# Plasmonic nanostructures employed for optical and colorimetric (bio)sensing strategies

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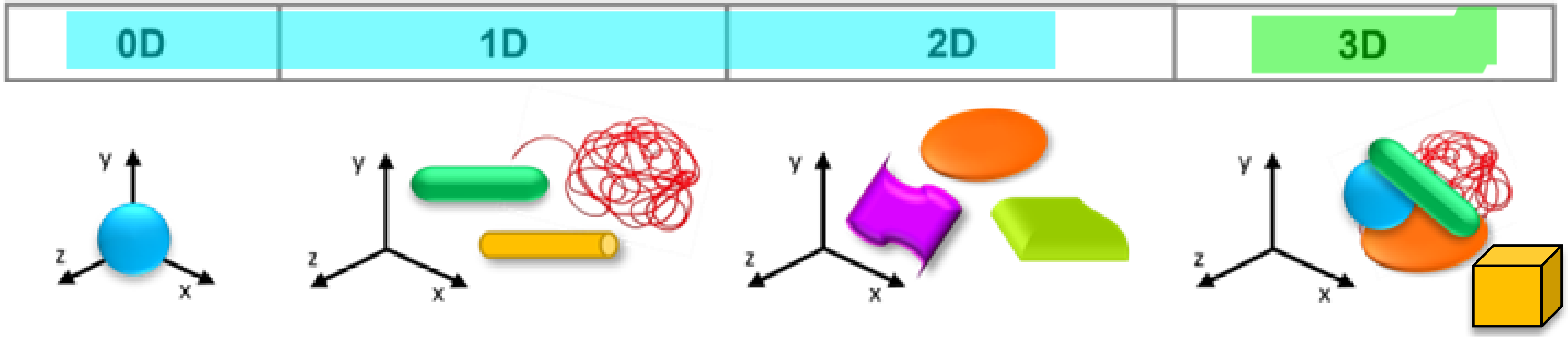
# Nanomaterials

“any intentionally produced material that has one or more dimensions of the order of 100 nm or less

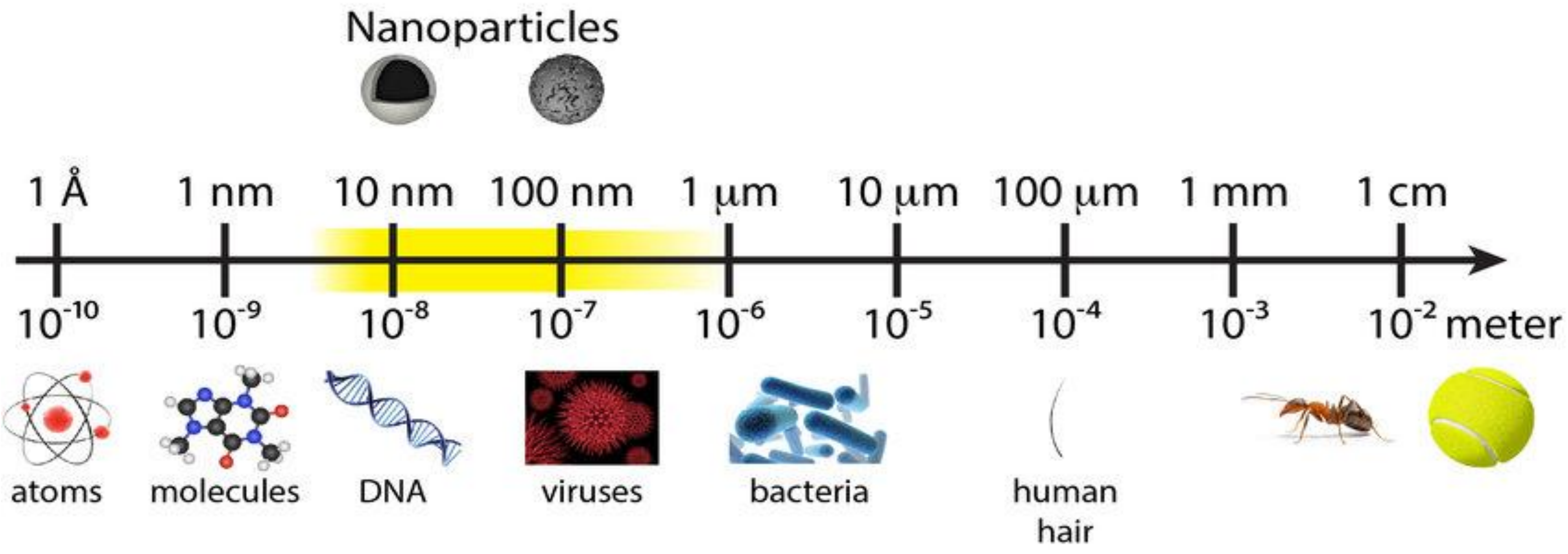
or that is composed of discrete functional parts, either internally or at the surface, many of which have one or more dimensions of the order of 100 nm or less, including structures, agglomerates or aggregates, which may have a size above the order of 100 nm but retain properties that are characteristic of the nanoscale”.

