Design of broadband antireflective layer stacks with low surface energy prepared by sol-gel method on glass for photovoltaic application

Cecilia Agustín-Sáenz[a]*, Maider Machado[a], Iryna Savych[b], Agnieszka Tercjak[c]

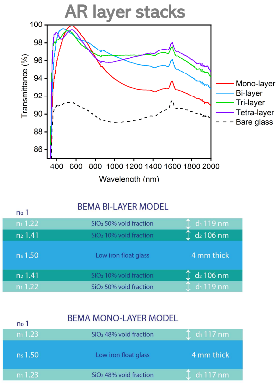
Introduction

The aim of this work is the development of a broadband antireflective (AR) coating system with low surface energy against soiling adherence for solar cover glass ($\tau_{300\text{-}2000}$ 90 %), capable to contribute in the design of PV systems with high energy yield, long lifetime, using low cost technology with reduced maintenance cost, for achieving low electricity cost. The coating system should offer the following properties:

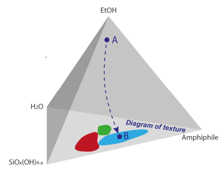
- Glass transmittance improvement over a broad wavelength range, ideally between 300 and 2000 nm.
- Easy-to-clean properties to diminish maintenance costs (OPEX).
- High performance stability under field temperature and humidity conditions.
- Resistance to abrasion and erosion phenomena to which they will be exposed during in-field installation, including cleaning operations.

Theoretical and experimental design of AR layer stacks

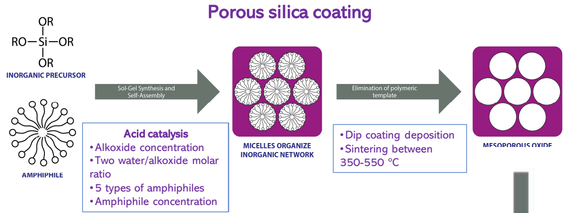
Theoretical calculation of broadband AR layer stacks



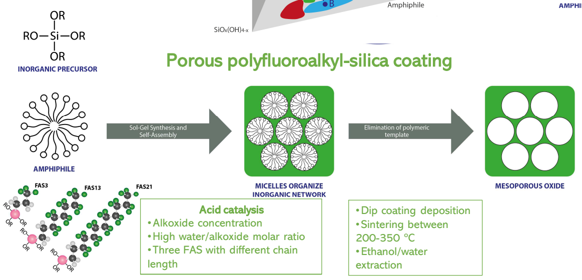
Acid-catalyzed sol-gel approach combined with Evaporation Induced Self-Assembly (EISA)



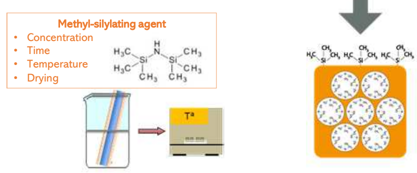
Porous silica coating



Porous polyfluoroalkyl-silica coating

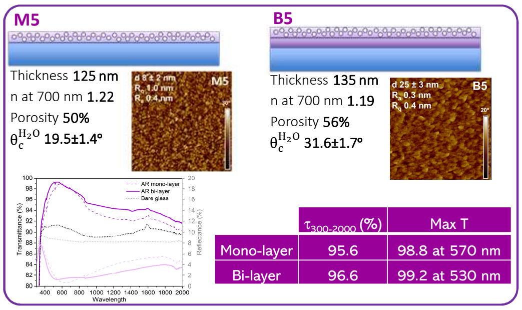


Methyl-silylated porous silica coating



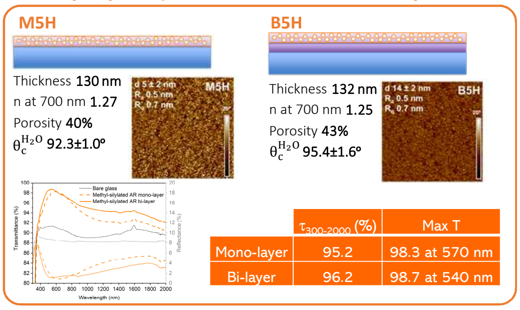
Characterization

Porous silica AR mono and bi-layer stacks



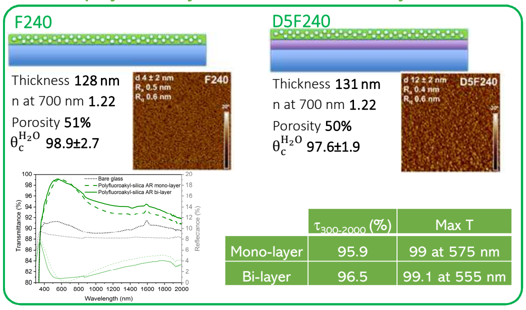
	$\tau_{300\text{-}2000}$ (%)	Max T
Mono-layer	95.6	98.8 at 570 nm
Bi-layer	96.6	99.2 at 530 nm

