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Image Article

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Structure-Property Relationships of Nanostructured Materials: from Synthesis to Characterization for Multiple Applications

Sara Cerra

Dept of Chemistry, Sapienza University of Rome, Italy

***Corresponding author**
Sara Cerra, Dept of Chemistry, Sapienza University of Rome, Italy.

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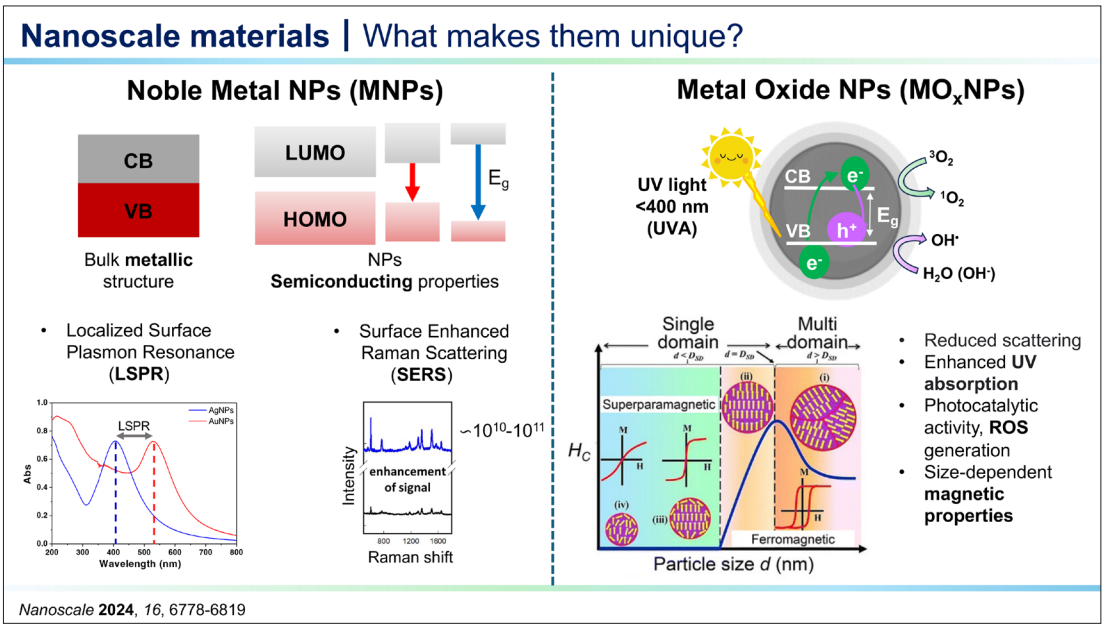
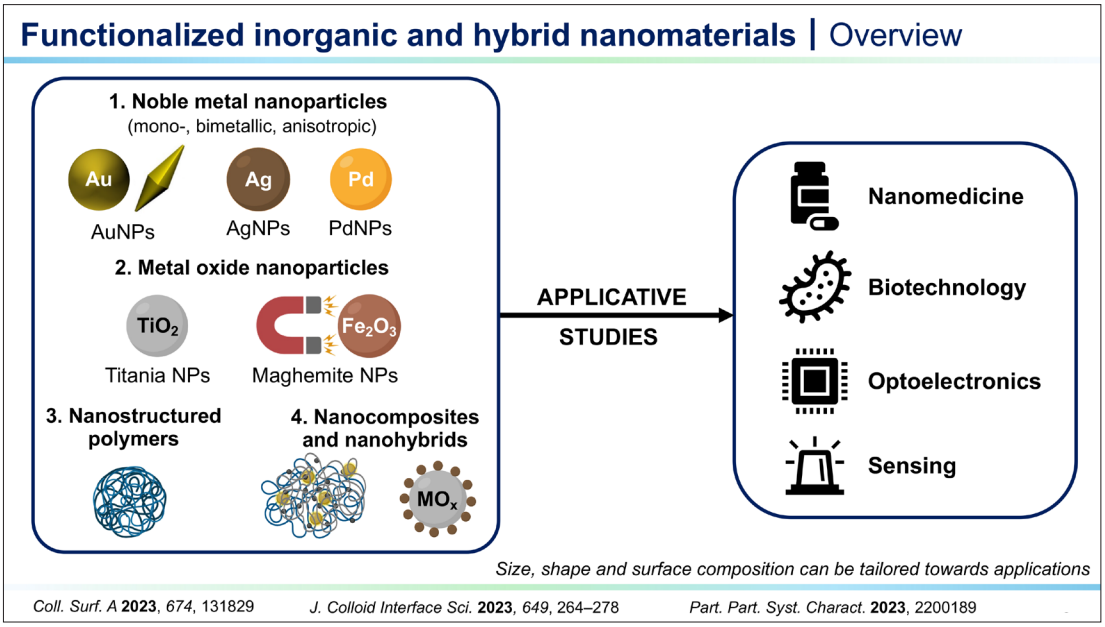
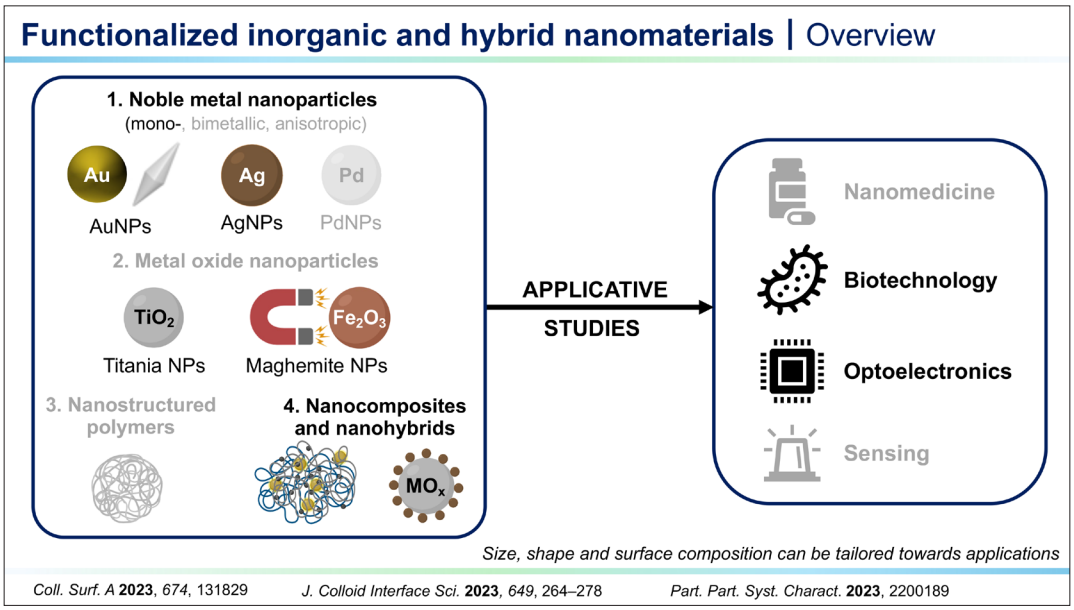
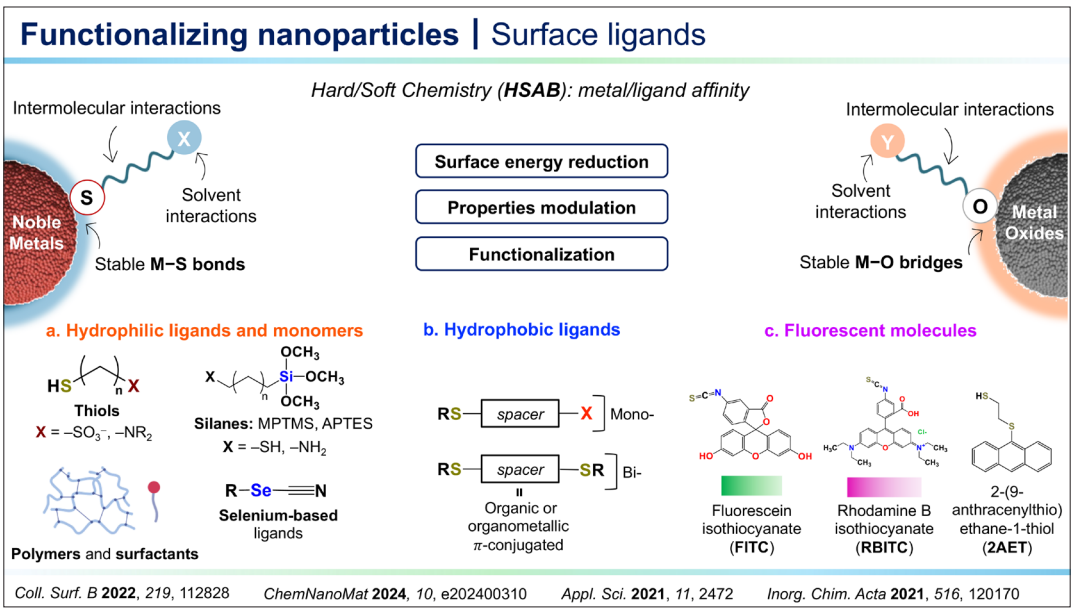
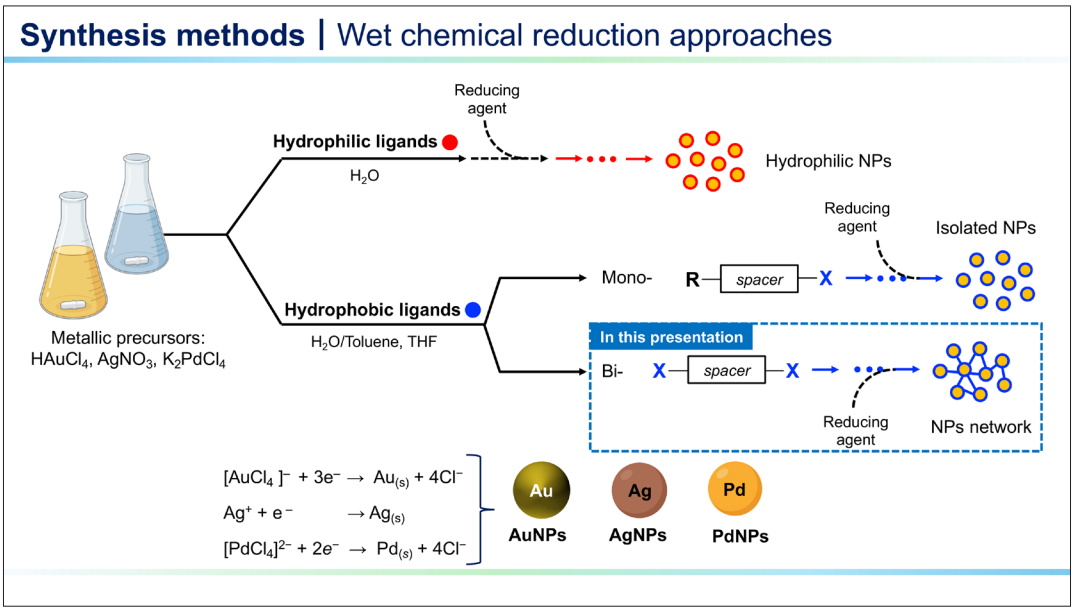





