Ion Energy / Sputter Yield
  eV to K: 1eV~1.16*e4K



Emission characteristics of a cathodic arc source.



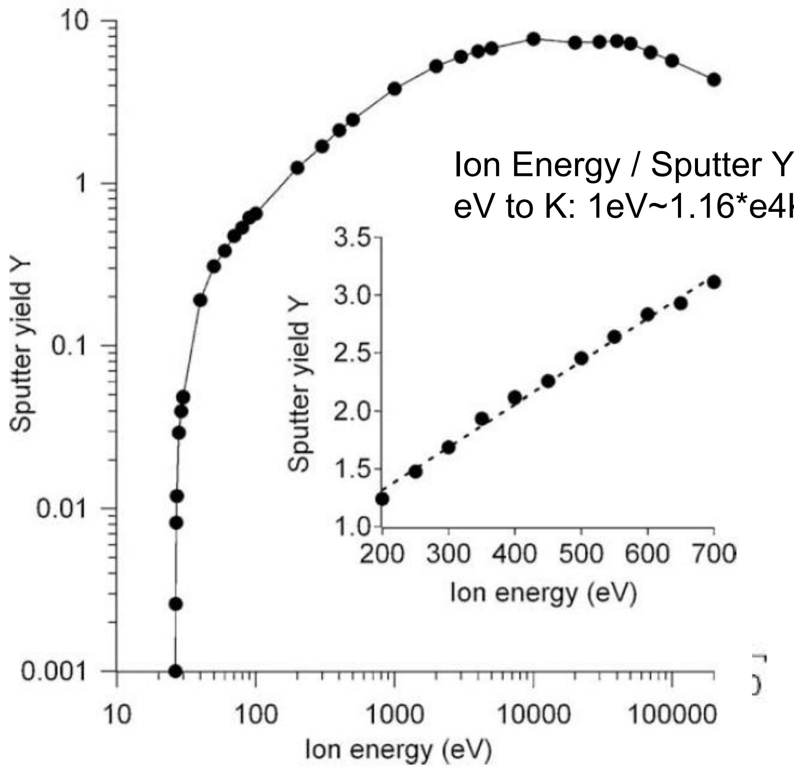
Schematic of a cathodic arc deposition system.

H. Randhawa - Coating Technology Handbook

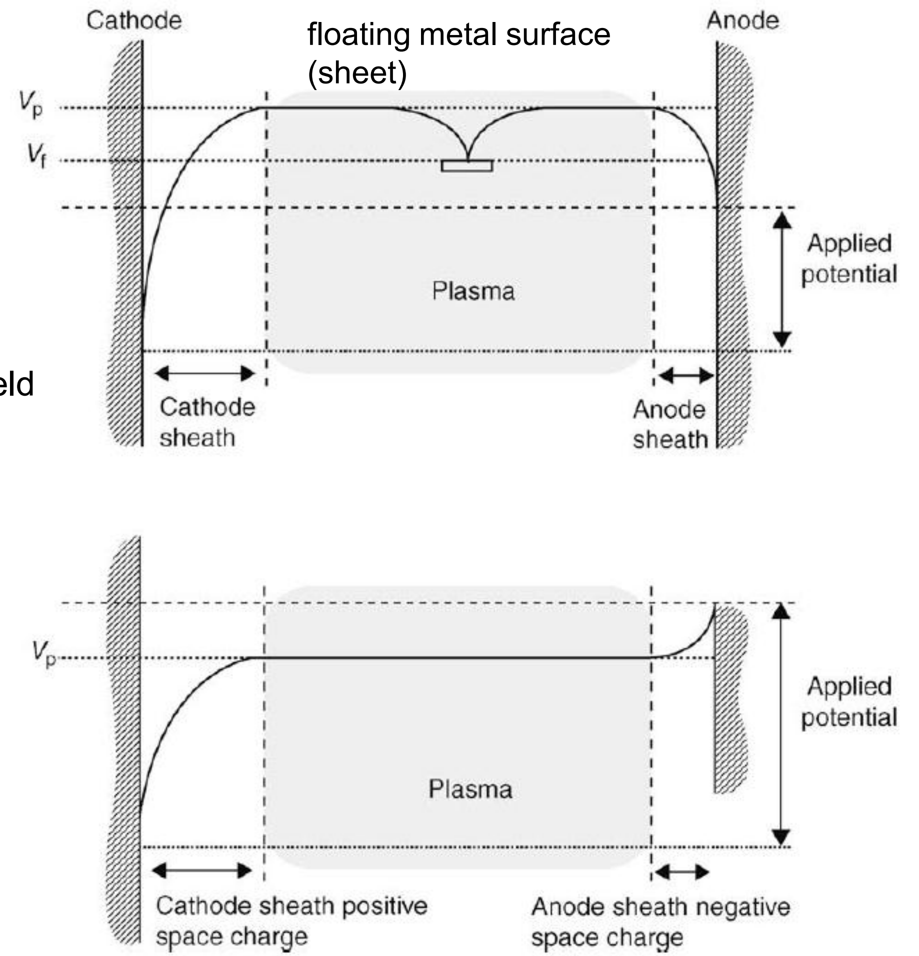
- **Coating Methods / Plasma potential**

Electrical "Parameters" / Ion Energy

Ion Energy / Sputter Yield
eV to K: 1eV~1.16*e4K



Sputter yield Y as a function of the Ar+ ion energy at normal incidence in a magnetron sputtering process.