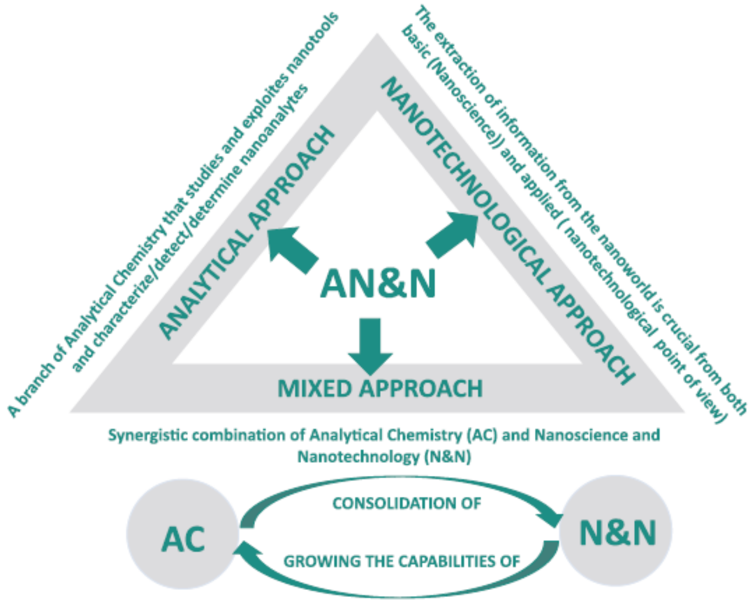


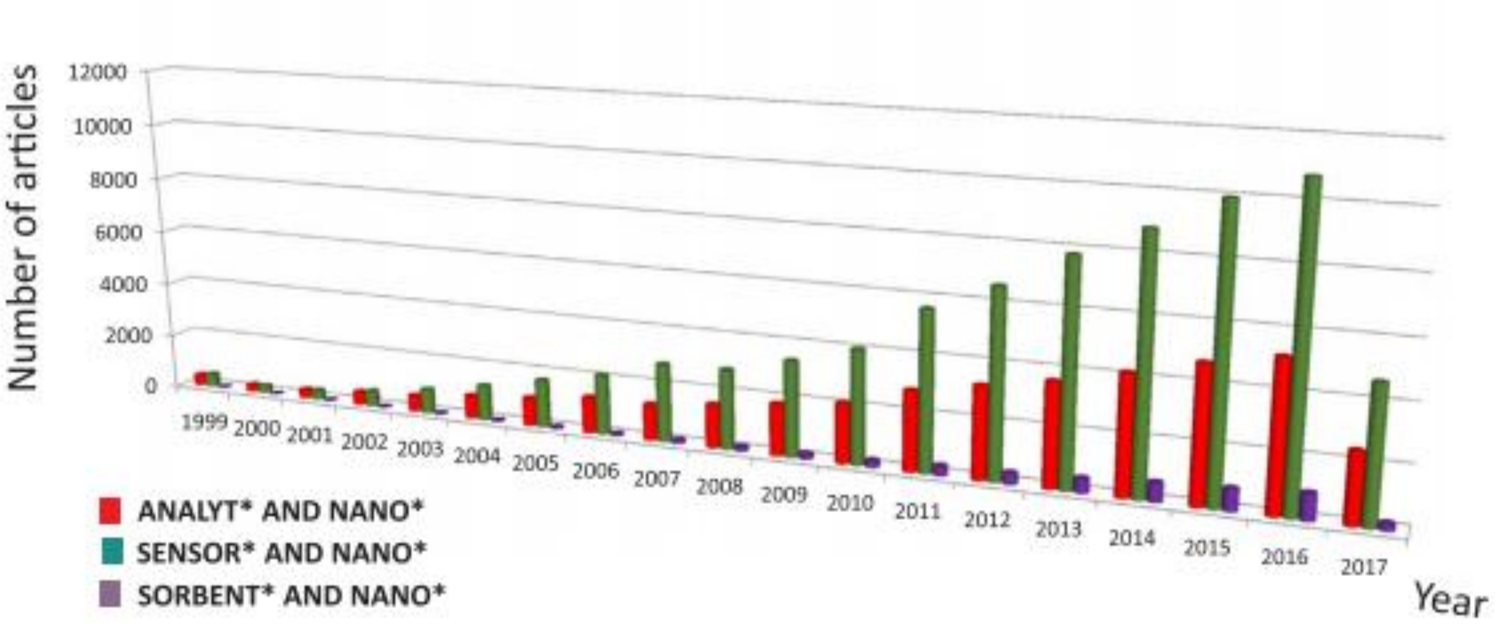

(also films and coats)

Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001 (Text with EEA relevance)

# Is this Nano?



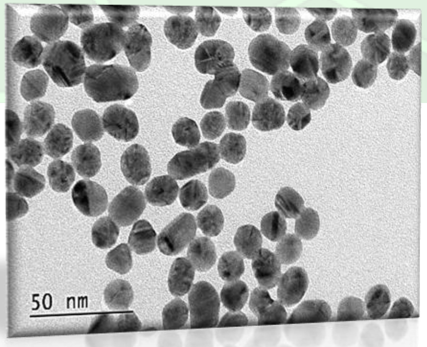



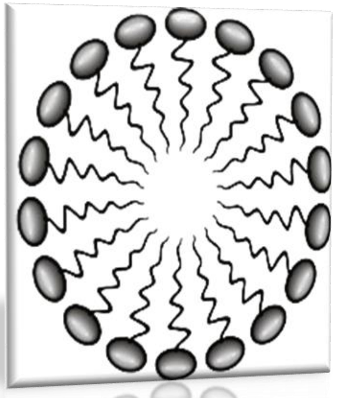

European Commission, Commission Recommendation of 18 October 2011 on the definition of nanomaterial, Official Journal of the European Union. 2011/696/EU: 38-40, 2011

# Nanomaterials

Metal NPs

Nano-objects
Nano-particles

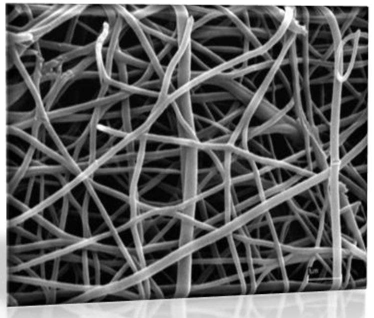


Micelle

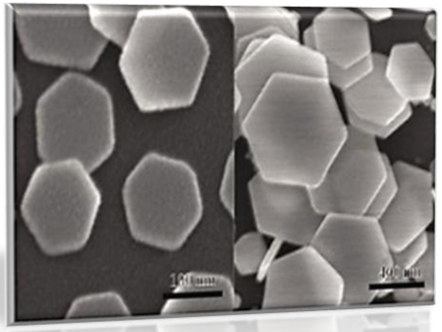
Nanomaterials
(NMs)