Functionalized inorganic and hybrid nanomaterials | Overview
1. Noble metal nanoparticles
(mono-, bimetallic, anisotropic)
Au
Ag
Pd
AuNPs
AgNPs
PdNPs
2. Metal oxide nanoparticles
TiO2
Fe2O3
Titania NPs
Maghemite NPs
3. Nanostructured polymers
4. Nanocomposites and nanohybrids
MOx
APPLICATIVE STUDIES
Nanomedicine
Biotechnology
Optoelectronics
Sensing
Size, shape and surface composition can be tailored towards applications
Coll. Surf. A 2023, 674, 131829
J. Colloid Interface Sci. 2023, 649, 264–278
Part. Part. Syst. Charact. 2023, 2200189

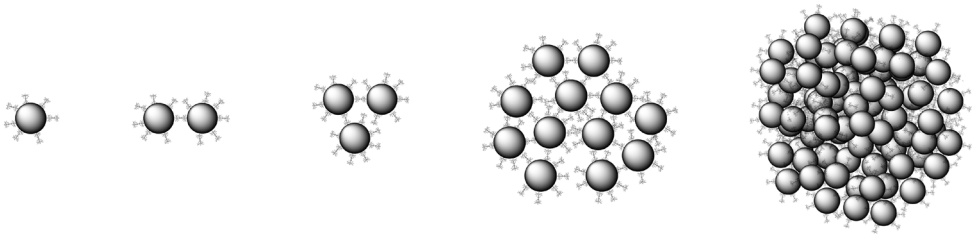

Functionalizing nanoparticles | Surface ligands
Hard/Soft Chemistry (HSAB): metal/ligand affinity
Intermolecular interactions
Noble Metals
Solvent interactions
Stable M–S bonds
Surface energy reduction
Properties modulation
Functionalization
Intermolecular interactions
Solvent interactions
Metal Oxides
Stable M–O bridges
a. Hydrophilic ligands and monomers
Thiols
X = –SO3−, –NR2
Silanes: MPTMS, APTES
X = –SH, –NH2
Selenium-based ligands
Polymers and surfactants
b. Hydrophobic ligands
Mono-
Bi-
Organic or organometallic π-conjugated
c. Fluorescent molecules
Fluorescein isothiocyanate (FITC)
Rhodamine B isothiocyanate (RBITC)
2-(9-anthracenylthio) ethane-1-thiol (2AET)
Coll. Surf. B 2022, 219, 112828
ChemNanoMat 2024, 10, e202400310
Appl. Sci. 2021, 11, 2472
Inorg. Chim. Acta 2021, 516, 120170