Schematic illustration of the plasma sheaths which form between a plasma apparatus walls for large anode and small anode.

Scott G. Walteon and J. E. Greene – Plasma Deposition Processes

Selective Absorber

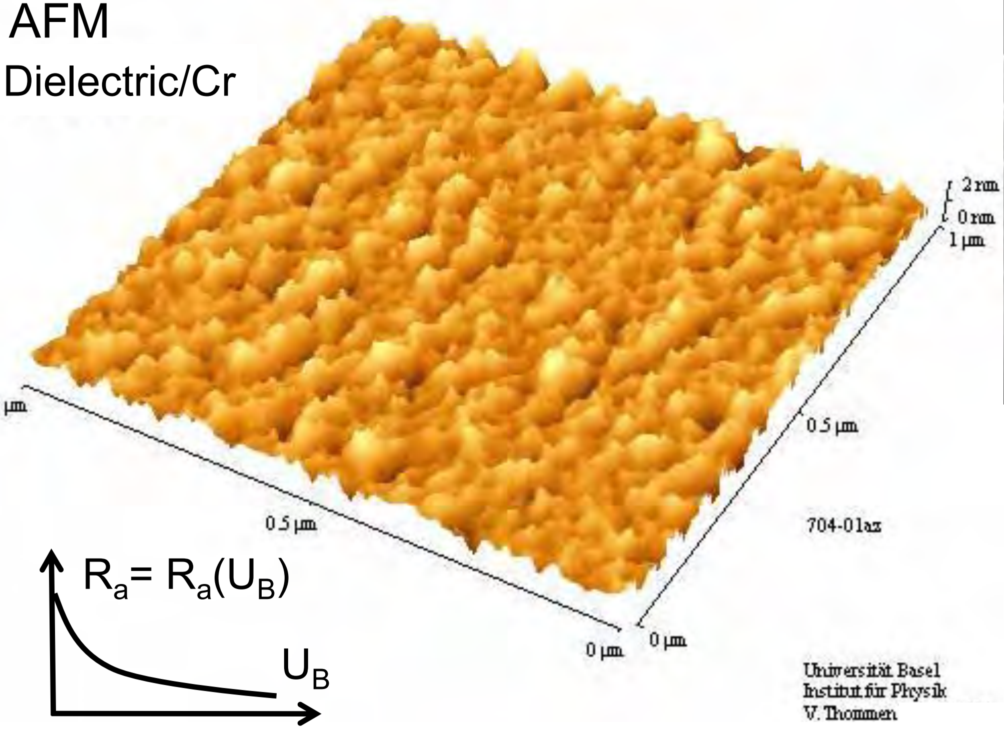
- **CERMET absorber surface**

  Substrate Bias Voltage

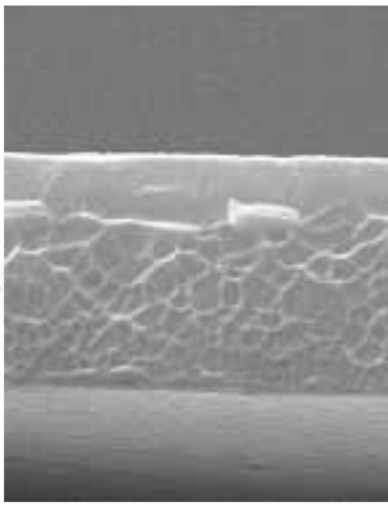
Surface roughness – optical & stability behaviour