Nanofiber

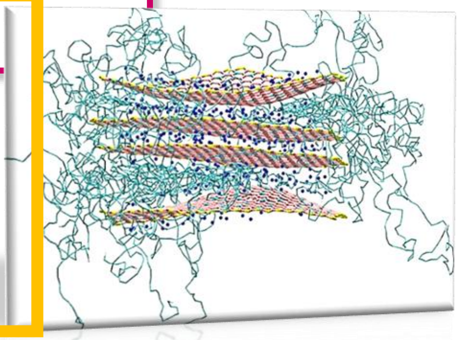


Nanoformulations

Nanoplate



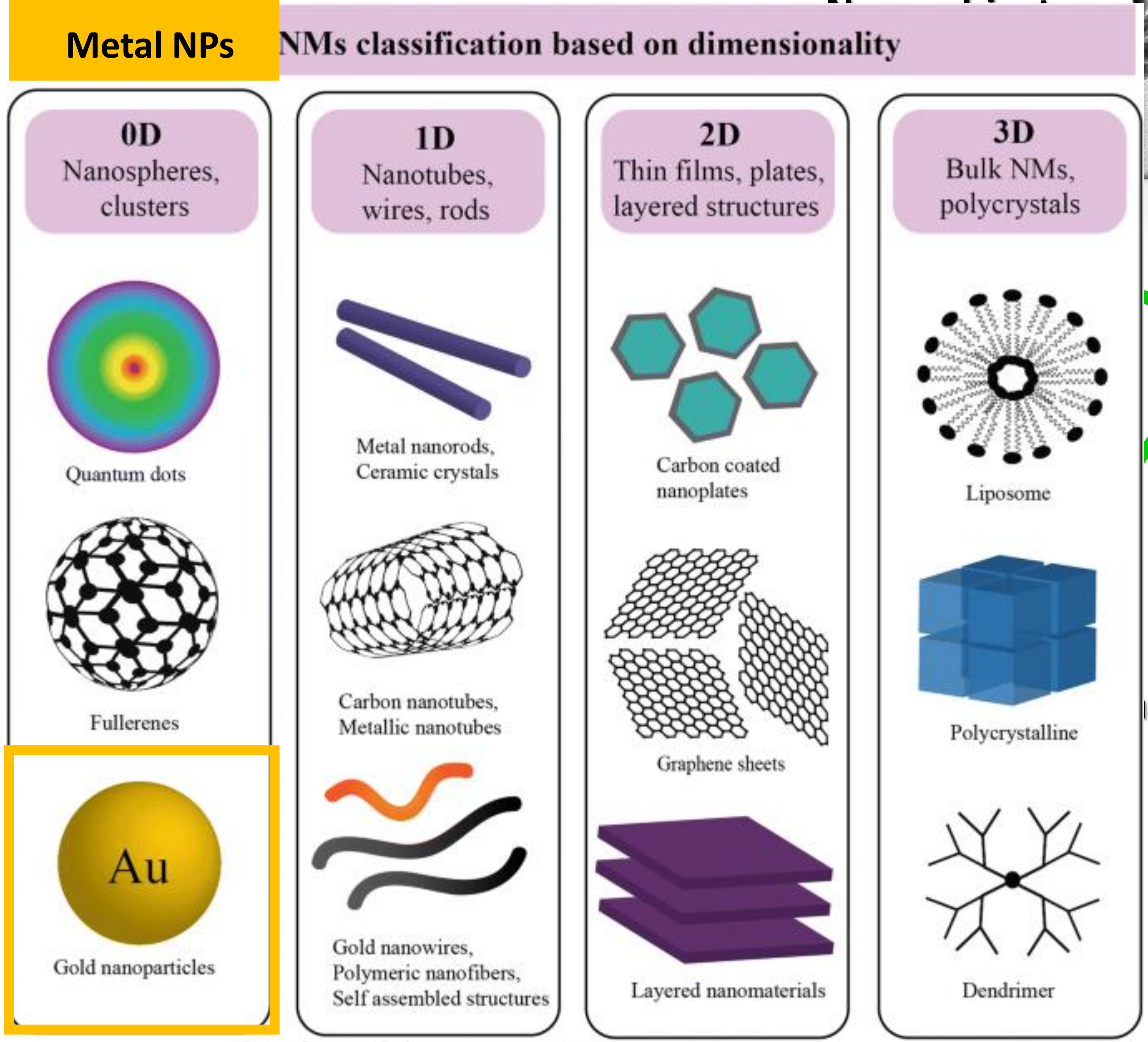
*Nanocomposite*

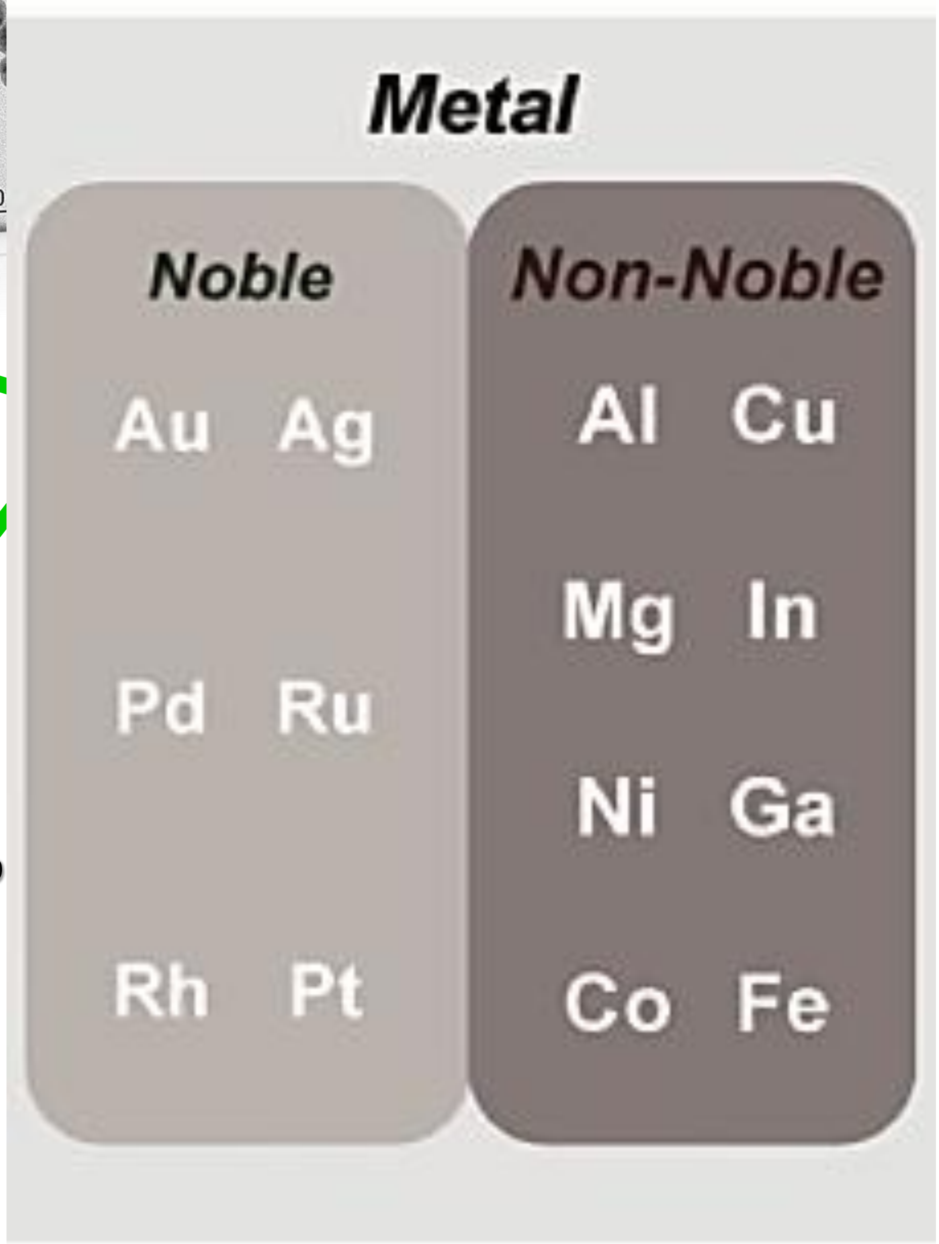


# Nanomaterials

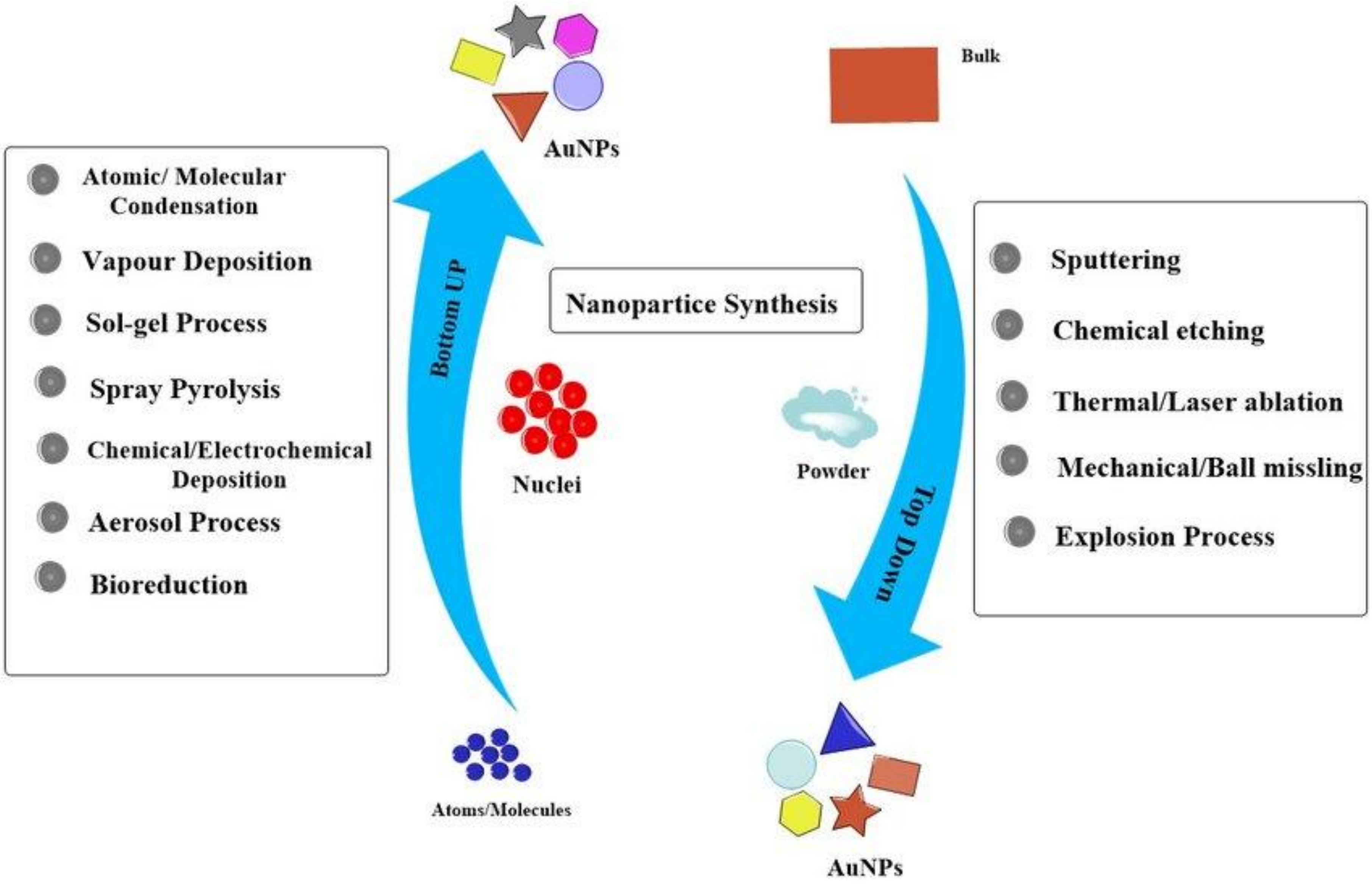


