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Multifunctional plasmonic nanoparticles for biomedical applications

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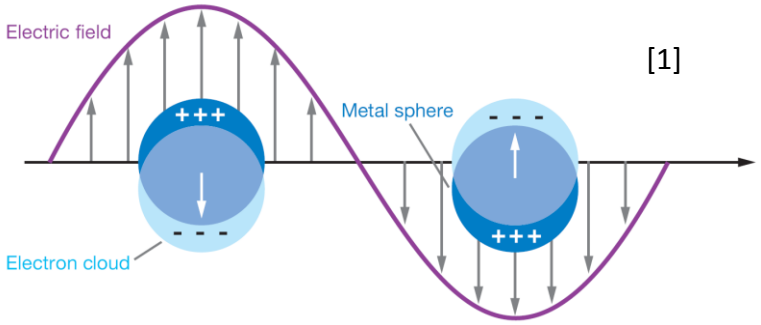
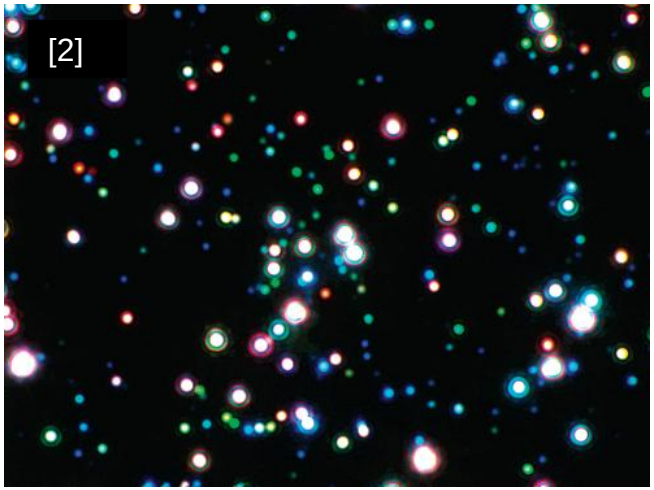
Plasmonic materials

- Noble metals (Gold, silver)
- Plasmons: Oscillation of surface conduction electron by electromagnetic radiation
- Silver is better than gold but also more toxic[1]

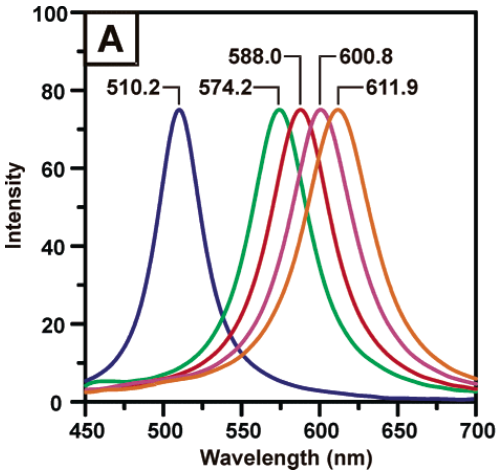


- Strongly scatter light[2]

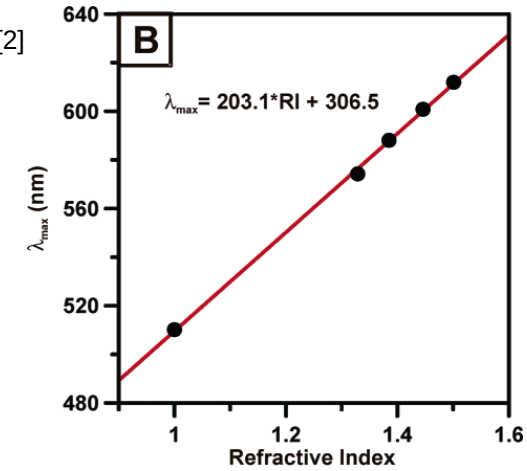


Dark field image of silver nanoparticles

- Plasmon absorption band: depends on refractive index surrounding plasmonic particles[2]



[2]



[1] Willets and Van Duyne, *Annu. Rev. Phys. Chem.* (2007), **58**, 267.
[2] McFarland and Van Duyne, *Nano Letters* (2003), **33**, 1057.

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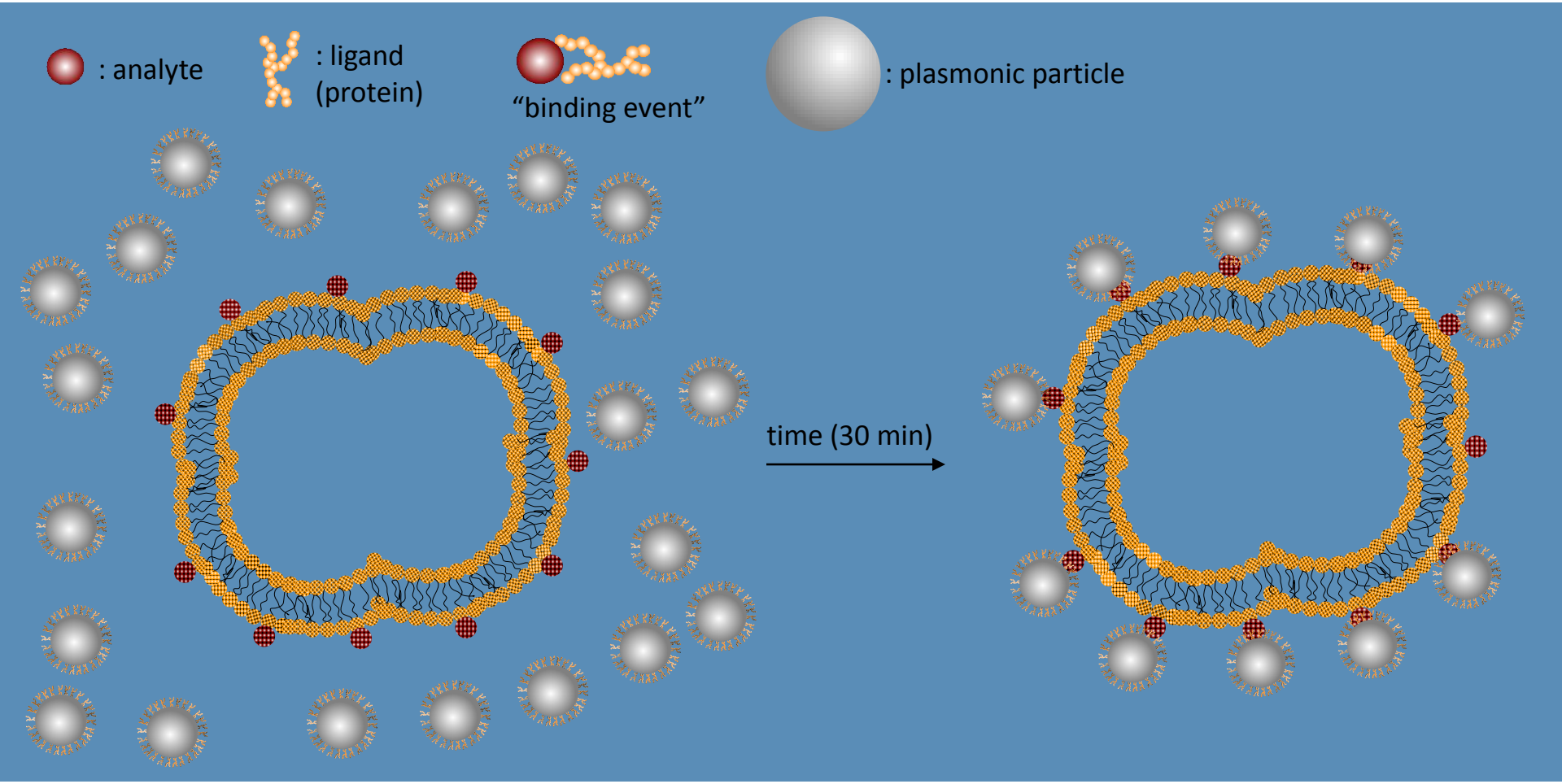
Plasmonic (e.g. Au, Ag) particles in bioimaging