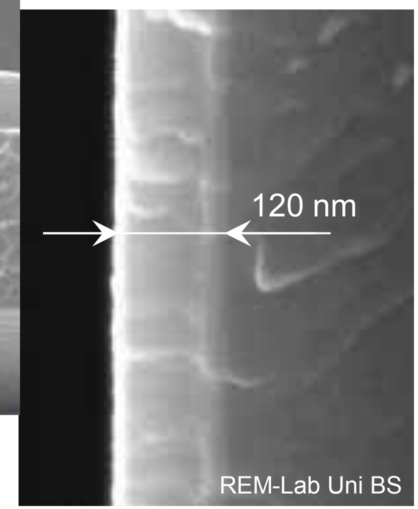
AFM

Dielectric/Cr



SEM



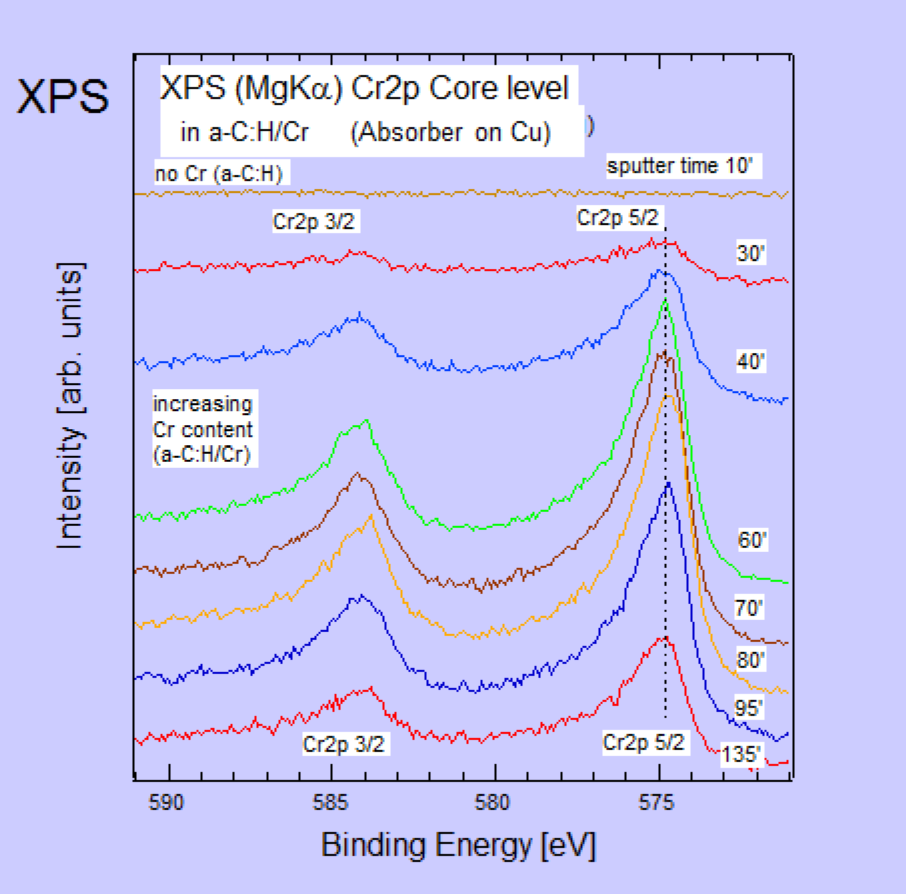


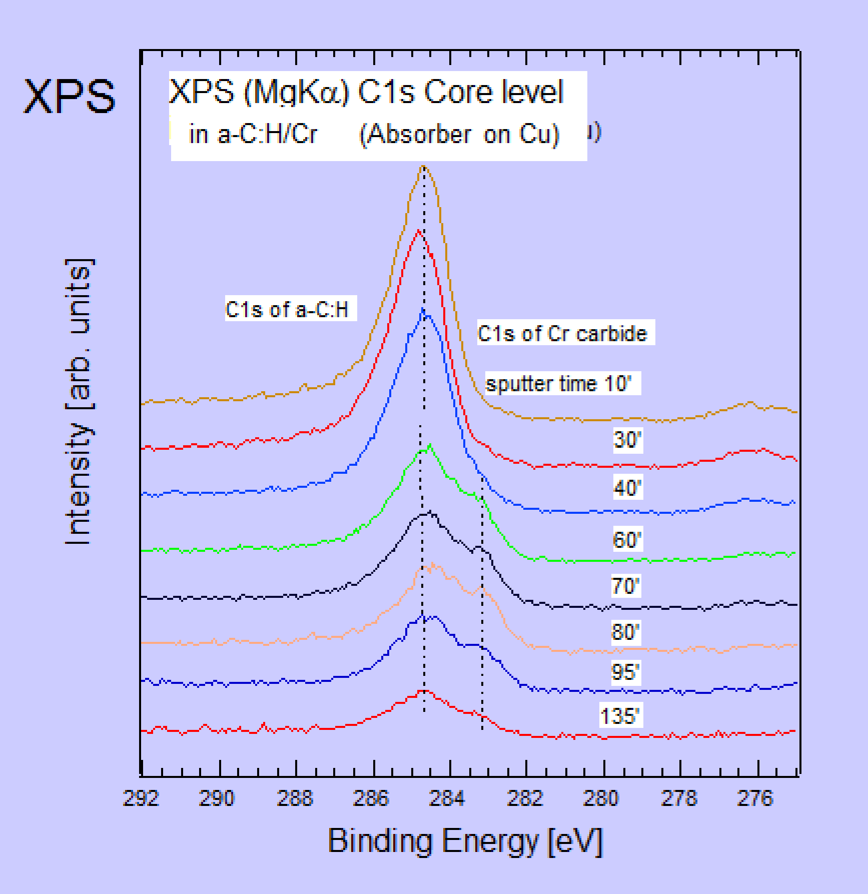
CERMET on Si

Selective Absorber

- **Chemical composition of an absorber coating**