Metal NPs

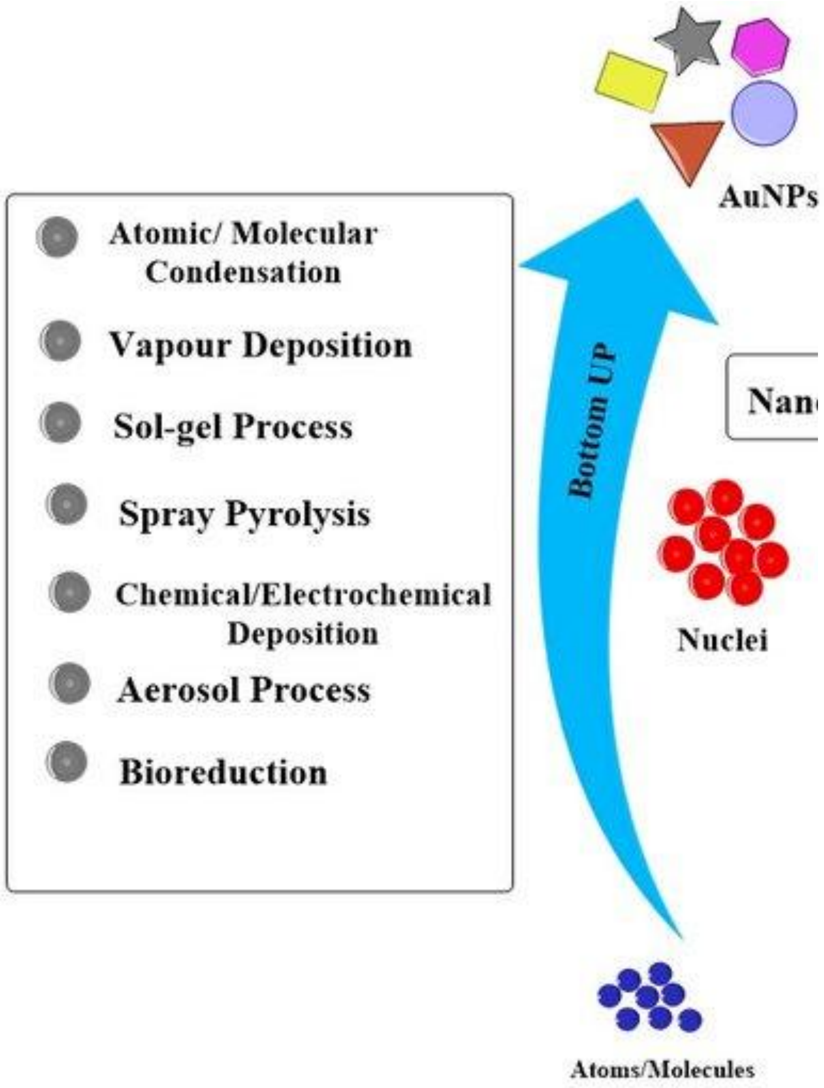


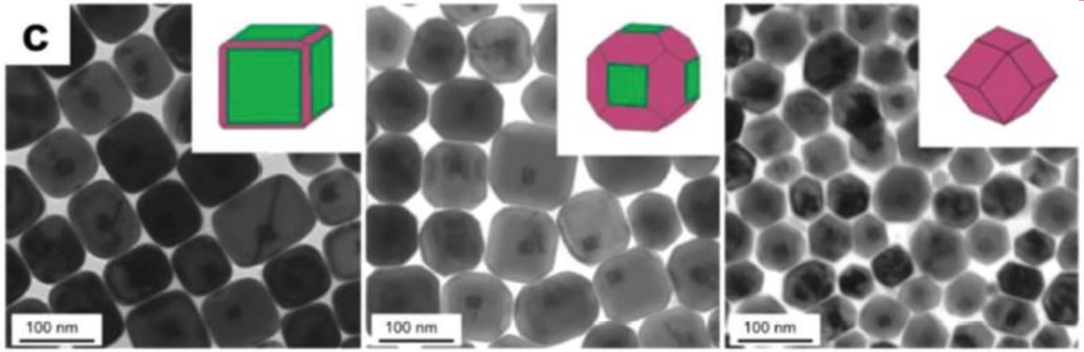
# Metal based Nanoparticles



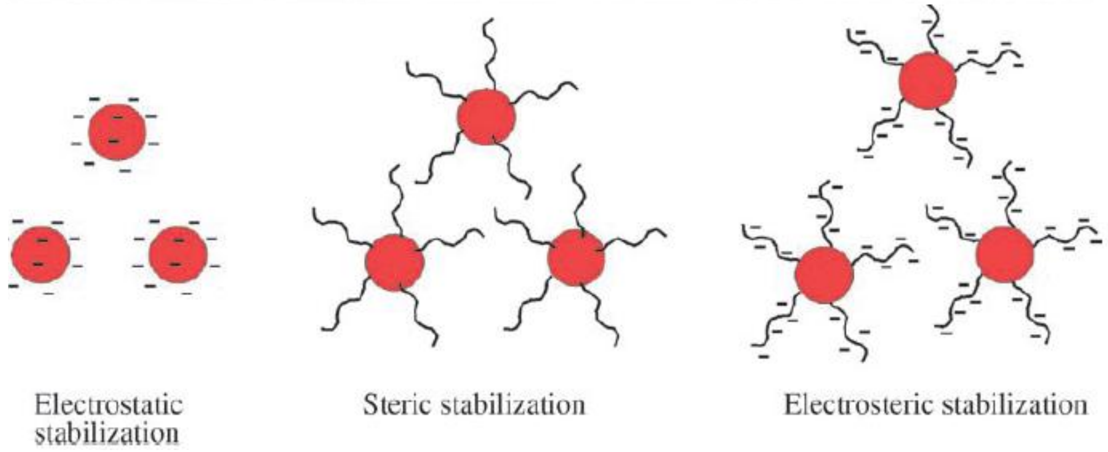
# Metal based Nanoparticles



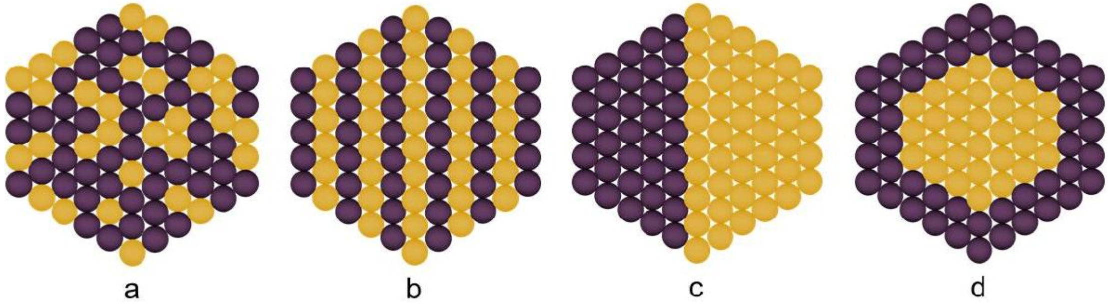

SHAPE