Synthesis methods | Wet chemical reduction approaches
Reducing agent
Hydrophilic ligands
H2O
Hydrophilic NPs
Metallic precursors:
HAuCl4, AgNO3, K2PdCl4
Hydrophobic ligands
H2O/Toluene, THF
Mono-
Isolated NPs
In this presentation
Bi-
NPs network
[AuCl4]− + 3e− → Au(s) + 4Cl−
Ag+ + e− → Ag(s)
[PdCl4]2− + 2e− → Pd(s) + 4Cl−
AuNPs
AgNPs
PdNPs

Bifunctional ligands | The way to NPs interconnection

Bifunctional ligands → Interconnected network of spherical MNPs

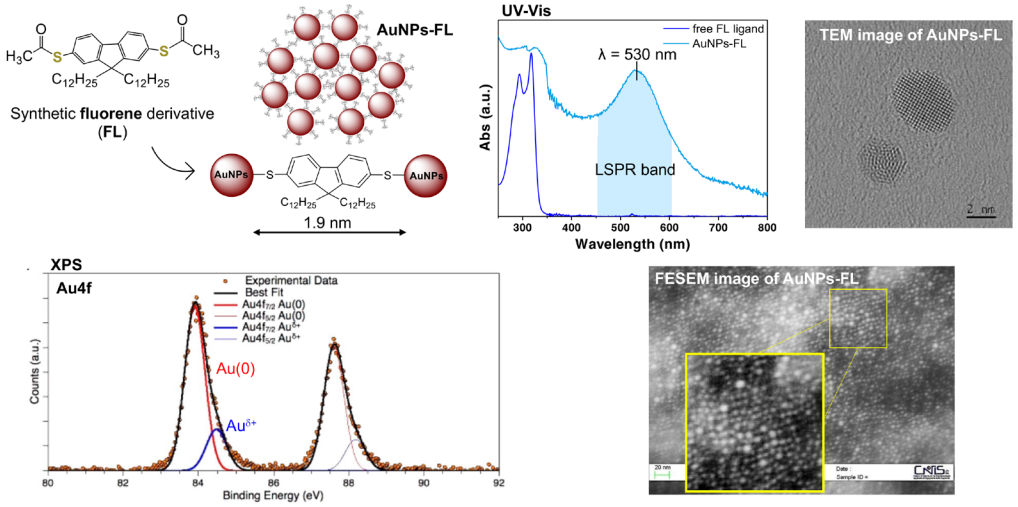
- ✓ Hydrophobic: dispersion in organic solvents
- ✓ 3D, extended π-conjugated electronic system
- ✓ Tunable distance between NPs



Covalent Self-Assembly & Colloidal Stability

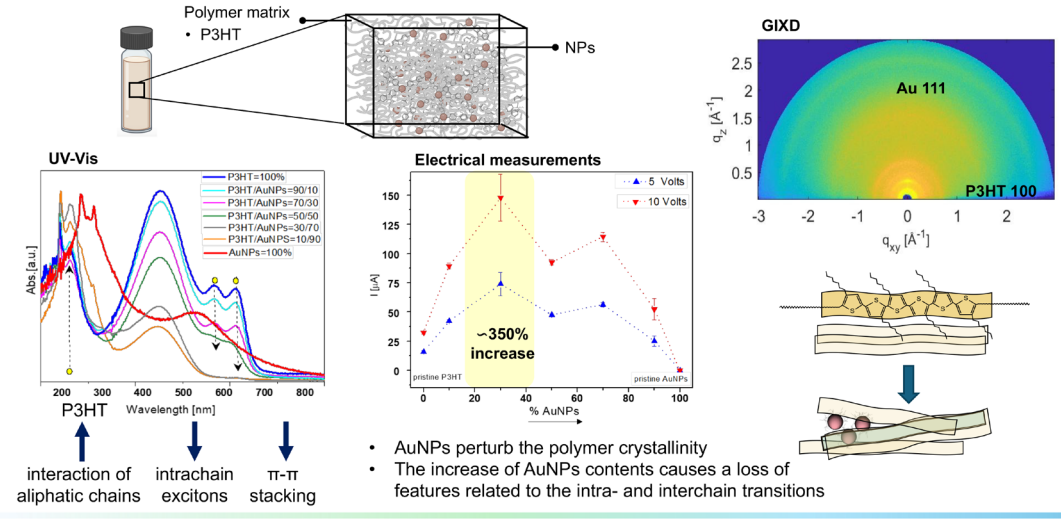
R. Li Voti et al., *Nanoscale Adv.* **2022**, *3*, 4692–4701