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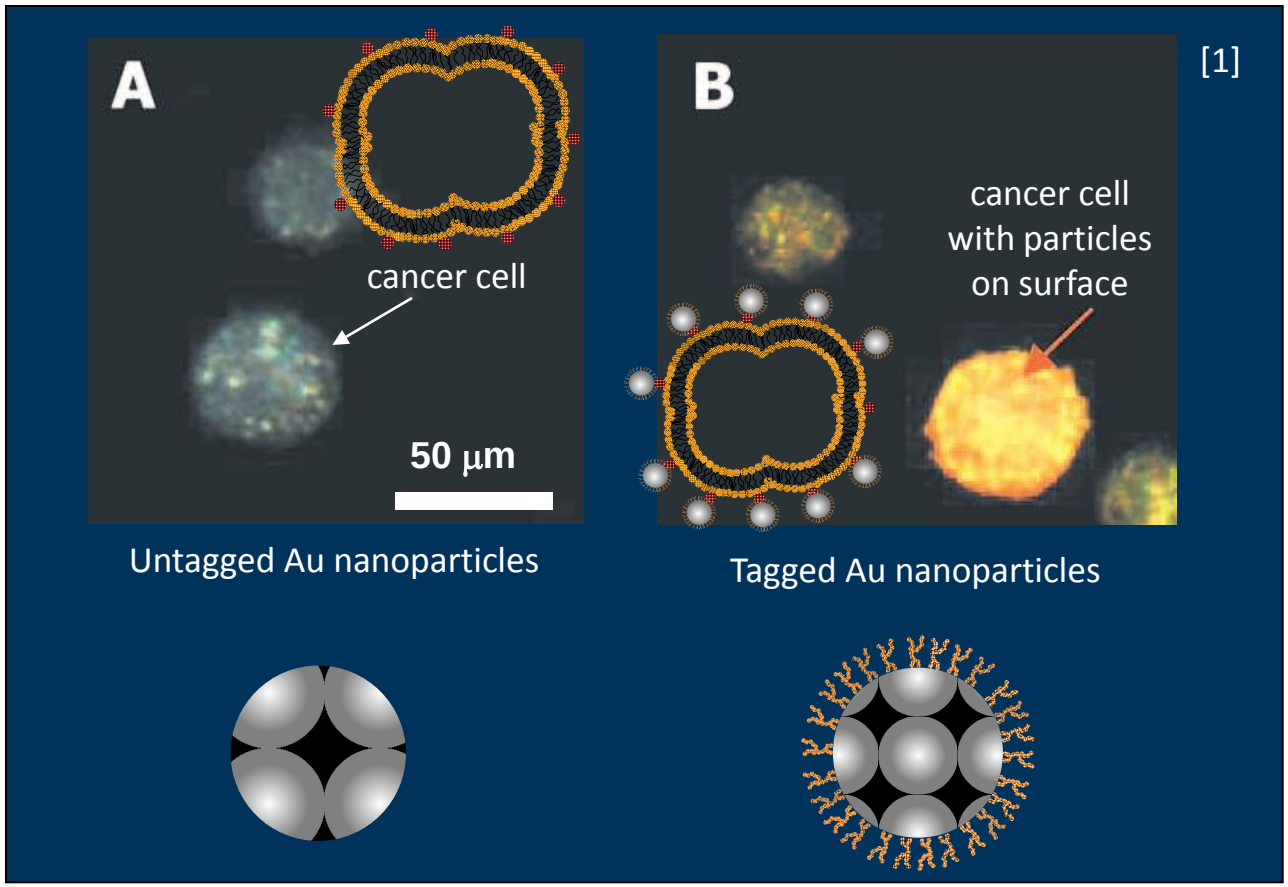

[1] Aaron, Nitin, Travis, Kumar, Collier, Park, Jose-Yacaman, Coghlan, Follen, Richards-Kortum, Sokolov, *J. Biomed. Opt.* **12**, 034007 (2007).

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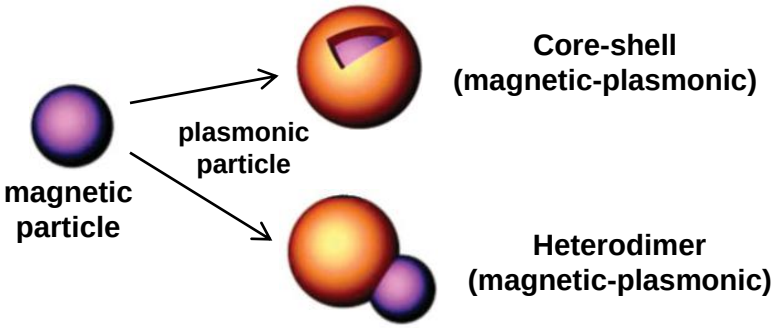
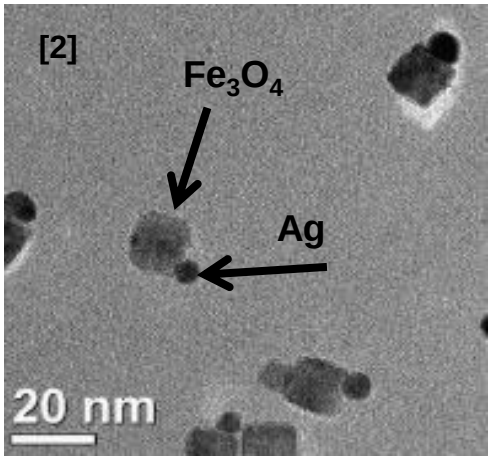
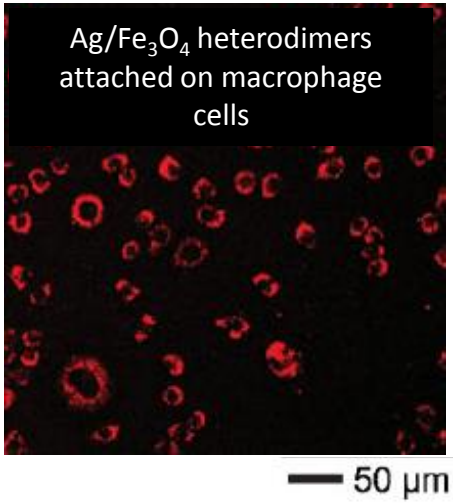
Multifunctional plasmonic-magnetic nanoparticles

- Hybrid **plasmonic**-**magnetic** nanostructures[1]:
  - Dual imaging (**microscopy**, **MRI**)
  - **Magnetic separation**
  - Therapy (**phototherapy**, **hyperthermia**)





- **Challenges:**
  - Toxicity?[3]
  - Stability against flocculation[4]
  - Many process-steps[1]



[1] Sotiriou, *WIREs Nanomed. Nanobiotechnol.* **in press**, DOI: 10.1002/wnan.1190 (2012).
[2] Jiang, Gu, Shao, Devlin, Papaefthymiou, Ying, *Adv. Mater.* **20**, 4403 (2008).
[3] Anker, Hall, Lyandres, Shah, Zhao Van Duyne, *Nature Mater.* **7**, 442 (2008).
[4] Ruenraroengsal, Cook, Florence, *J. Control. Release* **141**, 265 (2010).

