Development of new material coatings based on hybrid Au@Ag nanostars and PVDF for biocide applications

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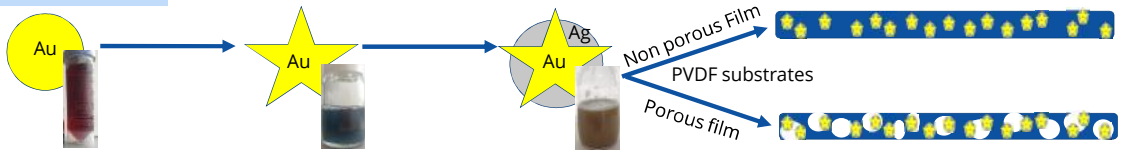
Introduction

The widespread use of antibiotics is generating the appearance of multiresistant microorganisms, which will become one of the most dangerous hazards for human health in the next years. Physical methods with biocidal properties are appearing as a promising alternative to mitigate this problem. [1, 2, 3]

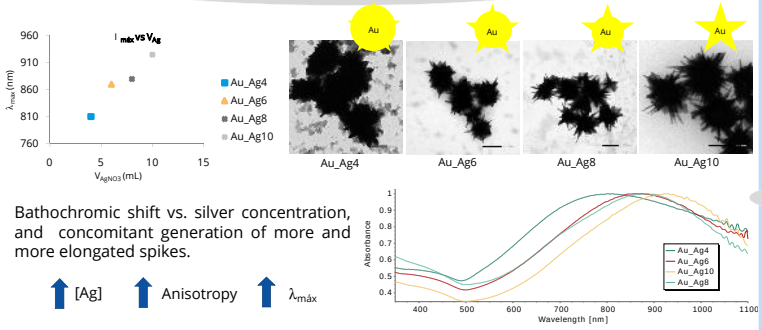
Here, several versions of silver-coated gold nanostars (Au@Ag NSs) were synthesized through seed-mediated growth processes, generating partially coated nanostars exhibiting Au tips that protrude from the silver coatings. They exhibit good optical properties tunable in the visible and near IR regions. The nanoparticles were processed with PVDF polymers through two different methods, in the form of porous or continuous materials. These novel materials present dual photothermia and release of silver, becoming a promising material as substrate or coating for antibacterial surfaces and devices.

Preparation method



Nanoparticle synthesis and characterization

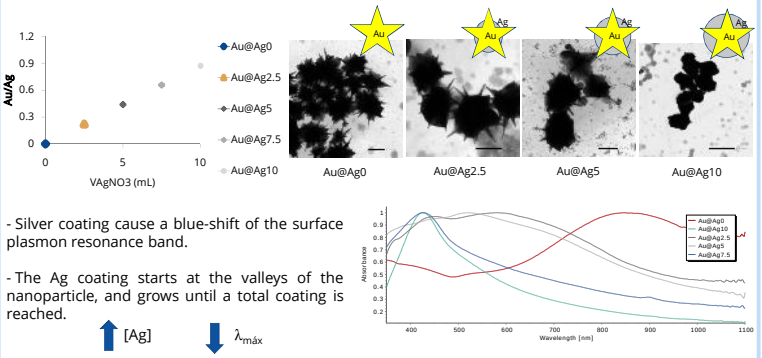
Anisotropy tuning



Bathochromic shift vs. silver concentration, and concomitant generation of more and more elongated spikes.

↑ [Ag] ↑ Anisotropy ↑ $\lambda_{máx}$

Coating Au@Ag tuning

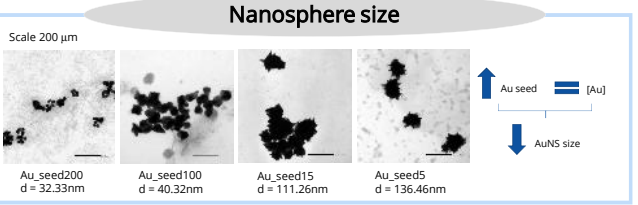


- Silver coating cause a blue-shift of the surface plasmon resonance band.