1. Gold nanoparticles | Fluorene-derivative aromatic di-thiol



S. Grigorian et al., *Synth. Met.* **2022**, *283*, 116973 *HR-TEM in collab. with Prof. O. Thomas, M. Textier group @Aix-Marseille Université*

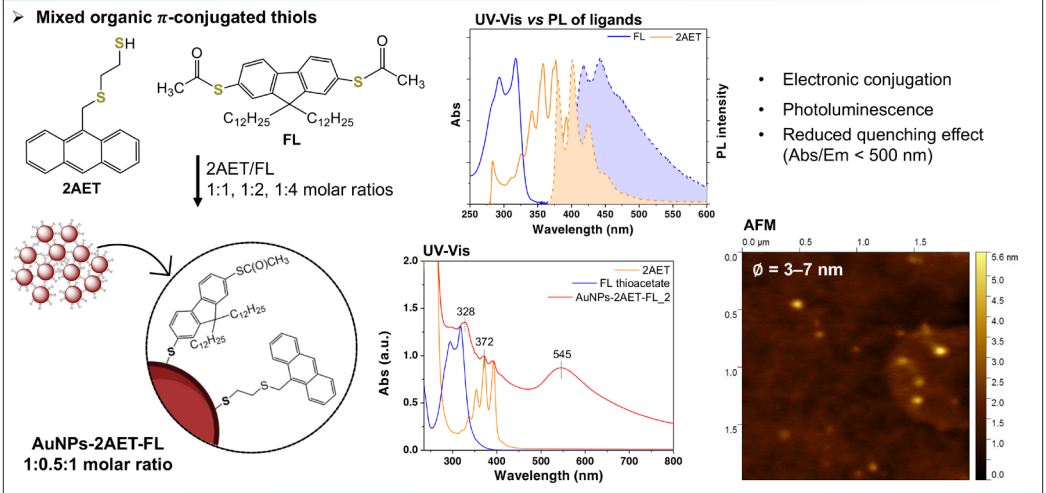
1. Gold nanoparticles | AuNPs-FL@P3HT: polymeric nanocomposite



- AuNPs perturb the polymer crystallinity
- The increase of AuNPs contents causes a loss of features related to the intra- and interchain transitions

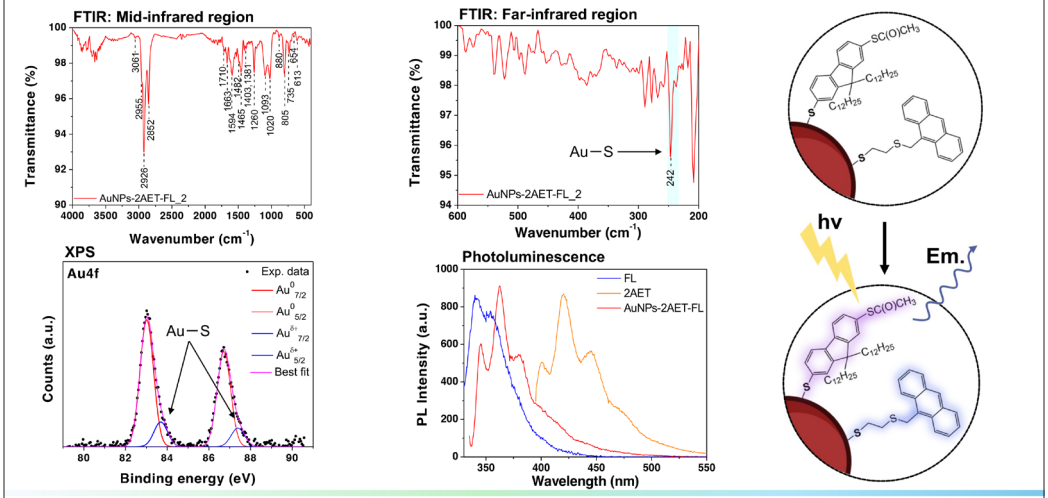
S. Grigorian et al., *Synth. Met.* **2022**, *283*, 116973