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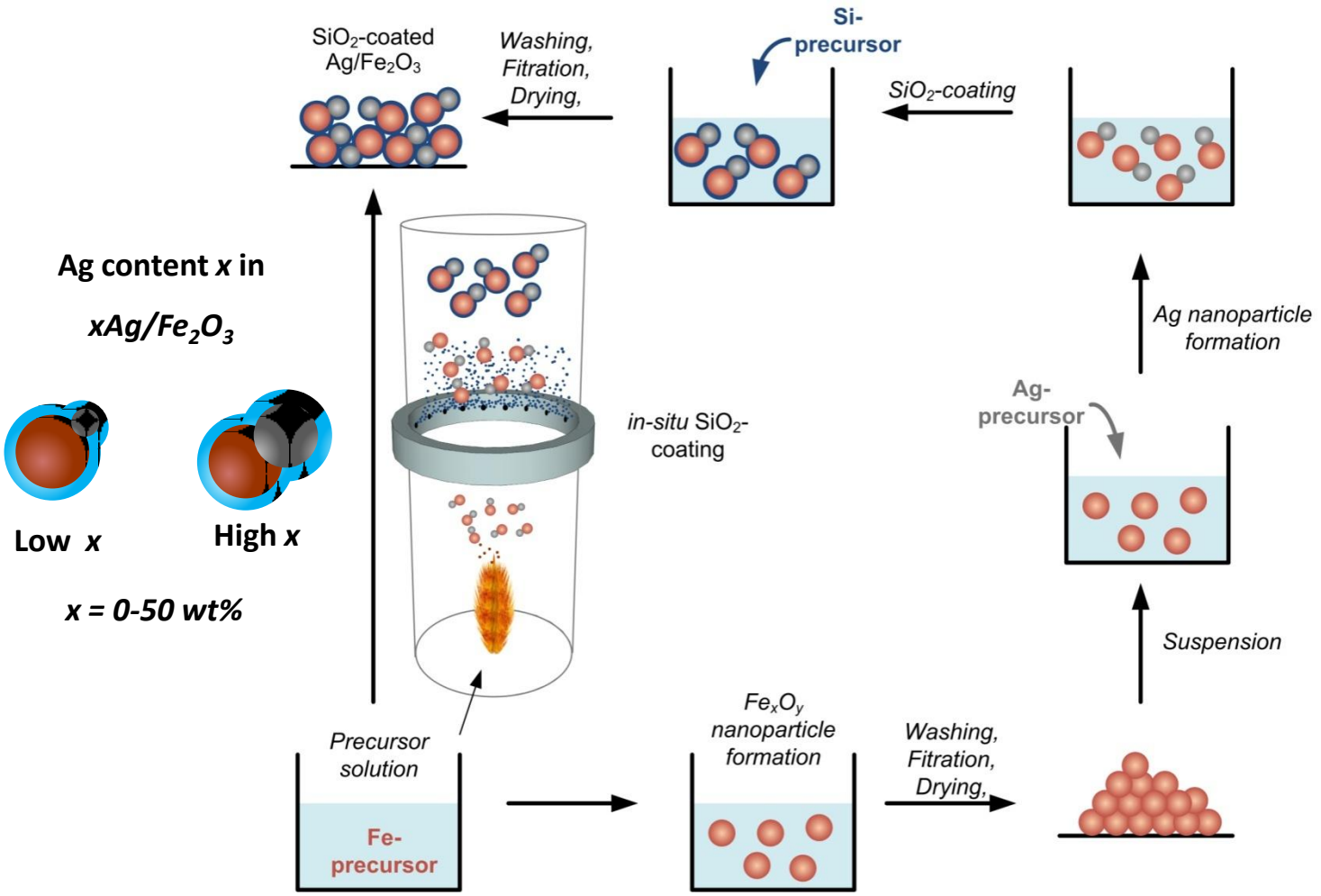
Hybrid plasmonic-magnetic nanoparticles - Synthesis



[1] Teleki, Heine, Krumeich, Akhtar Pratsinis, *Langmuir* **24**, 12553 (2008).
[2] Sotiriou, Sannomiya, Teleki, Krumeich, Vörös, Pratsinis, *Adv. Funct. Mater.* **20**, 4250 (2010).

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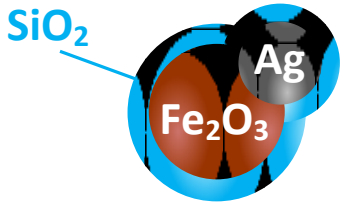
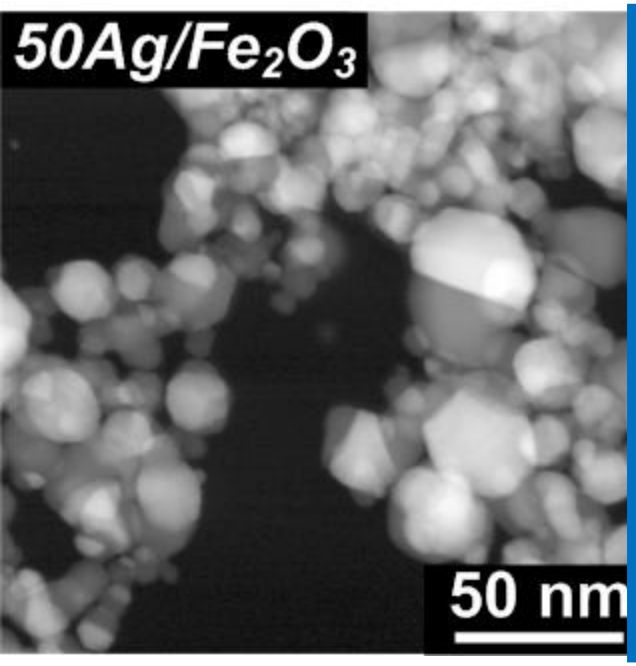
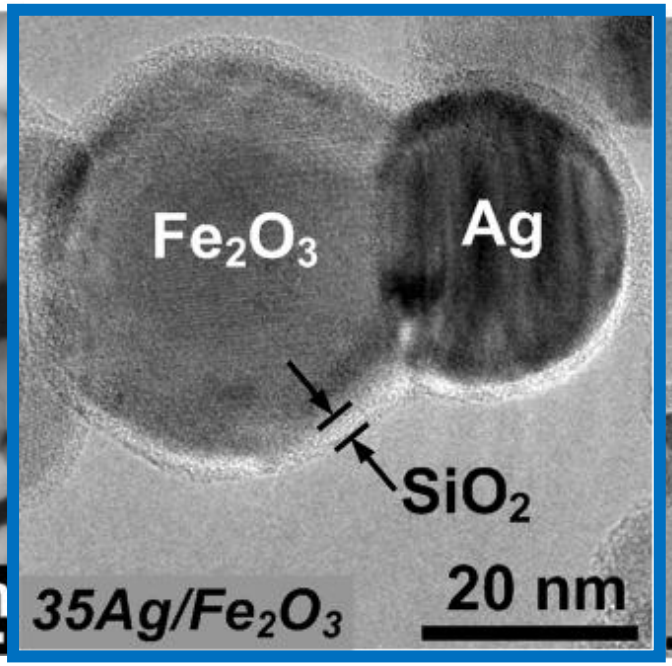
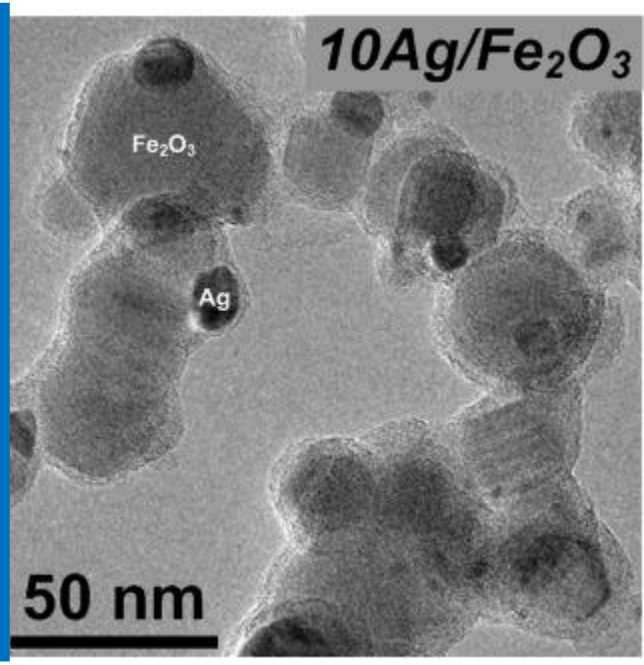
Hybrid Ag/Fe_2O_3 nanostructures









Sotiriou, Hirt, Lozach, Teleki, Krumeich, Pratsinis, *Chem. Mater.* **23**, 1985 (2011).