- The Ag coating starts at the valleys of the nanoparticle, and grows until a total coating is reached.

↑ [Ag] ↓ $\lambda_{máx}$

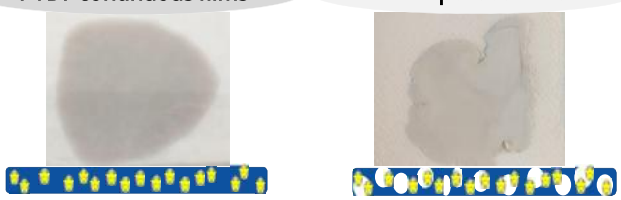
Nanosphere size



Substrate processing

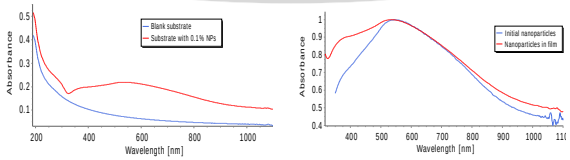
PVDF continuous films

PVDF porous films



PVDF films were processed by Dr. blade casting with 30 µm thickness and 0.1 wt.% nanoparticle loading.
Porous and non-porous substrates were generated by controlling the drying temperature to promote "temperature Induced phase separation (TIPS)" or to inhibit it.

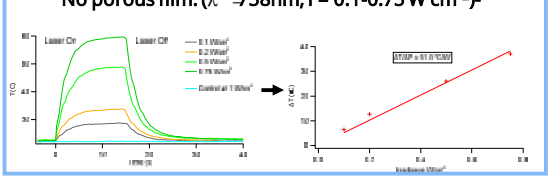
Film optical properties



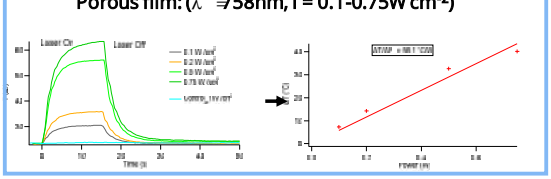
The composite film shows the three characteristic peaks of the nanoparticles, one from the silver at around 400nm, and two coming from the nanostars (around 520nm, and 750nm), indicative of non aggregated nanoparticles.

Photothermal properties

No porous film: (λ =758nm, I = 0.1-0.75 W cm^{-2})-



Porous film: (λ =758nm, I = 0.1-0.75W cm^{-2})



Conclusiones & outlook

- Seed-mediated-growth synthesis of Au NSs allows a fine tuning on the nanoparticle size and spikeness.
- Ag can successfully grow on the Au NSs to generate Au@Ag NSs with Au tips protruding from the Ag shell.
- PVDF substrates were successful porcessed with porous and non-porous structures and with good dispersion of the nanoparticles in its interior.
- Both substrates show extraordinary photothermal transduction capabilities with a ΔP/ΔT = 50-60 °C/min at only 0.1% nanoparticle concentration.
- Antibacterial tests will be performed using synergistically both the Ag toxicity and photothermia. Optical conditions will be evaluated to achieve the highest antibacterial efficiency

Referencias:
[1] Andrew M. et al. Development of Hybrid Silver-Coated Gold Nanostars for Nonaggregated Surface-Enhanced Raman Scattering. *The Journal of Physical Chemistry C.* 2014, *118* (7), pp 3708-3715. doi:10.1021/jp4091393
[2] Shuangmei, Wu. et al. Silica-Coated Gold–Silver Nanocages as Photothermal Antibacterial Agents for Combined Anti-Infective Therapy. *ACS Applied Materials & Interfaces.* 2019, *11* (19) , pp 17177-17183. doi.:10.1021/acsami.9b01149
[3] Litti, Lucio. et al. Manipulating chemistry through nanoparticle morphology, Nanoscale Horiz., 2020, *5* (1) , pp 102-108. doi:10.1039/C9NH00456D