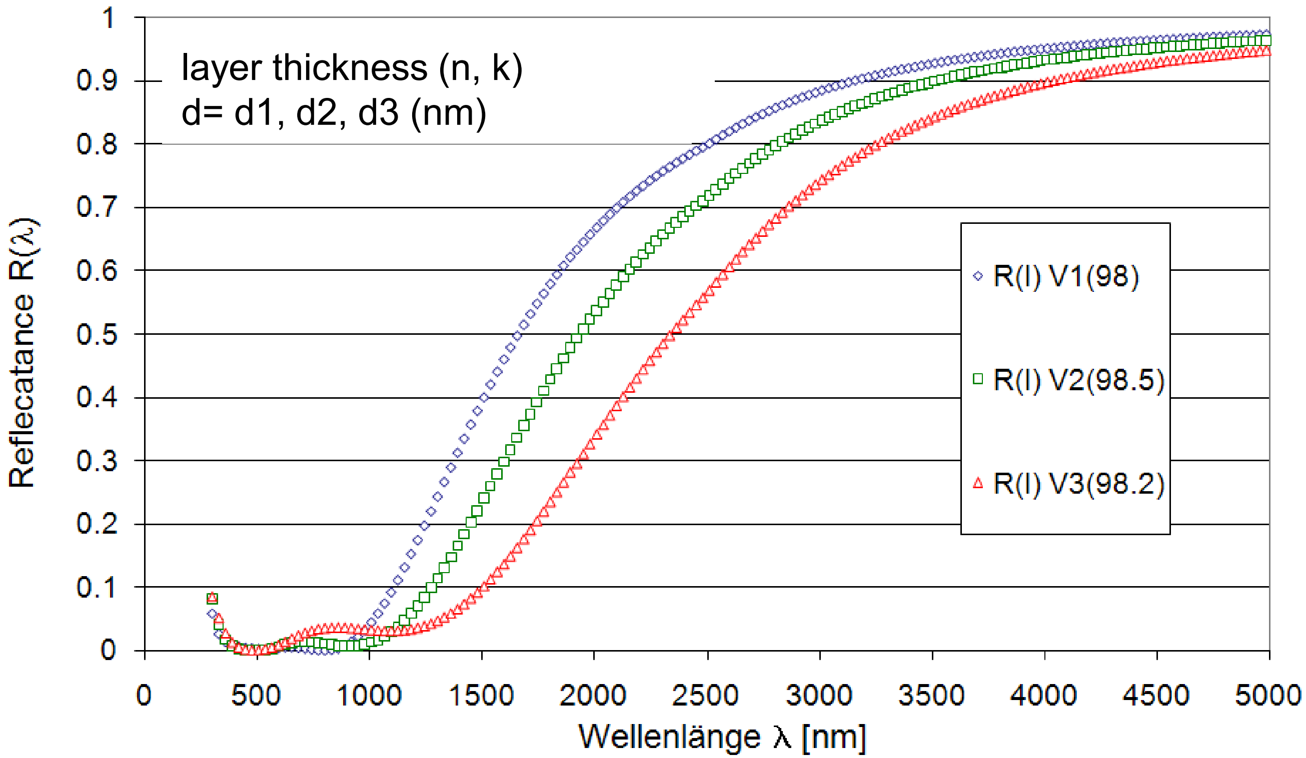
  Process Gas Composition / Substrate Temperature rf-Power …

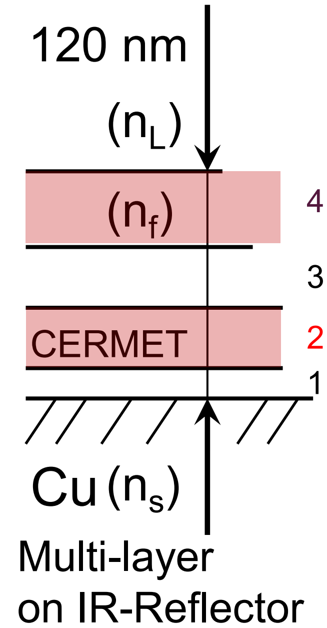




Multilayer Absorber

Reflection R(λ) in function of Wavelength λ - “sandwich layer”