SURFACE

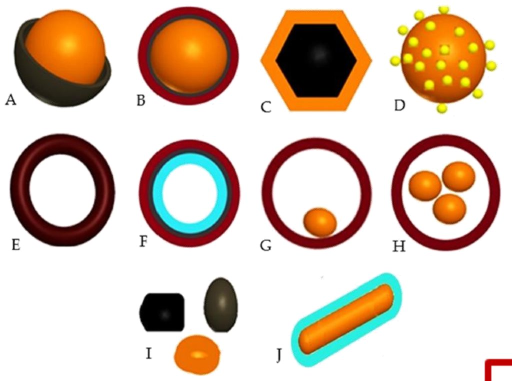


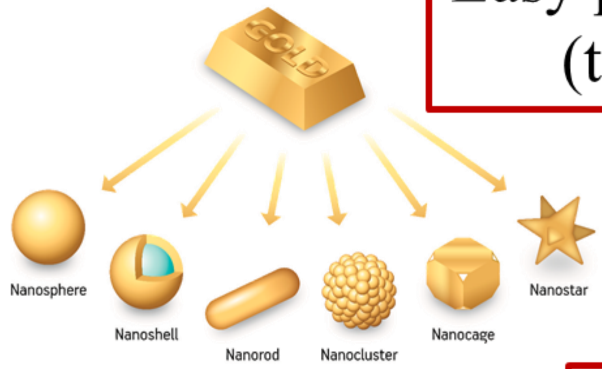

COMPOSITION



# Advantages of metal nanoparticles for analyitical purposes



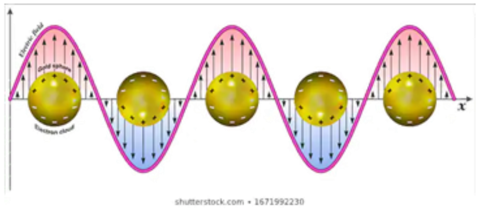


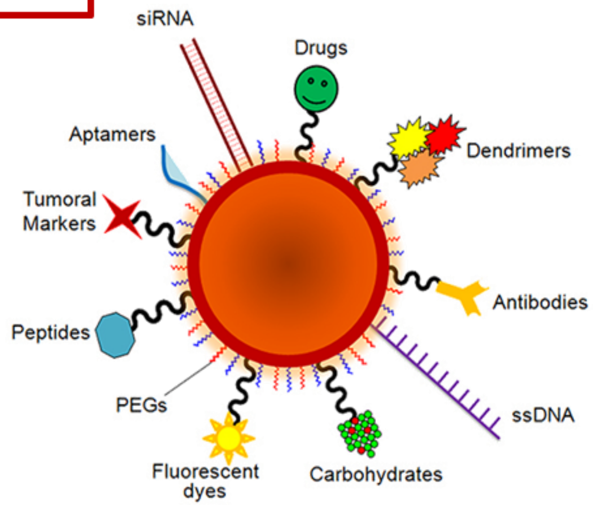