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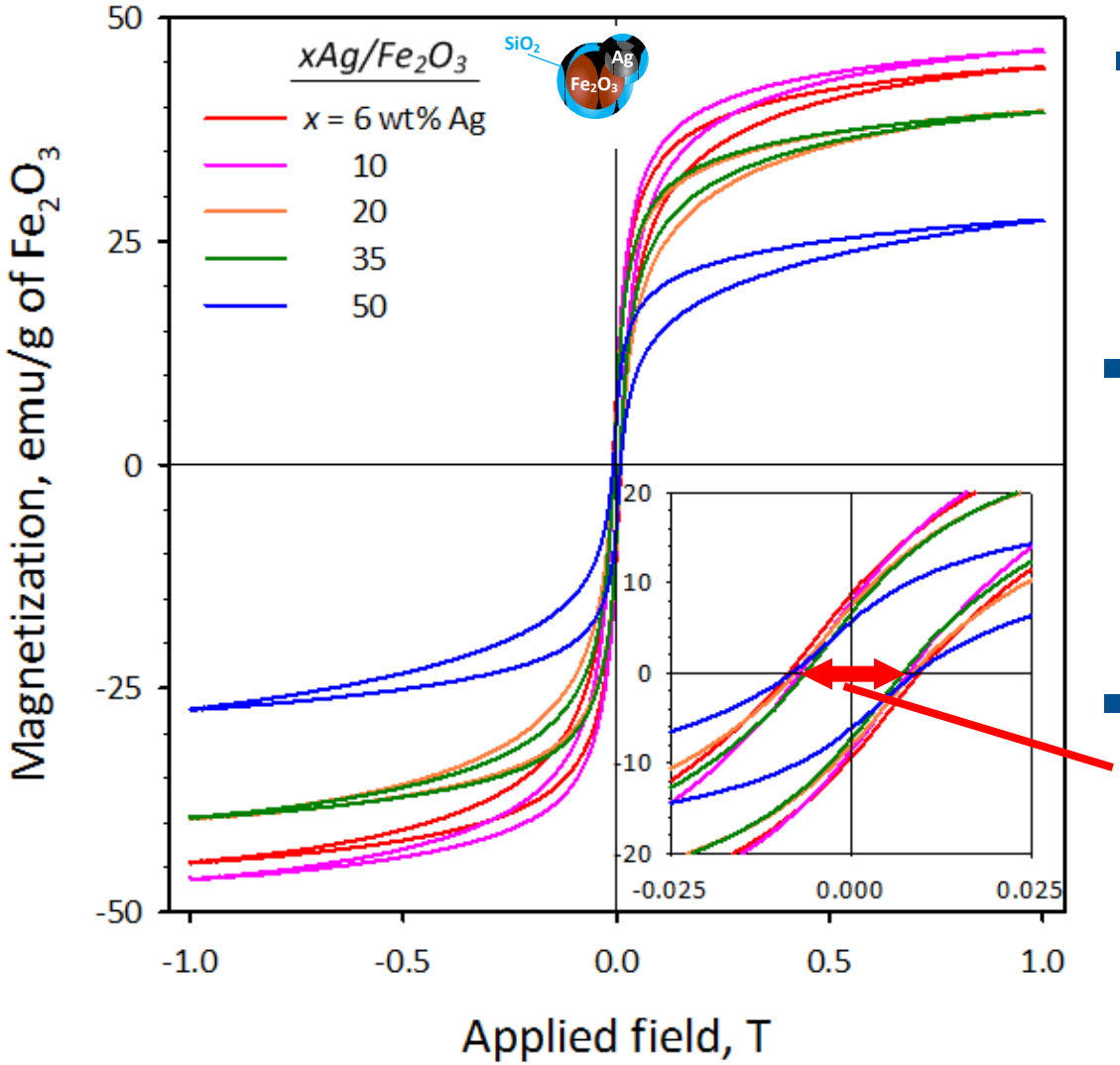
Magnetization of silica-coated Ag/Fe_2O_3



- Comparable magnetization for pure flame-made Fe_2O_3[1]
- Lower magnetization for x = 50 wt% Ag
  - Higher α-Fe_2O_3 content
- Near superparamagnetic behavior

[1] Teleki, Suter, Kidambi, Ergeneman, Krumeich, Nelson, Pratsinis, *Chem. Mater.* **21**, 2094 (2009).

