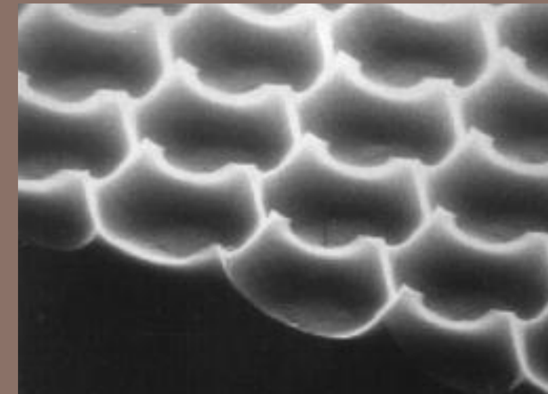
Nanophotonic coatings to enhance optical sensors For Earth observation from space



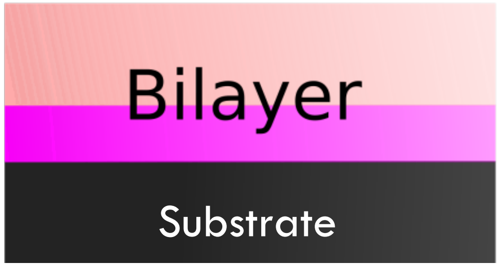
Pablo Aitor Postigo
IMN-CSIC

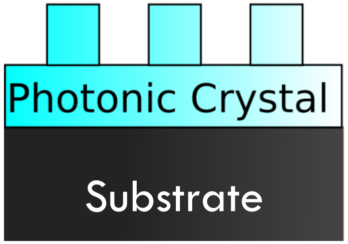
CSIC

Instituto de Micro y Nanotecnología
IMN-CNM-CSIC

cnm IMN micro nano

Introduction: Typical ARC Coatings

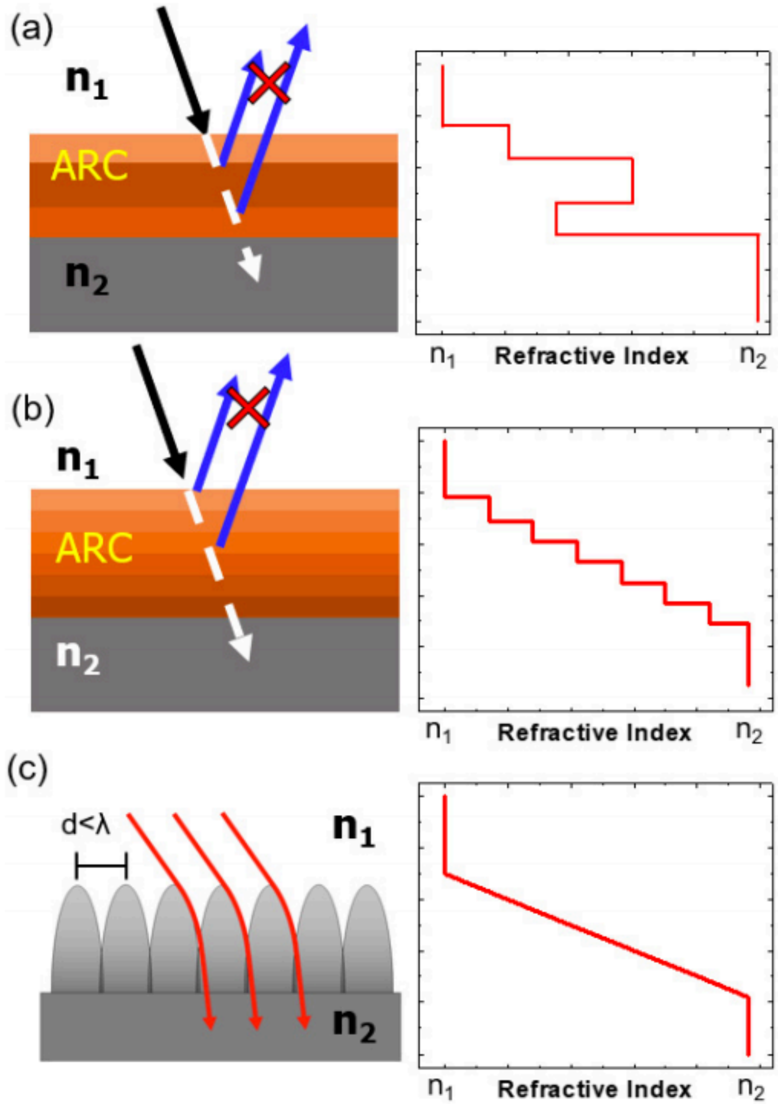




ARC based on planar layers (Bilayer)