**MNPs**

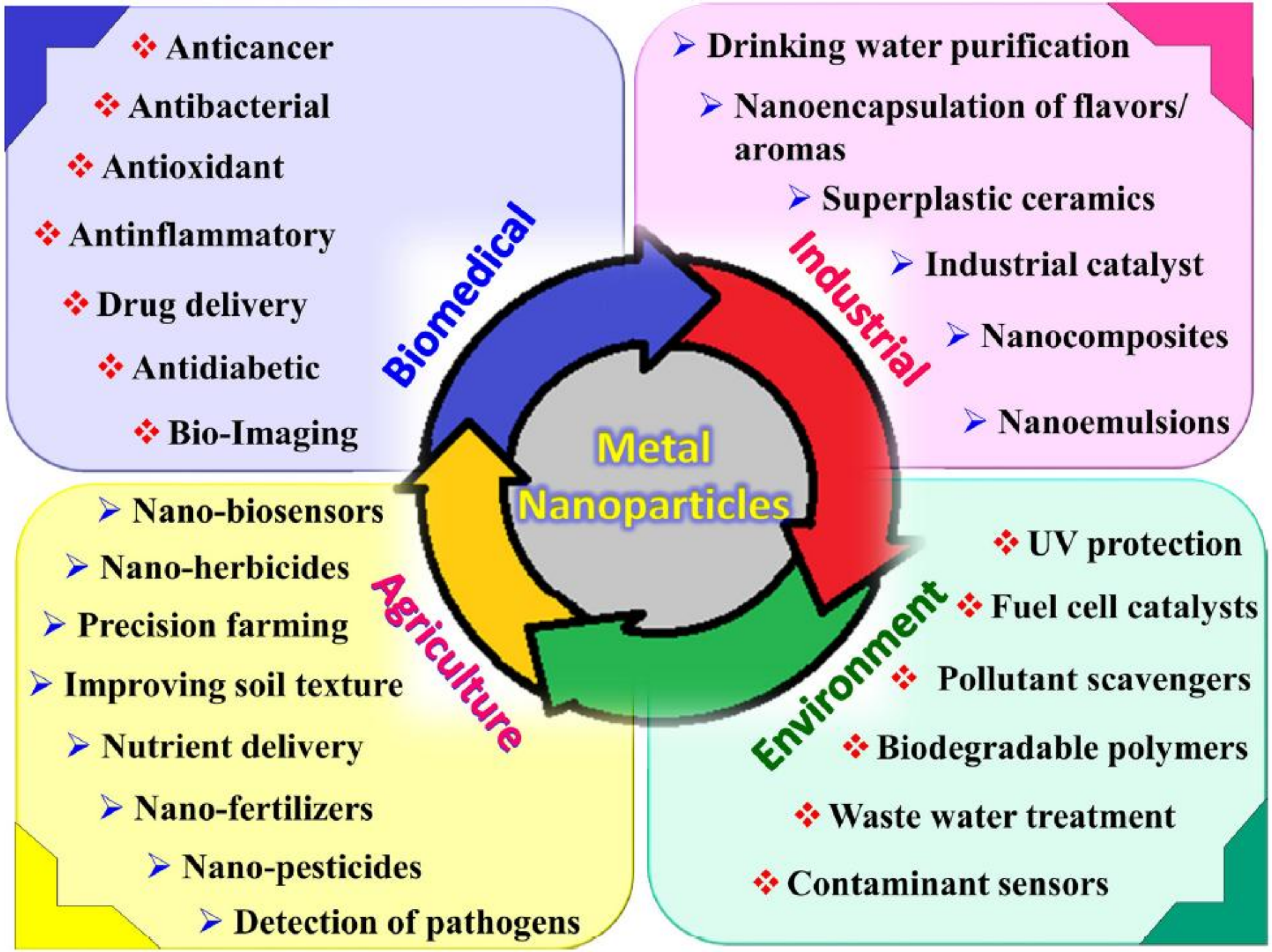
- Nano
- High conductivity
- Robust / stable

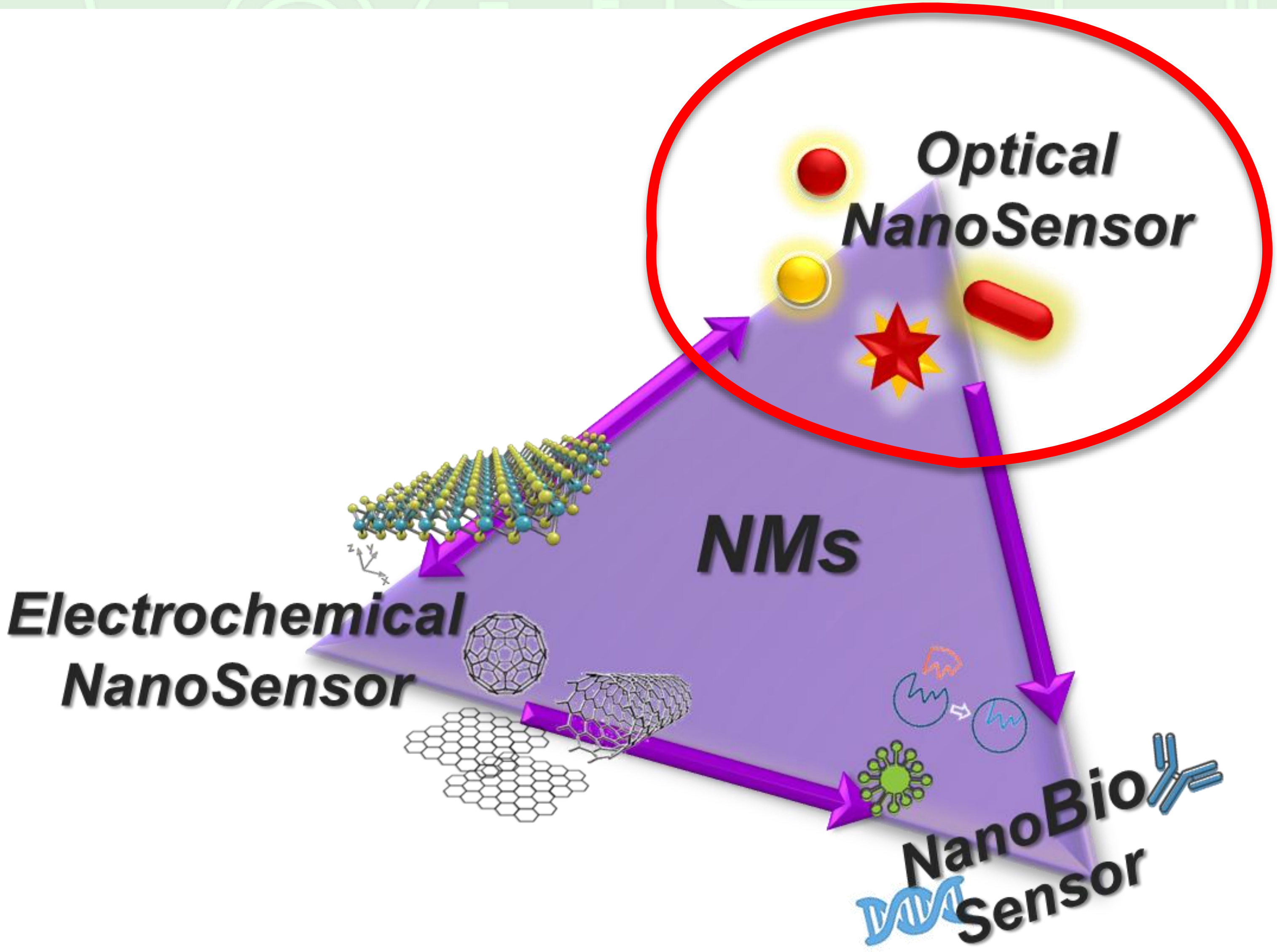
  *(Inhert)*
- Surface (Bio)functionalization
- Good biocompatibility
- Easy preparation (tunable)