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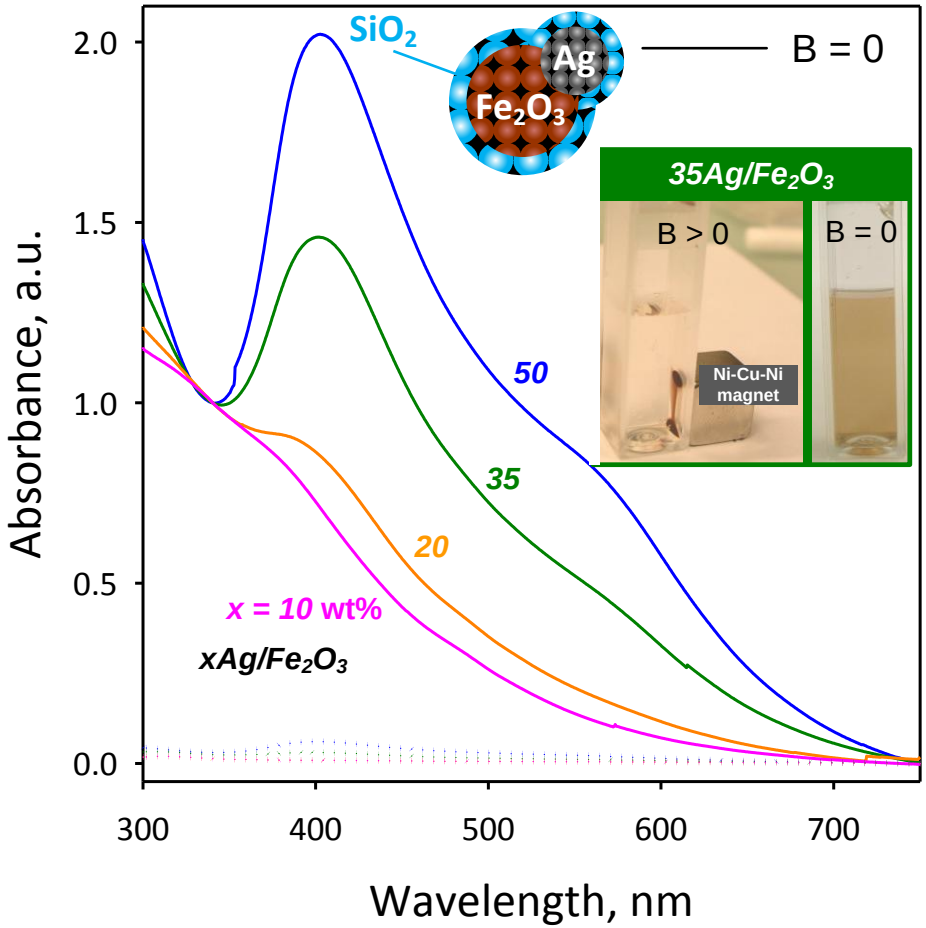
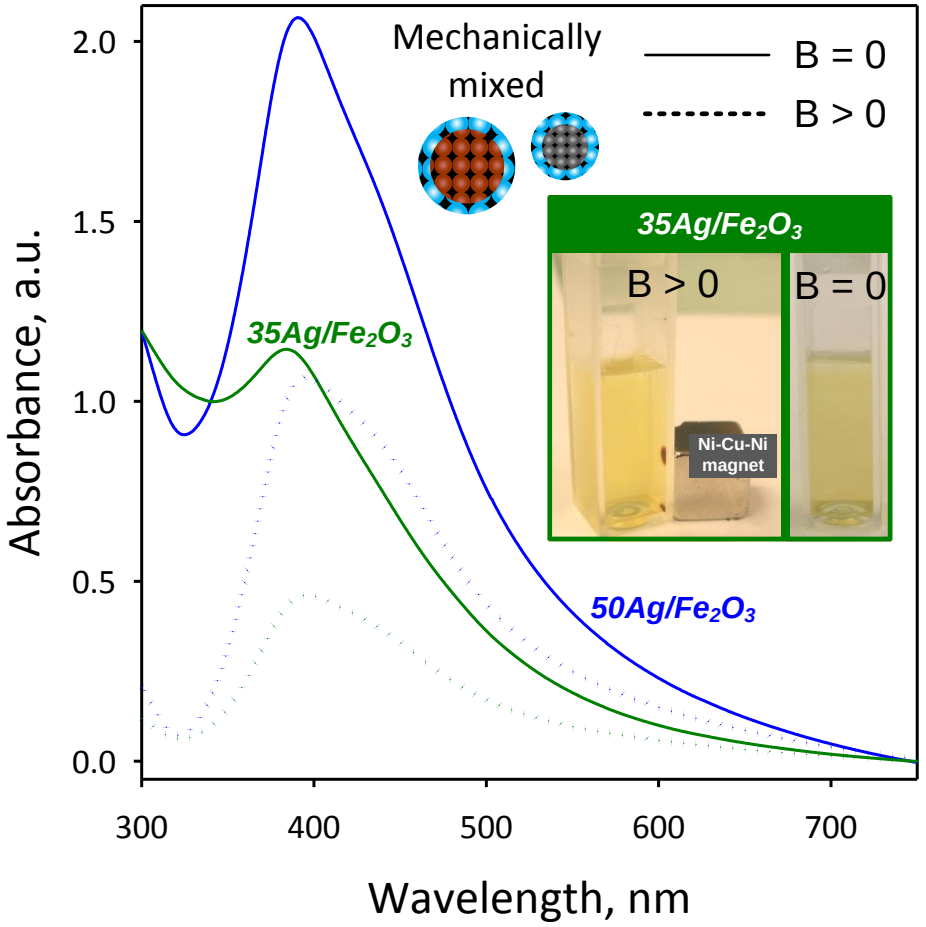
Plasmonic properties – Magnetic manipulation





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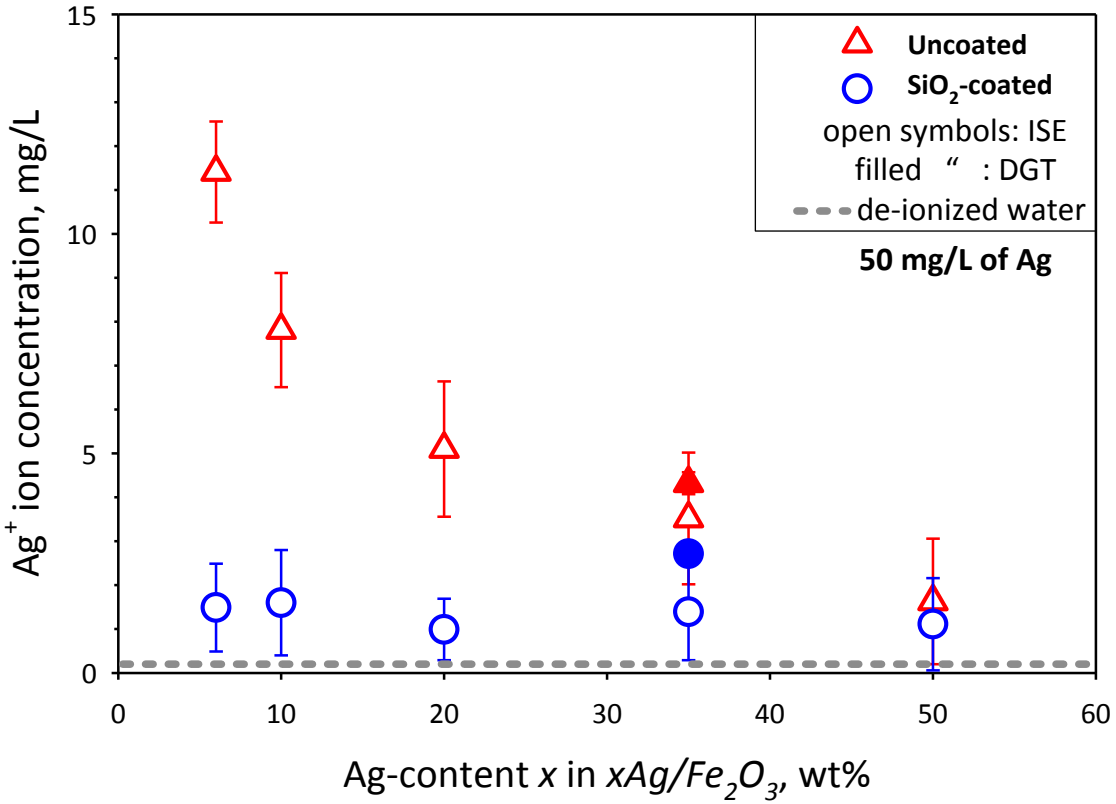
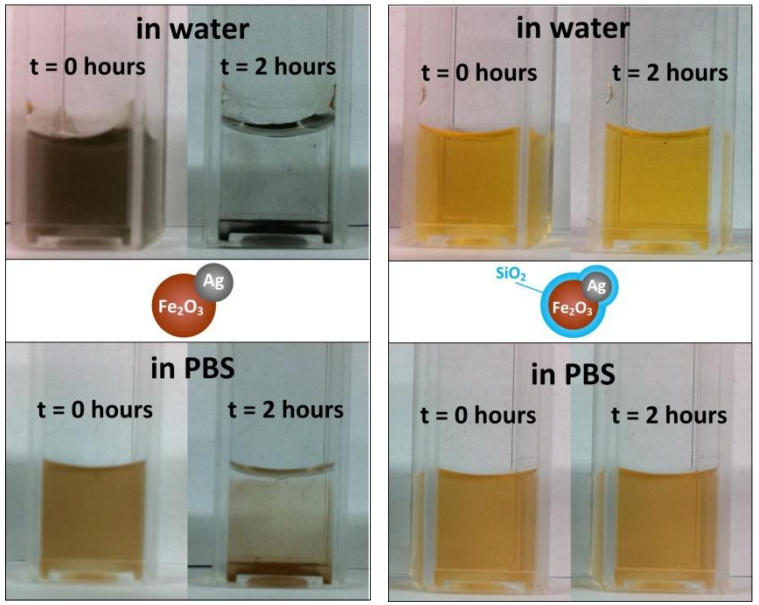
SiO_2-coating: Inhibition of toxic Ag^+ ion release



- Uncoated: Higher release for smaller Ag size[1,2]
- SiO_2-coating prevents Ag^+ ion release



[1] Sotiriou and Pratsinis, *Environ. Sci. Technol.* (2010), **44**, 5649.
[2] Sotiriou, Teleki, Camenzind, Krumeich, Meyer, Panke, Pratsinis, *Chem. Eng. J.* (2011), **170**, 547.