Nanostructured ARC (Single layer, can be same material than substrate)

The Nanostructured GRIN effect

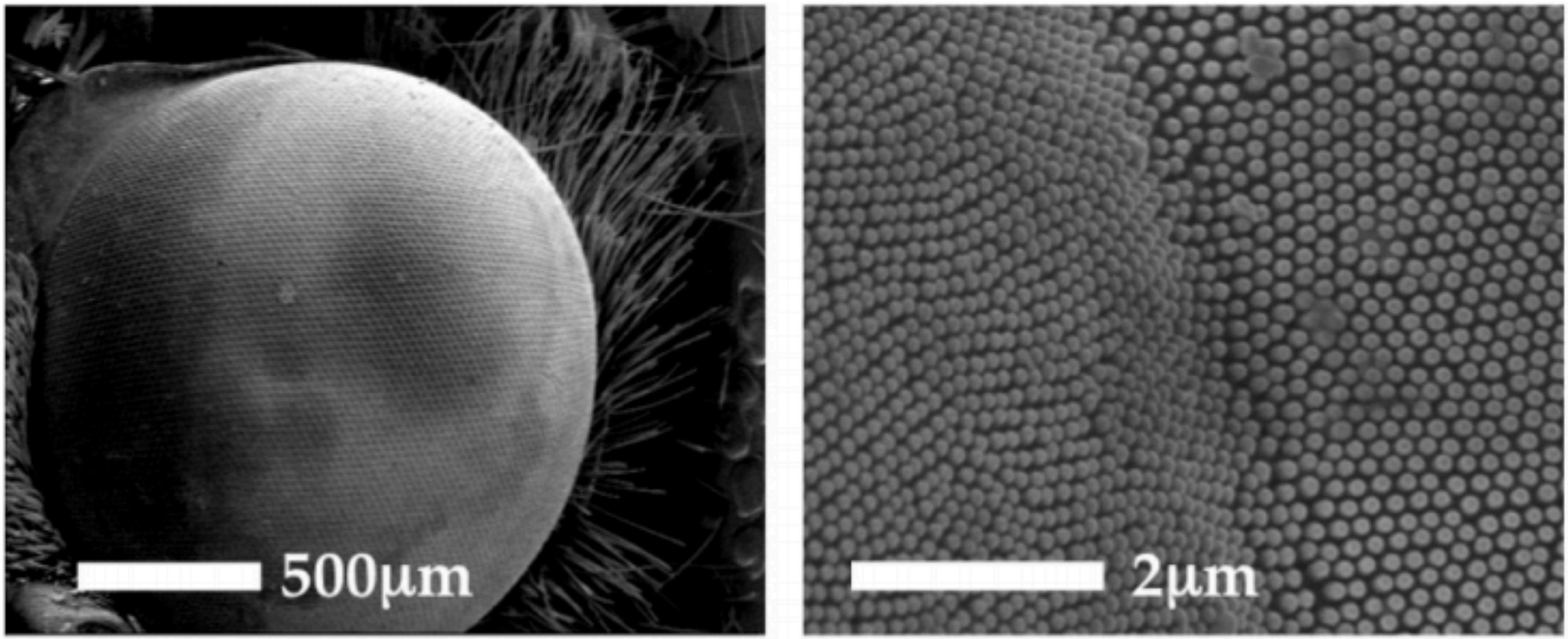


(a) Traditional (and commercial) ARC relies on destructive interference from dissimilar dielectric thin films (typically $\lambda/4$ thick. These interference-based ARCs are extremely effective in reducing surface reflections at specific wavelengths (e.g. $R < 0.01\%$), but **bandwidth and angular response are typically poor.**

(b) Idealized multilayer ARC that approximates a graded index (GRIN). While this structure would theoretically result in low reflection, it is **extremely difficult** to make as many layers with very specific refractive indices are required.

(c) GRIN produced by a nanostructured surface, like the moth eye, along with their qualitative refractive index profiles as a function of depth through the materials.