# Metal Nanoparticles application fields

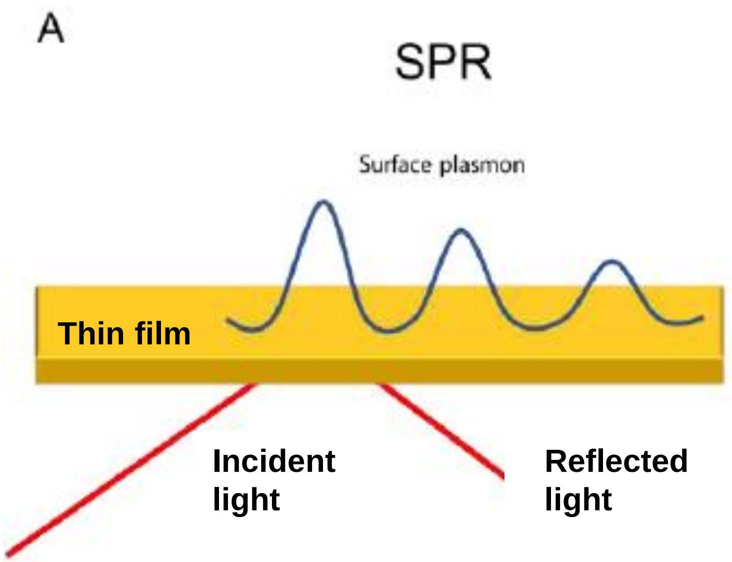


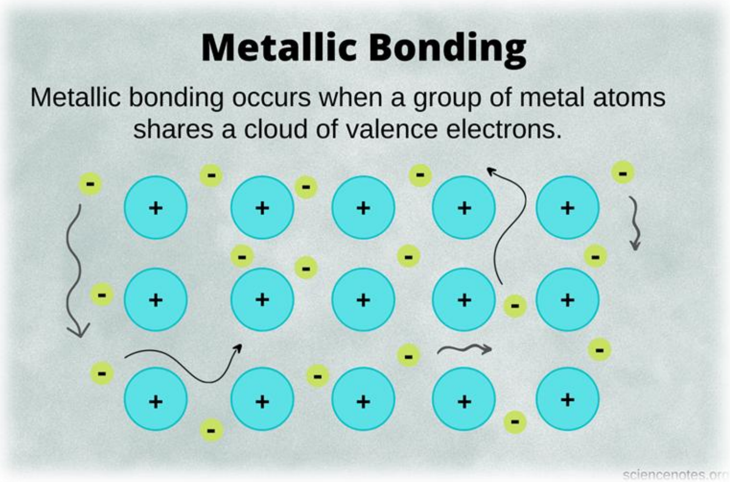

Optical
NanoSensor
NMs
Electrochemical
NanoSensor
NanoBio
Sensor

# Plasmonic-active nanostructured materials for sensing and biosensing

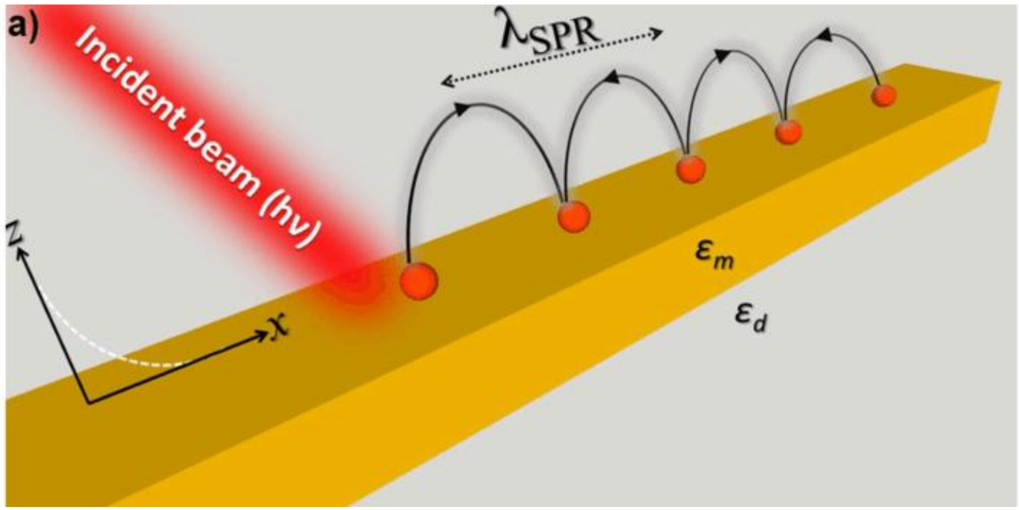


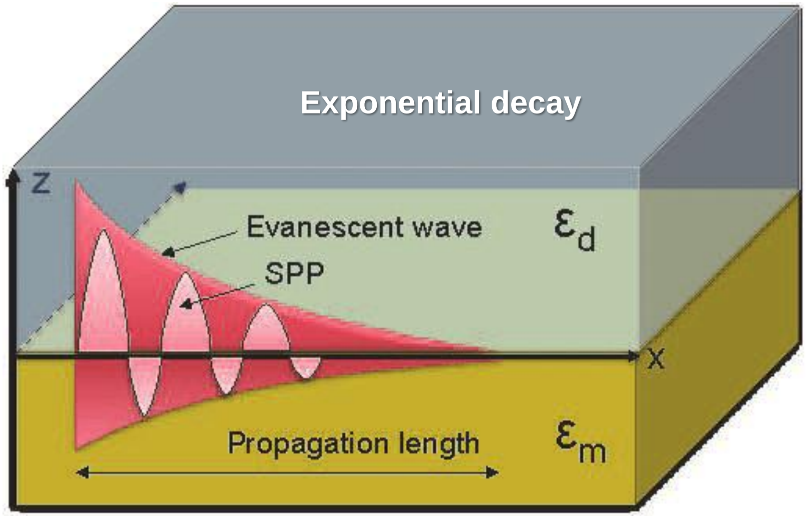
Surface plasmon resonance (SPR) is a phenomenon where the electrons in the metal surface layer are excited by photons of incident light with a certain angle of incidence, and then propagate parallel to the metal surface (Zeng et al., 2017)




Electromagnetic/Evanescent wave



# MNPs and (L)SPR



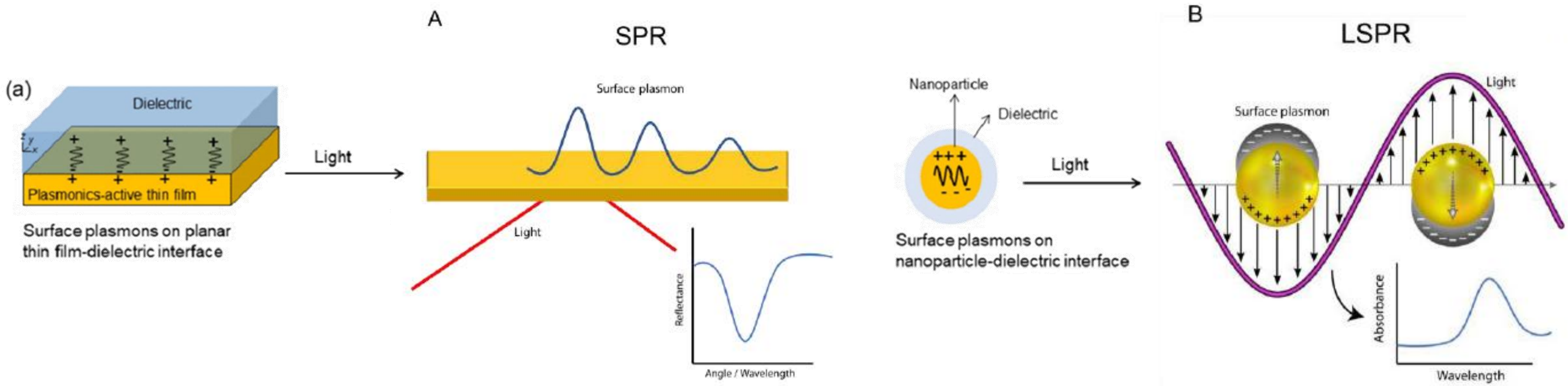



**Figure 1.** A) Prism coupling configuration of SPR, where a light beam impinges on a thin metallic film deposited on a prism. P-polarized light absorbed by the surface plasmon is seen from a minimum in the reflection spectra. B) Representation of the localized surface plasmon on nanoparticles and absorbance spectra obtained for binding events on nanoparticles.