2. Gold nanoparticles | FL/2AET mixed aromatic di-thiols synergy



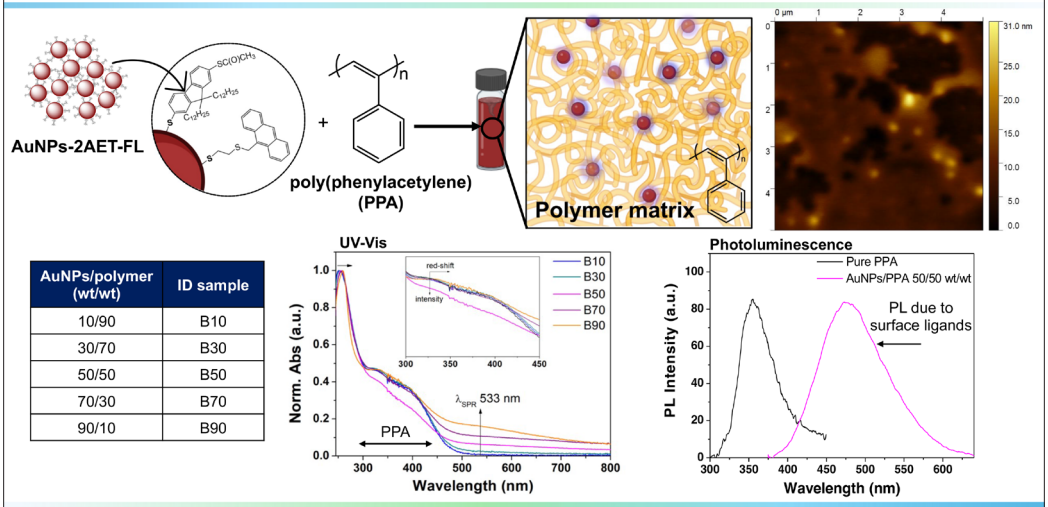
S. Cerra et al., *Inorg. Chim. Acta* **2025**, *579*, 122553

2. Gold nanoparticles | FL/2AET mixed aromatic di-thiols synergy



S. Cerra et al., *Inorg. Chim. Acta* **2025**, *579*, 122553

2. Gold nanoparticles | AuNPs-2AET-FL@PPA: polymeric nanocomposite



AuNPs/polymer (wt/wt)	ID sample
10/90	B10
30/70	B30
50/50	B50
70/30	B70
90/10	B90

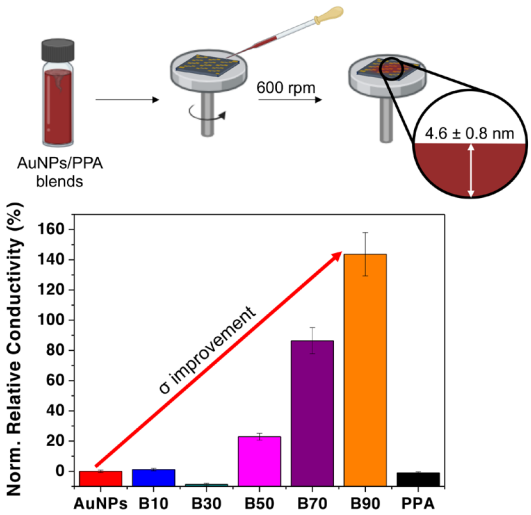
S. Cerra et al., *Inorg. Chim. Acta* **2025**, *579*, 122553

2. Gold nanoparticles | AuNPs-2AET-FL@PPA: polymeric nanocomposite

AuNPs/polymer (wt/wt)	Band gap ± 0.05 eV
AuNPs	4.13
PPA	2.47
10/90 (B10)	2.44
30/70 (B30)	2.41
50/50 (B50)	2.35
70/30 (B70)	2.34
90/10 (B90)	2.15