Natural nanostructured GRIN efect

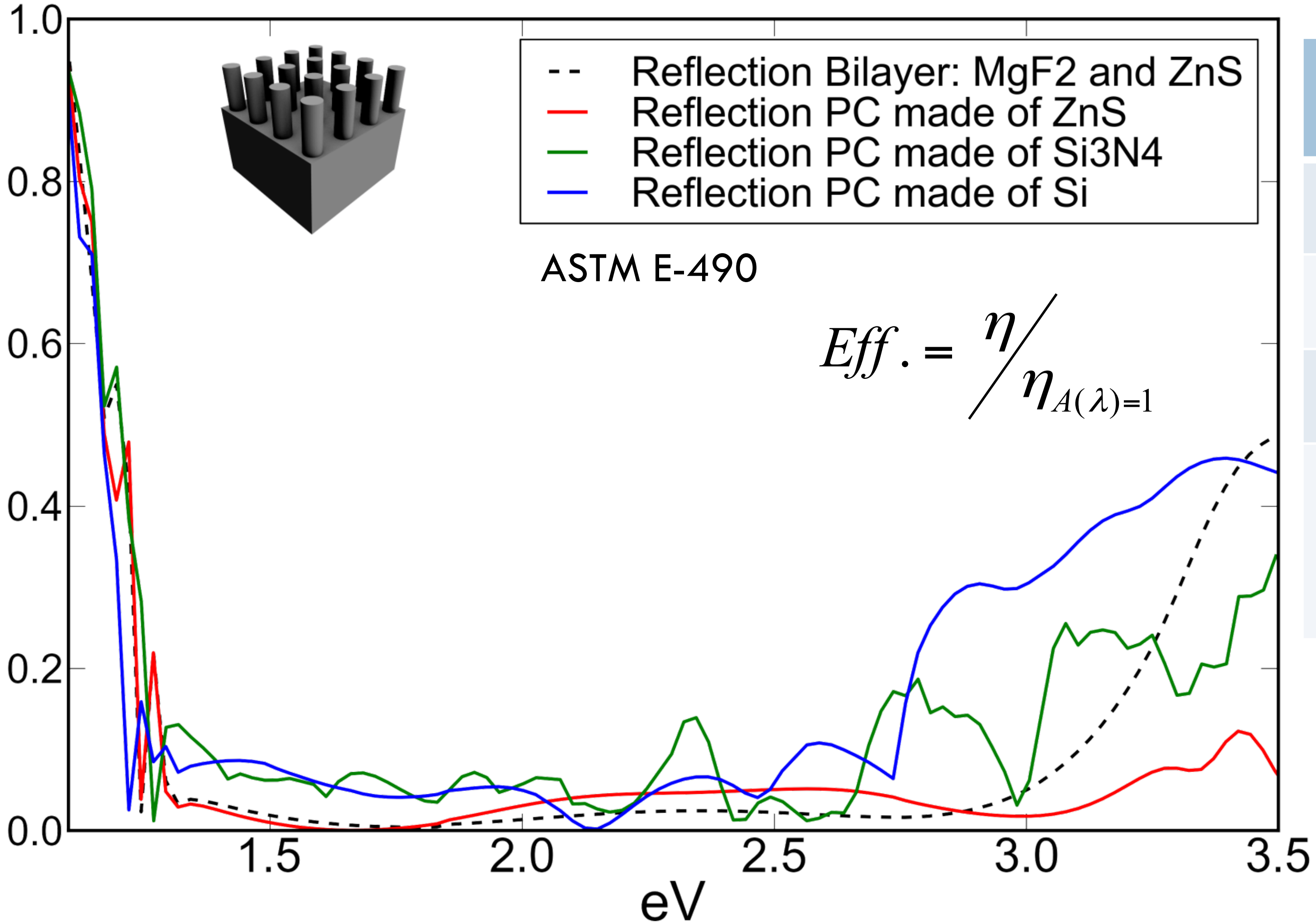


SEM images of the eye of the common gray moth (likely *Anavitrinella pampinaria*) showing sub-wavelength tissue protuberances

Advantages of Nano-ARCs vs Bilayers

- **Broad spectral band** with **omni-directional anti-reflectivity (R<1%)**
- **High resistance to thermal changes**, since they are part of the substrate and not based in multi-layers, which tend to crack due to thermal stress.
- Work for **any wavelength range**
- **Can add different properties** to the substrate if a different material is used for the nano-ARC (for example **radiation hardness**)
- Can be **easily fabricated** by large-area nanoimprint and plasma etching, both industry-scalable techniques
- They are **anti-water and anti-dust** repellent