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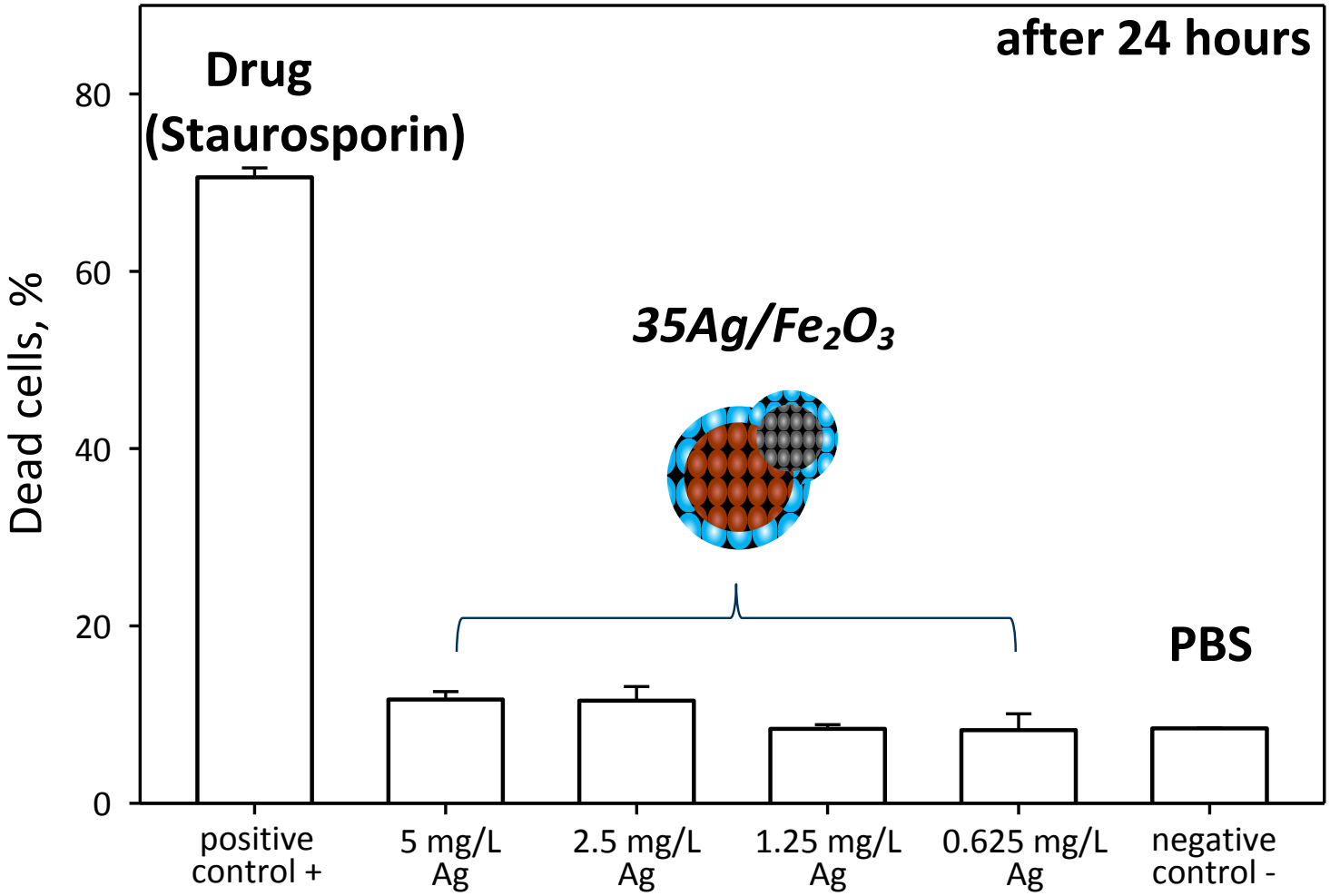
Biocompatible hybrid nanoparticles (HeLa cells)



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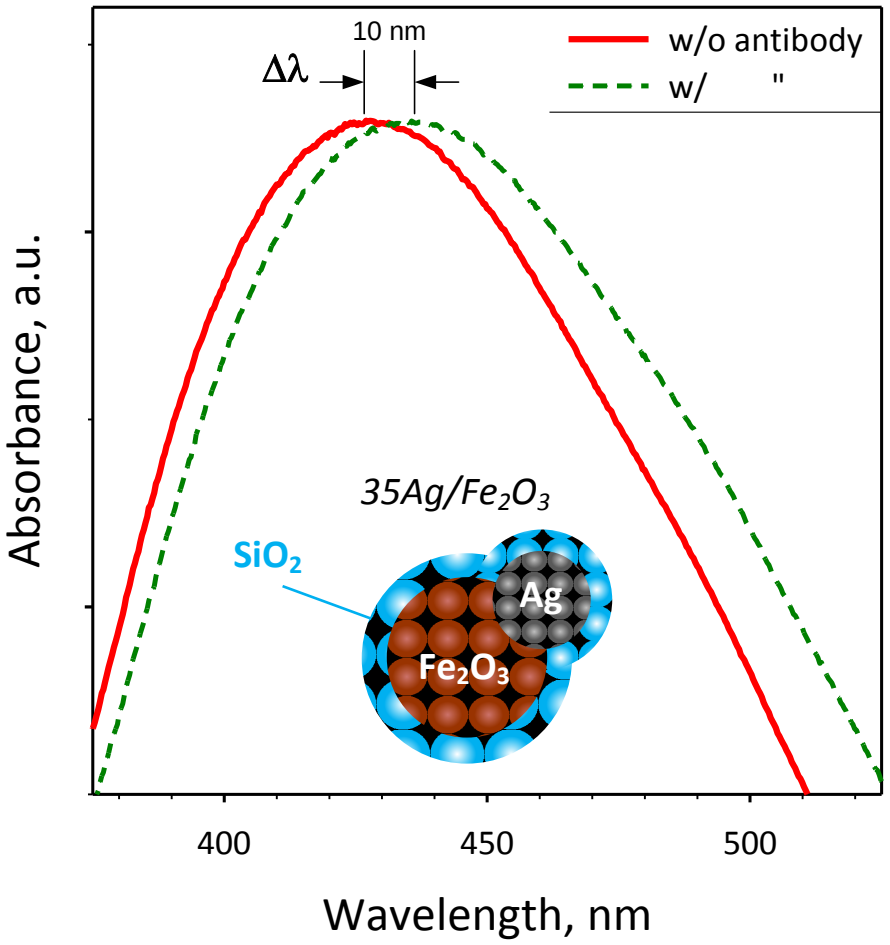
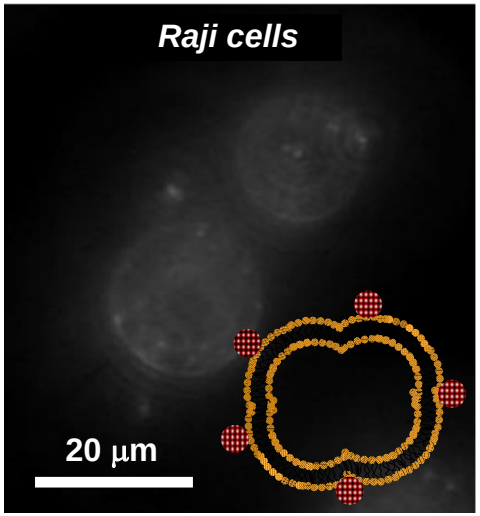
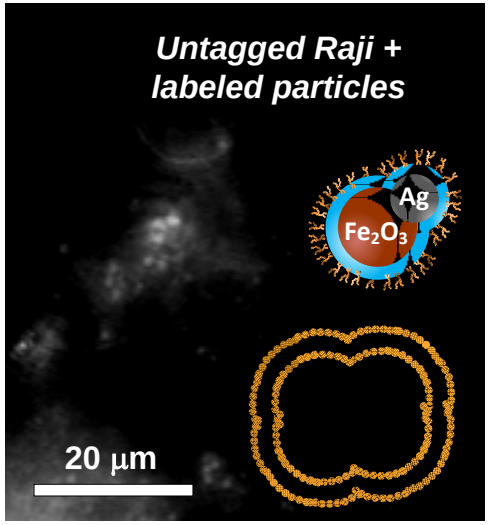
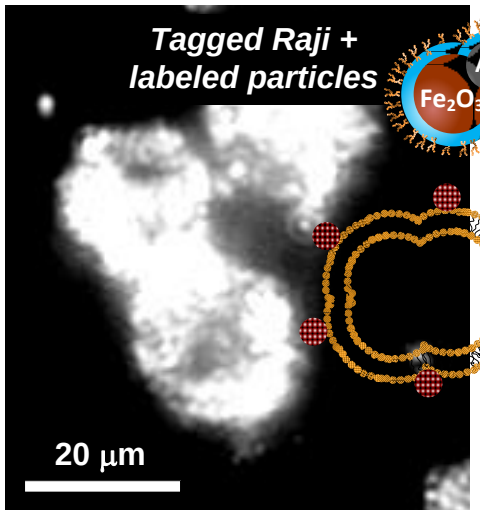
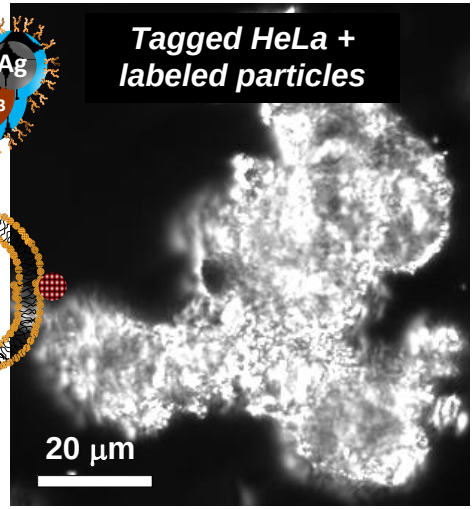
Biofunctionalization – Cell detection