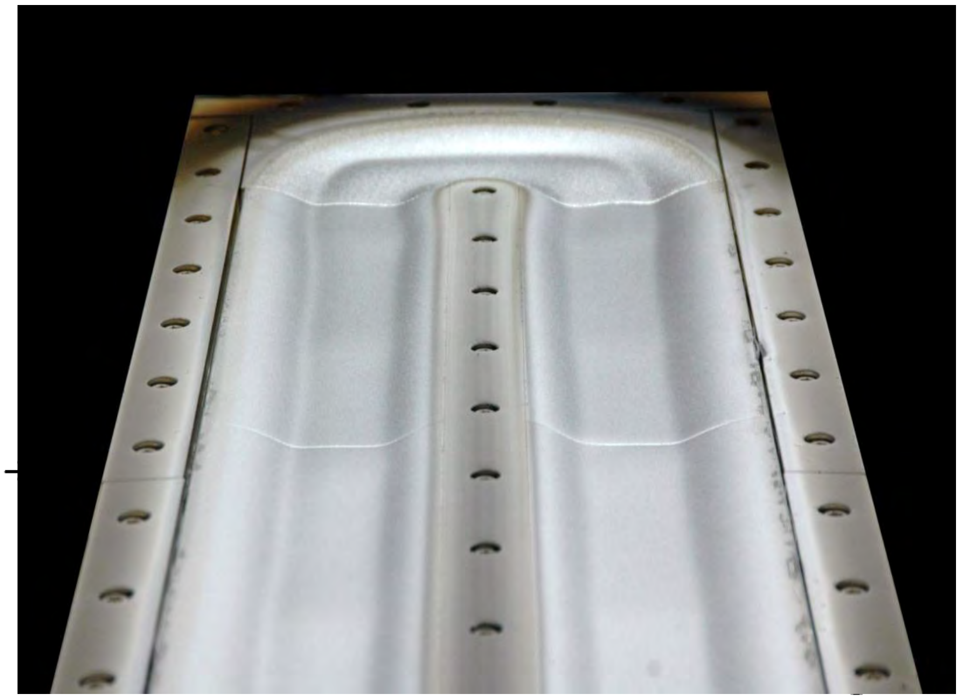




Selective Absorber

- **Scale up of substrate bias - Plasma Potential variation**

  Absorber film properties depending of the plasma potential / Bias



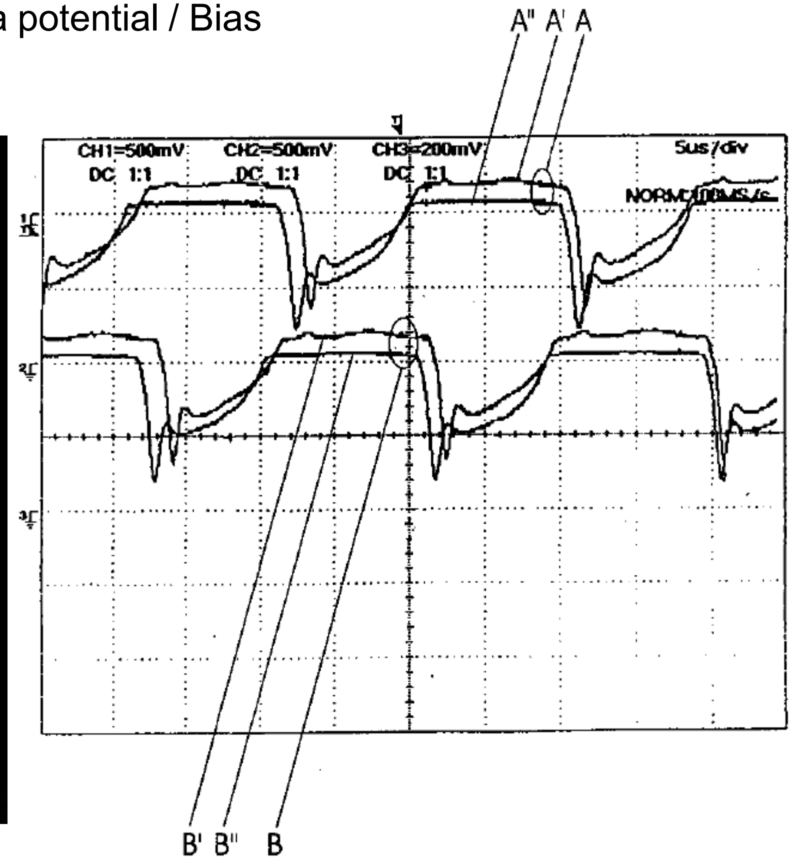
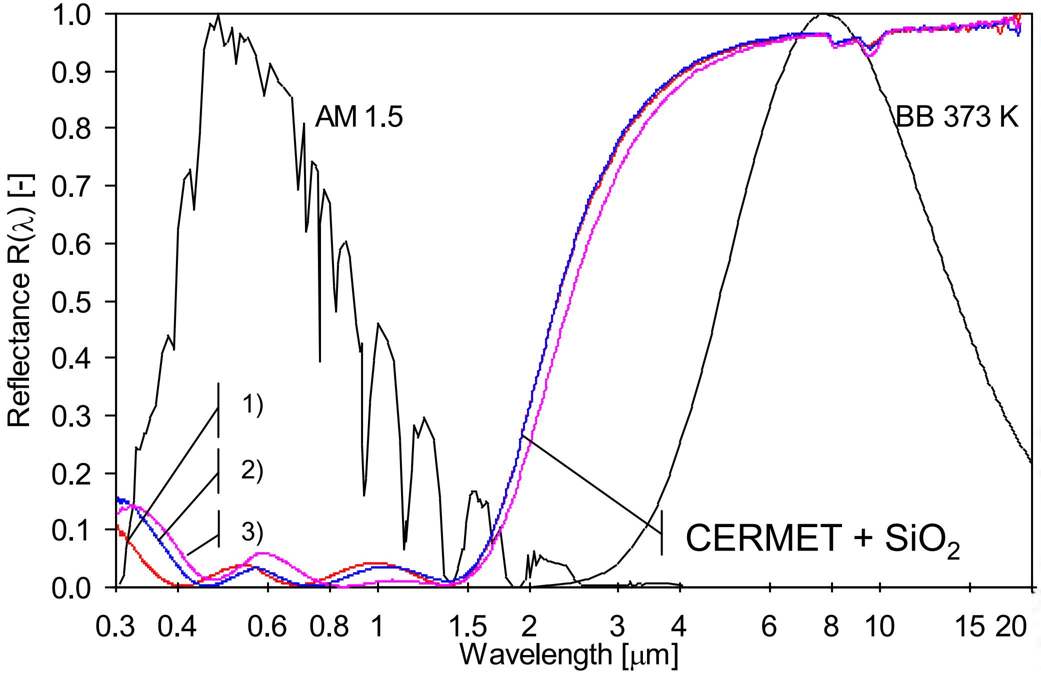