Methyl-silylated porous silica AR mono and bi-layer stacks



	$\tau_{300\text{-}2000}$ (%)	Max T
Mono-layer	95.2	98.3 at 570 nm
Bi-layer	96.2	98.7 at 540 nm

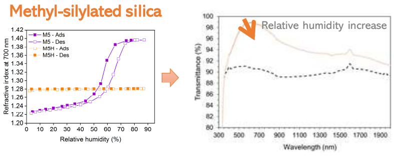
Porous polyfluoroalkyl-silica AR mono and bi-layer stacks



	$\tau_{300\text{-}2000}$ (%)	Max T
Mono-layer	95.9	99 at 575 nm
Bi-layer	96.5	99.1 at 555 nm

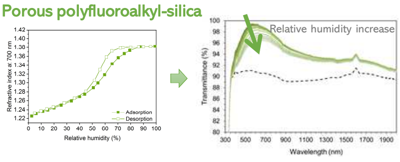
Water adsorption

Methyl-silylated silica



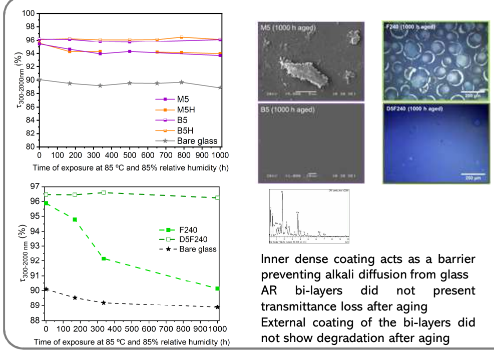
No water adsorption
Optical transmittance remains constant

Porous polyfluoroalkyl-silica



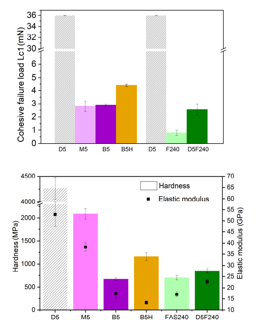
Water adsorption in the pores
Change of optical transmittance

Durability acc to IEC61215



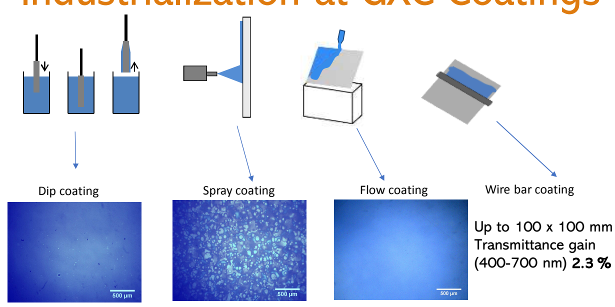
Inner dense coating acts as a barrier preventing alkali diffusion from glass
AR bi-layers did not present transmittance loss after aging
External coating of the bi-layers did not show degradation after aging

Mechanical properties



Only mono-layers display adhesive failure
Hardness is strongly affected by porosity
Hardness of the bi-layers are highly similar

Industrialization at GXC Coatings GmbH

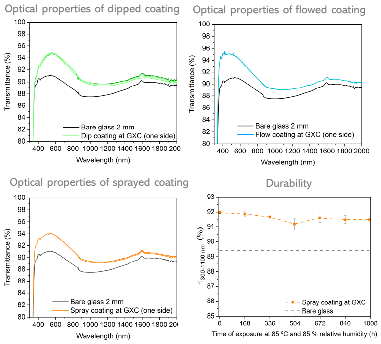


Dip coating: Up to 300 x 250mm, Transmittance gain (300-1100 nm) **3.3 %**

Spray coating: Up to 100 x 100 mm, Transmittance gain (300-1100 nm) **2.9 %**

Flow coating: Up to 2000 x 1000 mm, Transmittance gain (300-1100 nm) **3.4 %**

Wire bar coating: Up to 100 x 100 mm, Transmittance gain (400-700 nm) **2.3 %**



Conclusions

- Broadband antireflectance is achieved theoretically and experimentally through silica bi-layer stack with graded refractive index.
- Porous external coating presents different structure and porosity if directly grown on glass or on dense-structured inner coating.
- Hydrophobicity has been achieved by two routes: a) methyl-silylation of consolidated porous silica and b) addition of polyfluoroalkyl silane during sol preparation.
- Long durability and mechanical properties are linked to sintering temperature, the presence of dense-structured inner coating and porosity of external coating.
- Industrialization of AR mono-layer on one side of glass has been successfully accomplished by GXC coatings.
- Flow-coating is the most promising method for big plates.

Contact Information:
*Cecilia Agustín-Sáenz
cecilia.agustin@tecnalia.com

[a] TECNALIA C/ Mikeletegi Pasealekua, 2, 20009 Donostia-San Sebastián, Spain
[b] GXC Coatings GmbH Im Schleeke 27 - 31 , 38642 Goslar, Germany
[c] University of the Basque Country (UPV/EHU) Faculty of Engineering (Gipuzkoa) Plaza Europa 1, 20018 Donostia-San Sebastián, Spain

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