Sotiriou, Sannomiya, Teleki, Krumeich, Vörös, Pratsinis, *Adv. Funct. Mater.* **20**, 4250 (2010).
Sotiriou, Hirt, Lozach, Teleki, Krumeich, Pratsinis, *Chem. Mater.* **23**, 1985 (2011).

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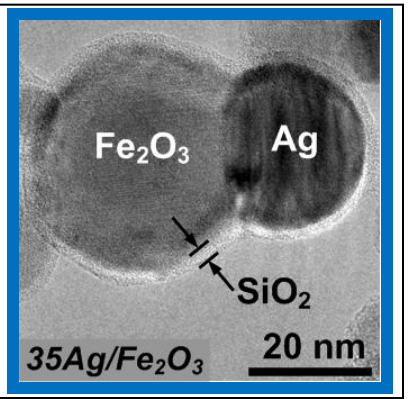
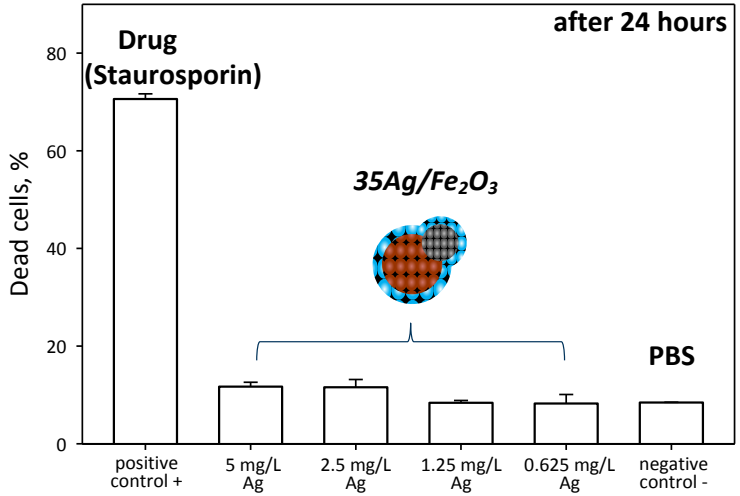
Conclusions

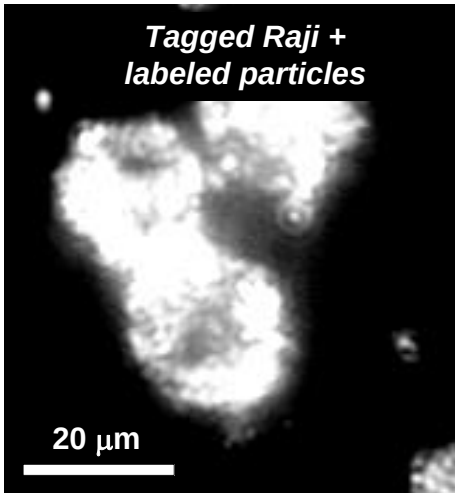
- **One-step** synthesis of SiO_2-coated Ag/Fe_2O_3