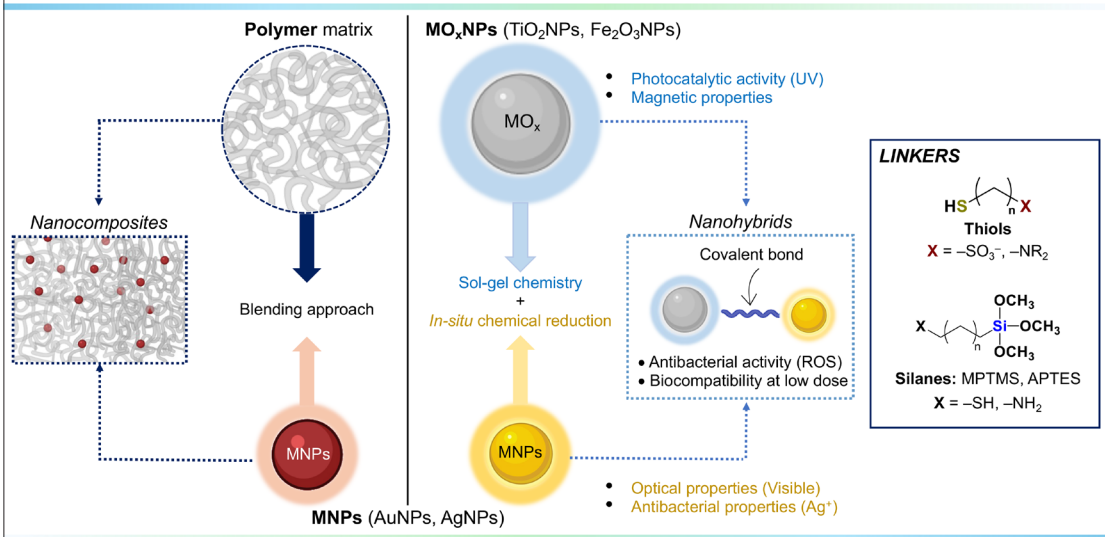
Band gap reduction

- About 50% band gap reduction after 10% PPA addition
- 2.5 times conductivity gain with respect to pristine AuNPs and pure PPA

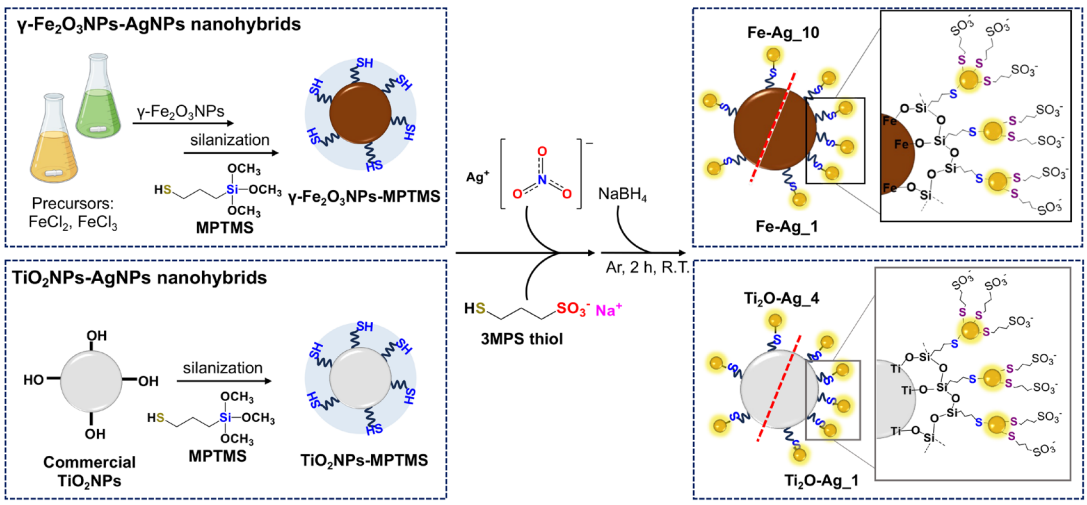


S. Cerra et al., *Inorg. Chim. Acta* **2025**, *579*, 122553

3. From polymeric nanocomposites to covalent nanohybrids

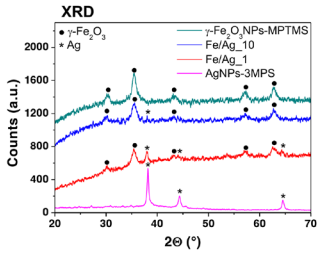


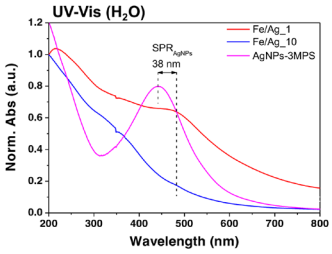
3. Hydrophilic MNPs-MO_xNPs nanohybrids | Fe_2O_3NPs-AgNPs and TiO_2NPs-AgNPs

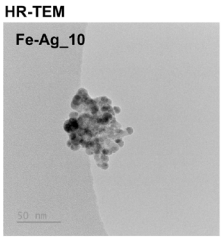


M. Mercurio et al. *ACS Appl. Nano Mater.* **2024**, *7*, 21124−21140 M. Mercurio et al. *ACS Appl. Nano Mater.* **2025**, *8*, 9227−9242