Fig. 2

Patentschrift: DE 198 30 404 B4

- **Multilayer solar selective absorber – Cermet / SiO_2**



R(λ) of three multilayer systems on copper metal sheets.
α_{sol} = 95.0 % to α_{sol} = 95.2 % ; ε_{th} = 3.1 % to ε_{th} = 3.7 %.

Absorber Coating Process

Parameter List (incomplete)

Geometry:	**Substrate Surface Orientation to Plasma Source** **Vacuum Chamber design**
Vacuum Chamber:	**Base Pressure / Rest Gases** **Vacuum Pump Technology**
Plasma Ignition:	**Frequency (DC, MF, RF, HF)** **Plasma Generator Technology / Plasma Density**
Reactant :	**Coating Material Educt / Target Material / Process Gases** **Process Pressure / Plasma Density**
Substrate:	**Material (el. behaviour)** **Roughness** **Temperature** **Speed**
Time:	**Coating time**

- **Tube Absorber Coating Machine**

Harding G. L.; US Patent 4309261 (1982)

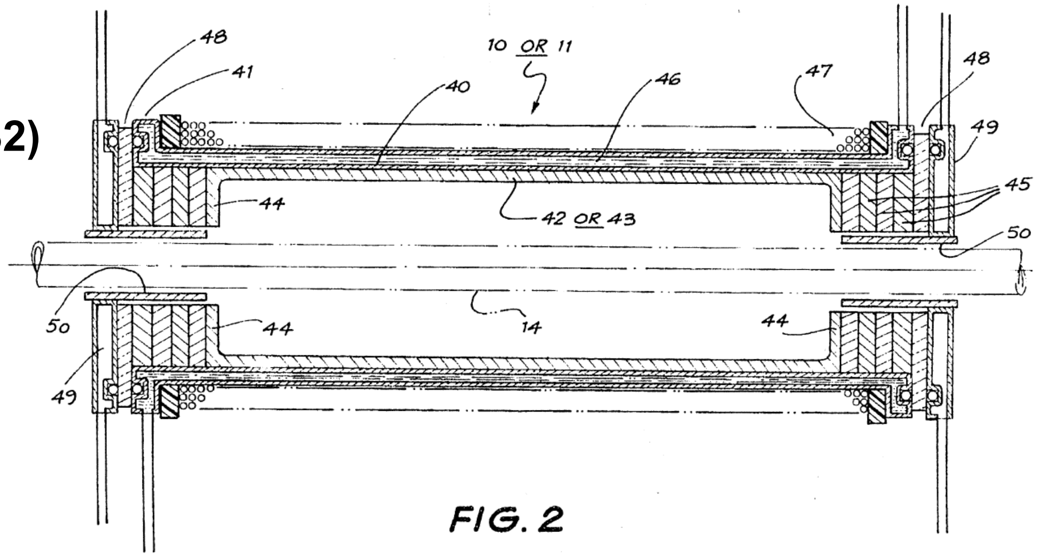


FIG. 2

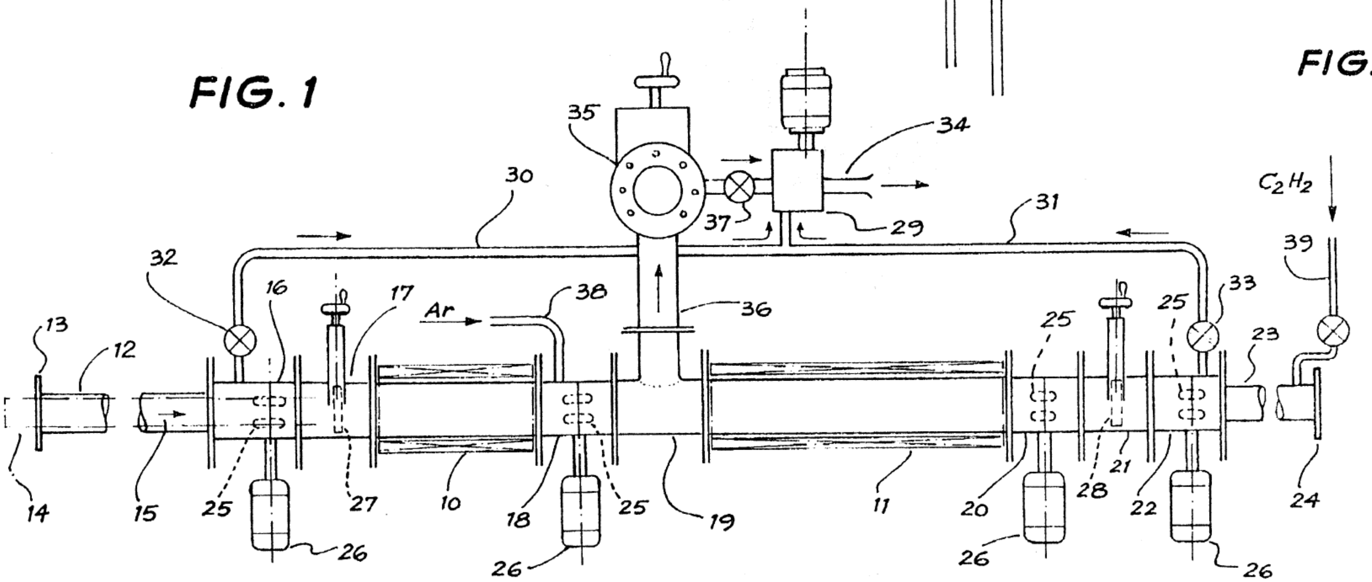
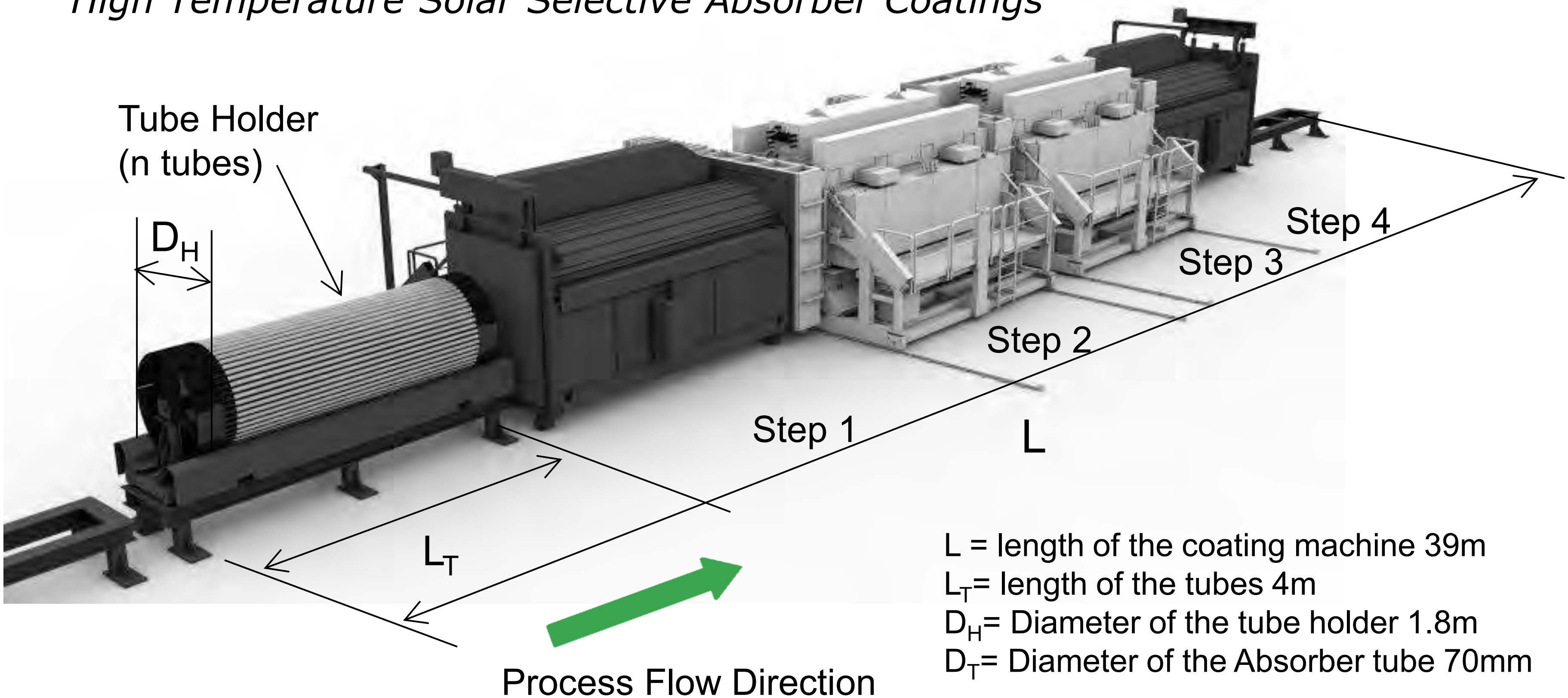