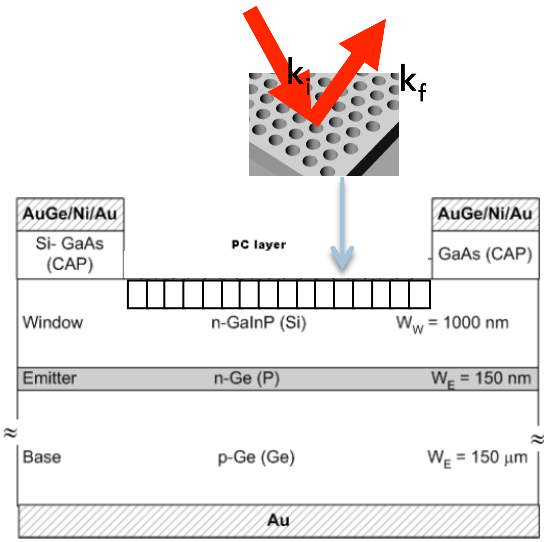
Nano-ARCs for a silicon solar cell



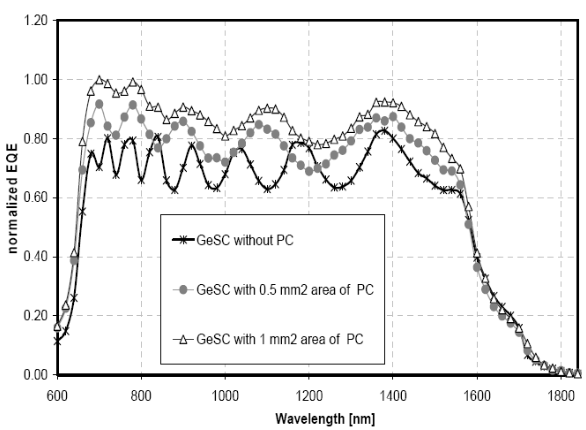
$$Eff. = \eta / \eta_{A(\lambda)=1}$$

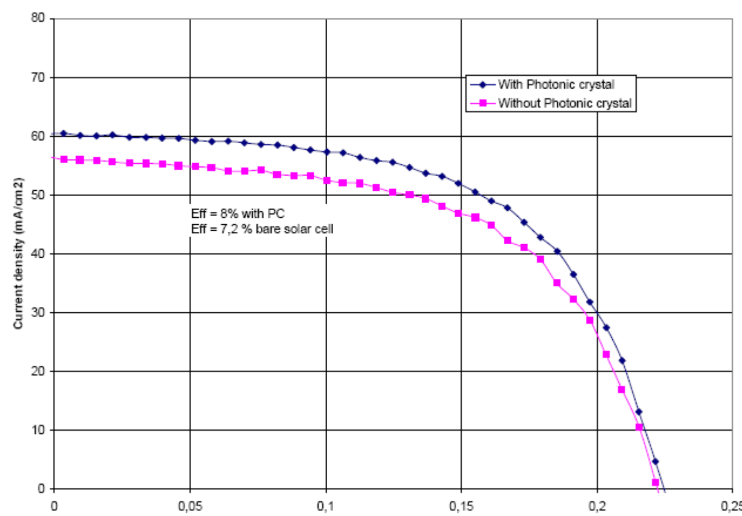
Mat.	Eff.
Si_3N_4	88%
Si	86%
ZnS	**91%**
Bilayer (MgF_2+ ZnS)	**91%**