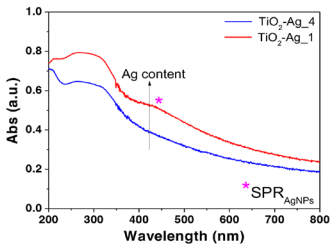
3. Hydrophilic MNPs-MO_xNPs nanohybrids | Fe_2O_3NPs-AgNPs and TiO_2NPs-AgNPs

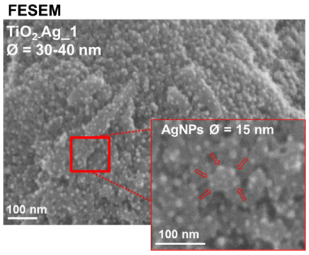






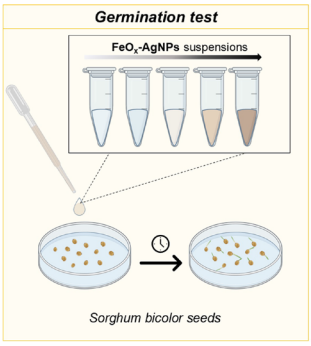
NPs type	NPs-MPTMS/$AgNO_3$ weight ratio
Fe-Ag_1	1:1
Fe-Ag_10	10:1
TiO_2-Ag_1	4:1
TiO_2-Ag_4	1:2.5

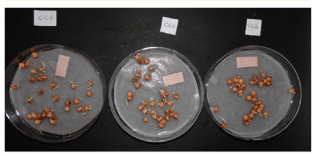




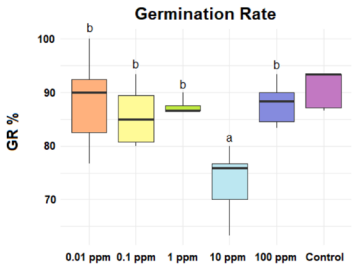
M. Mercurio et al. *ACS Appl. Nano Mater.* **2024**, *7*, 21124−21140 M. Mercurio et al. *ACS Appl. Nano Mater.* **2025**, *8*, 9227−9242

4. Hydrophilic Fe_2O_3NPs-AgNPs nanohybrids | Agri-food application





- Test as **seed nanoprimers** to evaluate their influence on *Sorghum bicolor* (L.) Moench Bianca seeds germination



ICP-OES

Fe_2O_3-Ag_10	Fe_2O_3-Ag_1
Ag = (15±1)%	Ag = (4±1)%
Fe = (45±1)%	Fe = (56±2)%
O = (40±1)%	O = (40±1)%

^{1}H-NMR metabolomic analysis (45 metabolites):
- **(0.01-1) ppm** → slight **increase in germination and metabolic activity**
- **(10-100) ppm** → lipid level decrease, reduced GR% oxidative stress and damage

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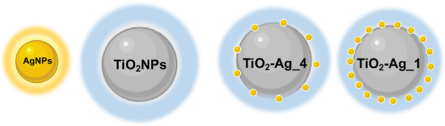
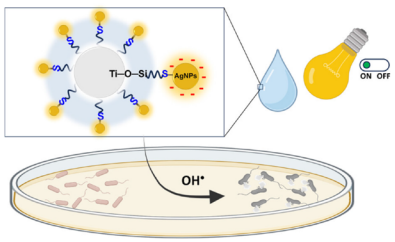
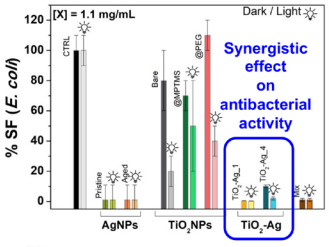
5. Hydrophilic TiO_2NPs-AgNPs nanohybrids | Antibacterial application



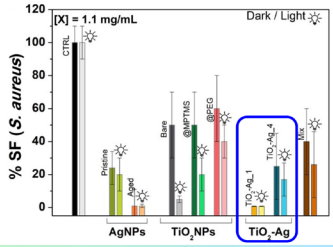
Ag⁺ concentration (ICP): **TiO_2-Ag_4**: 25.00 ± 0.01 µg/mL
TiO_2-Ag_1: 57.00 ± 0.01 µg/mL



25 min exposition in light/dark conditions



gram-negative bacteria
E. coli (10^5 CFU/mL)



gram-positive bacteria
S. aureus (10^5 CFU/mL)

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