FIG. 1

- **Tube Coating Machine**
  High Temperature Solar Selective Absorber Coatings

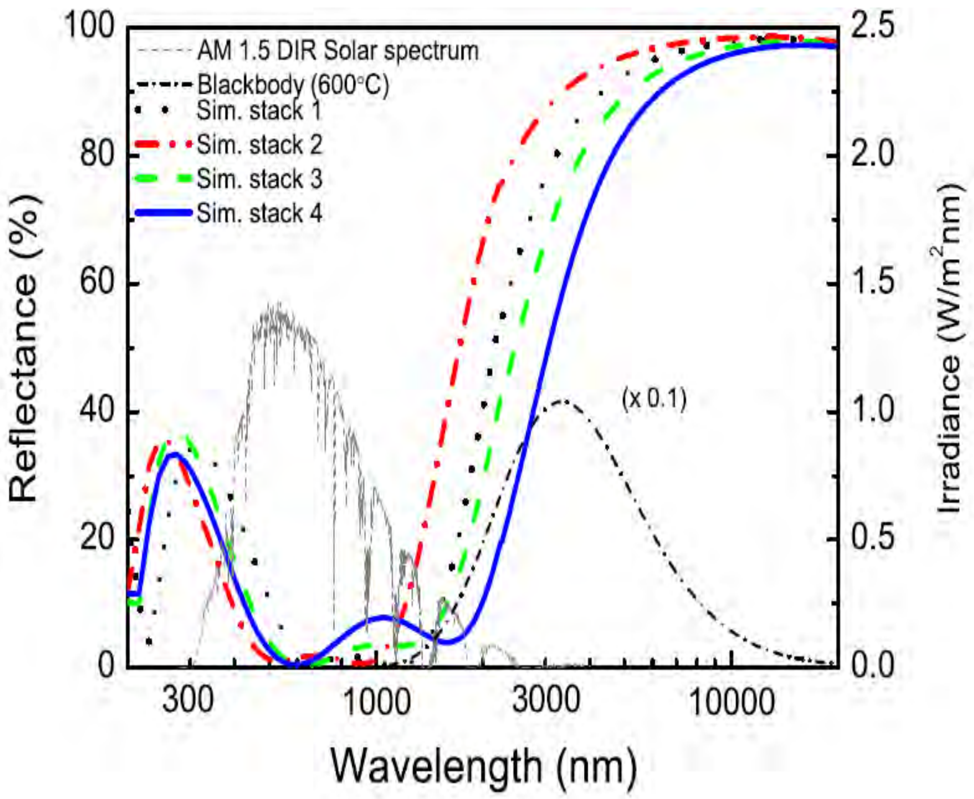


L = length of the coating machine 39m
L_T= length of the tubes 4m
D_H= Diameter of the tube holder 1.8m
D_T= Diameter of the Absorber tube 70mm

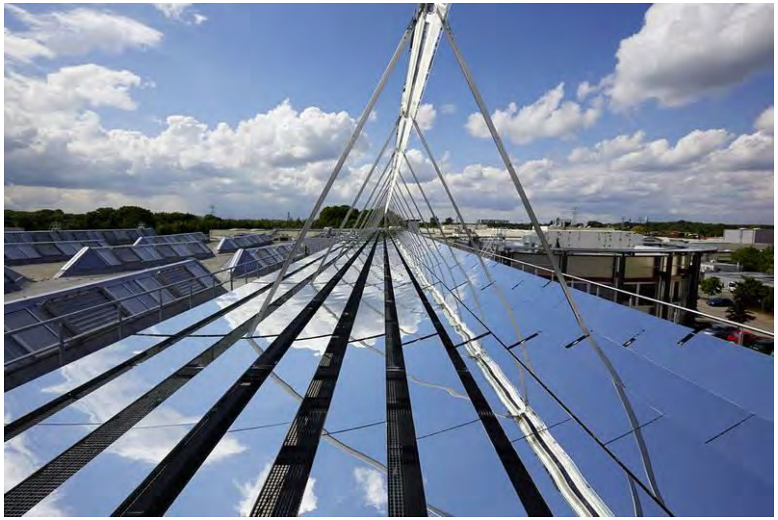
Source: Von Ardenne GmbH
Plattleite 19/29 | 01324 Dresden | Germany

Selective Absorber

- **Selective absorber - literature**



CERMET Mo-Si_3N_4
R. Escobar-Galindo et al.



Thank you for your attention!

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