Nano-ARC fabricated on solar cell



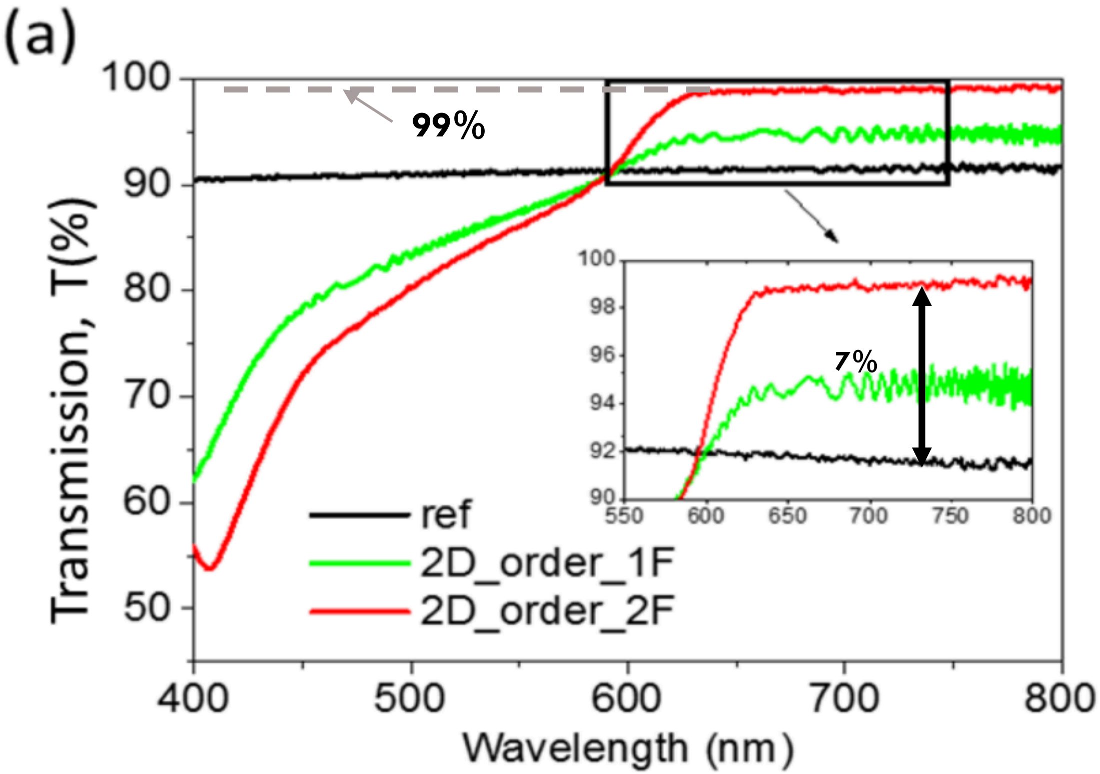
We have used a 2DPC ARC on the InGaP window layer of a single-junction Ge/InGaP solar cell. No degradation of cell performance has been observed. Enhancements of the external quantum efficiency (EQE) of 22% for a wide range of wavelengths and up to a 46% for specific wavelengths has been measured, which **increases the total photocurrent between 16% and 25%** (AM1.5D).

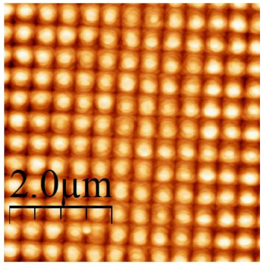




I. Prieto, P.A. Postigo et al, Appl. Phys. Letters 94, 19, 191102 (2009)

LIMES: Nano-ARC on Solar Glass





Nano-ARC glass with silicon-based solar cells would result in an increment close to 0.7%. For multiple-junction solar cells, efficiencies can reach 46% and the enhancement using our glass would be around 1.2%, which is a significant value in the field of solar energy, especially on satellites.

E Baquedano, L Torné, P Caño, PA Postigo "Increased efficiency of solar cells protected by hydrophobic and hydrophilic anti-reflecting nanostructured glasses", Nanomaterials 7 (12), 437 (2017)

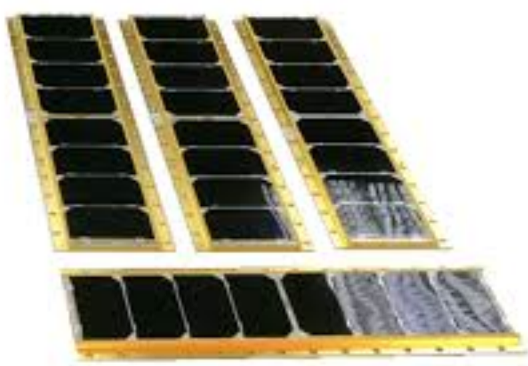
Nano-ARCs for space optical sensors

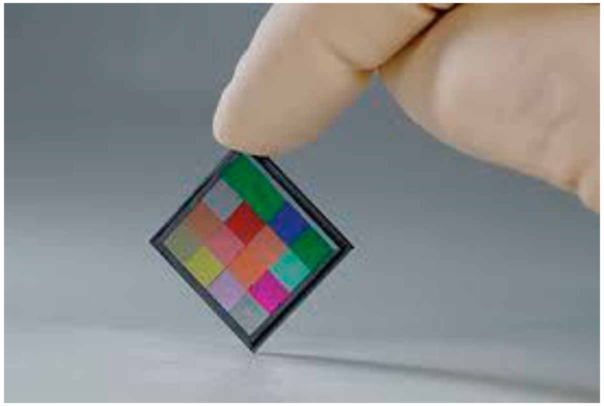
Nano-ARCs can be used for:

-space solar cells

-optical components materials

-multispectral filters for satellite sensors





Thank you for your attention!

I will be pleased to answer your questions!