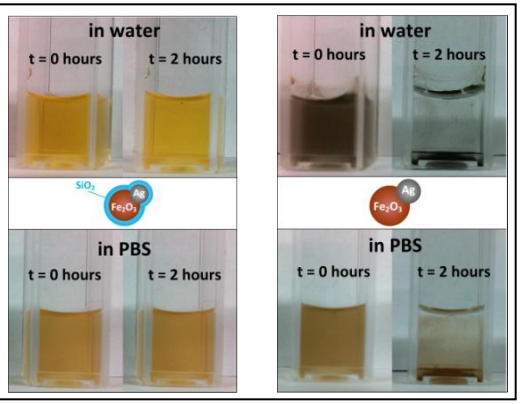
- Biocompatible hybrid nanoparticles



- Selective binding and detection of cells

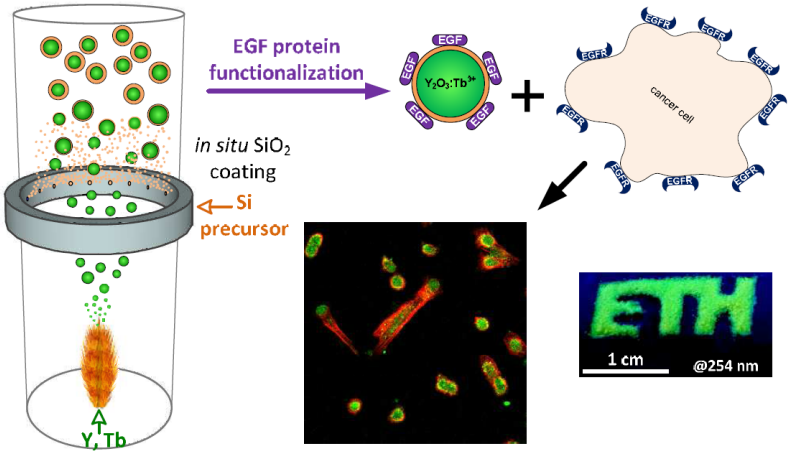


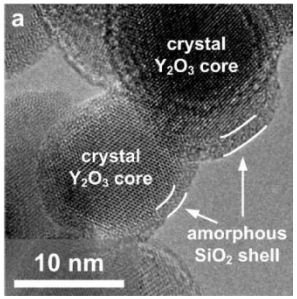
- SiO_2 coating prevents flocculation



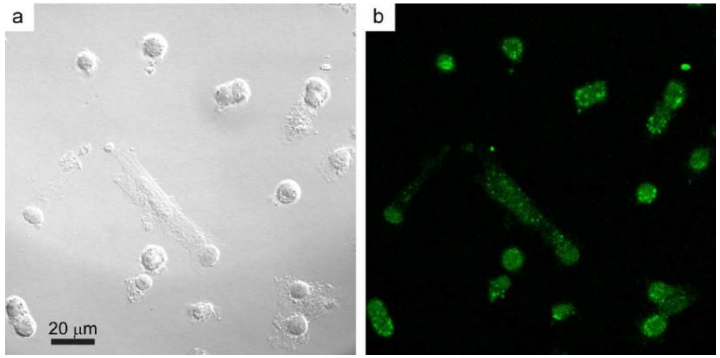
Outlook

- Surface biofunctionalization targeting cancer cells
- Photothermal treatment with IR laser
- *In-vitro* towards *in-vivo*



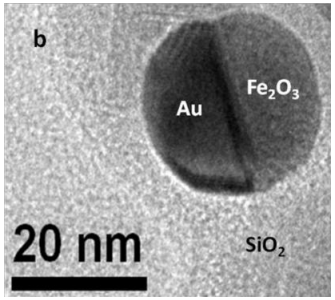


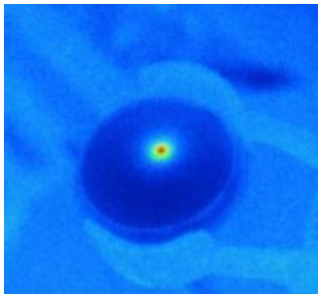
Biofunctionalization with EGF



Melanoma cells overexpressing EGF receptor

Under nanophosphor excitation

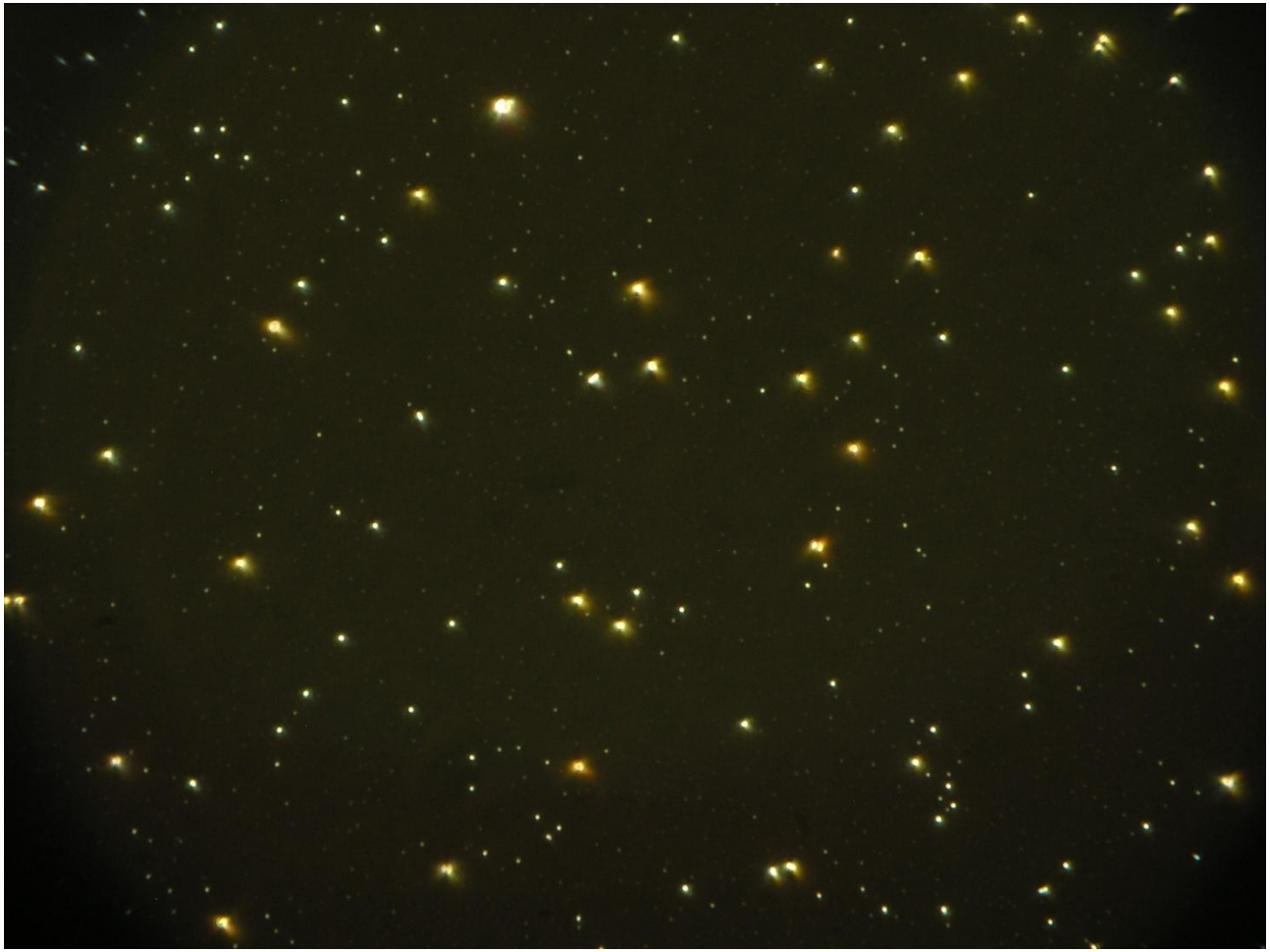


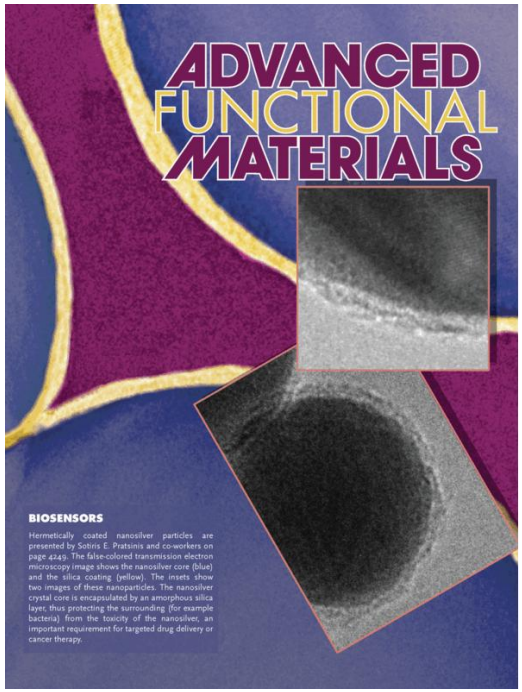


Under laser irradiation

Sotiriou, Franco, Poulikakos, Ferrari, *ACS Nano* **6**, 3888-3897 (2012).

Thank you for listening





"SiO_2-coated nanosilver particles dispersed in water under dark-field illumination"

Sotiriou, Sannomiya, Teleki, Krumeich, Vörös, Pratsinis, *Adv. Funct. Mater.* (2010), **20**, 4250.