UNIVERSITÀ DEGLI STUDI DI TERAMO UNITE

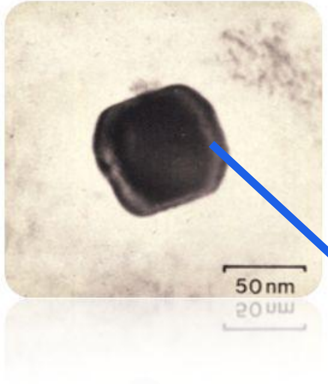
## Metal nanoparticles

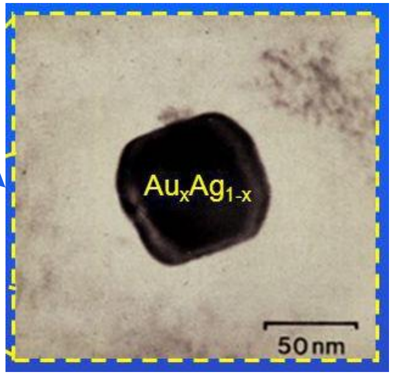
### From Romans…

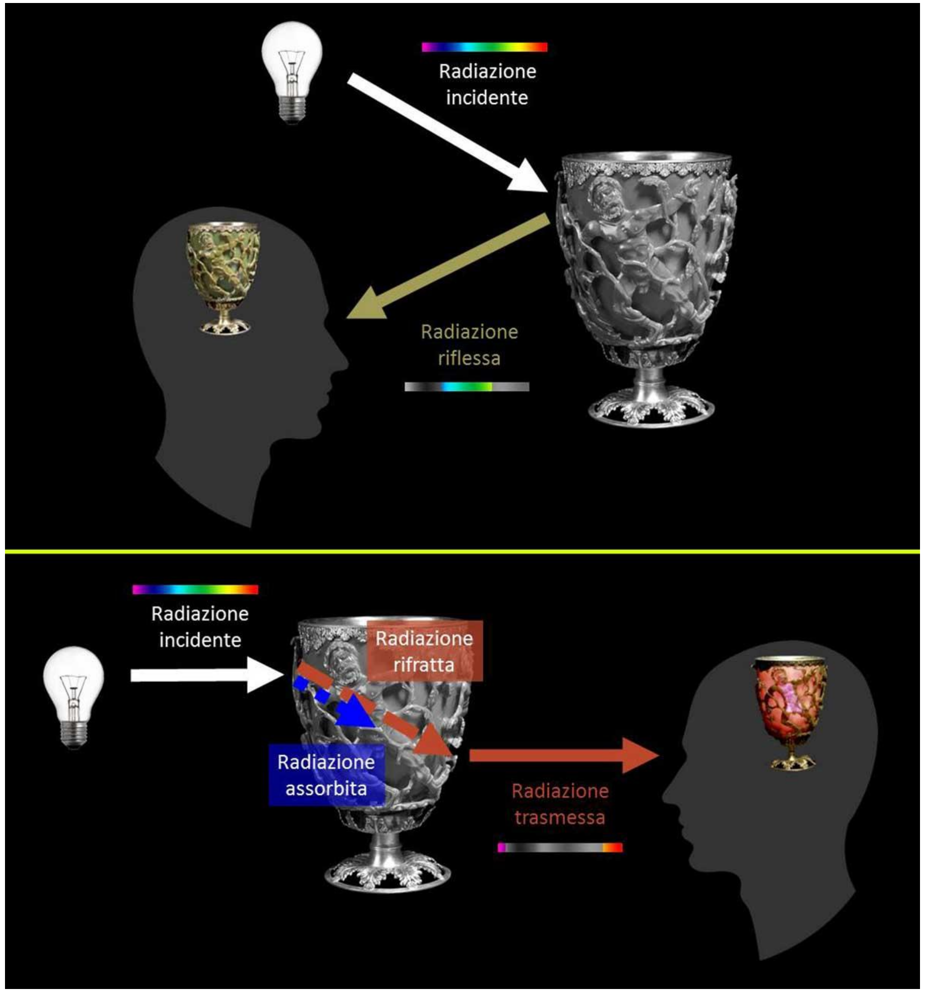
## Nanotecnologia romana

I colori cangianti della Coppa di Licurgo, datata IV secolo a.C., sono dovuti a nanoparticelle di oro e argento disperse nella matrice vetrosa.


(Coppa di Licurgo, British Museum)



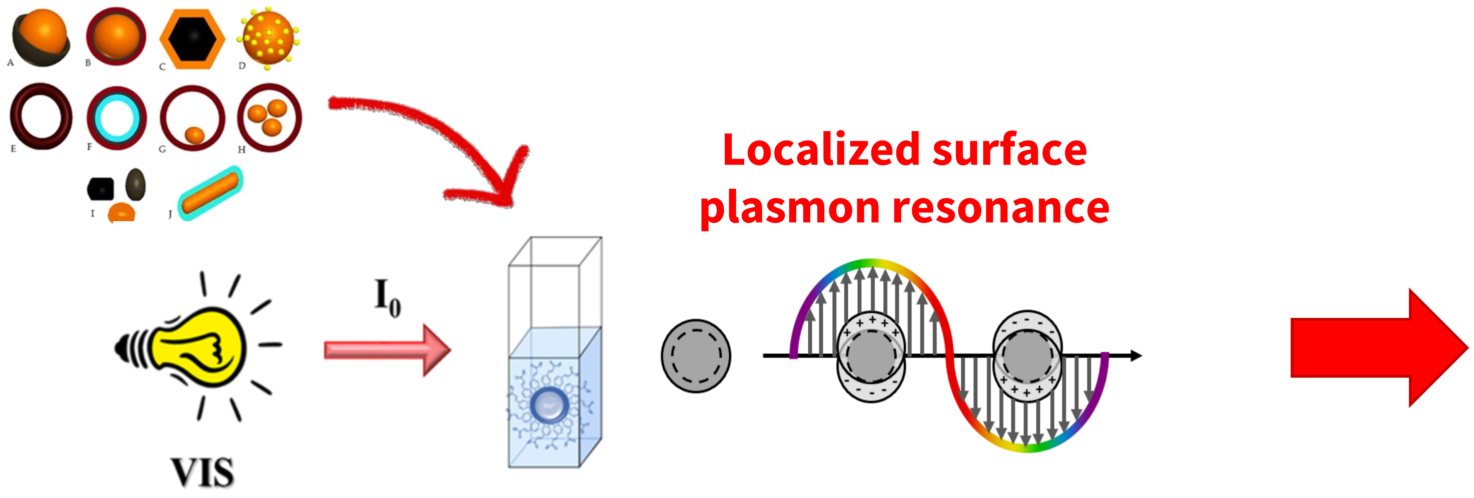



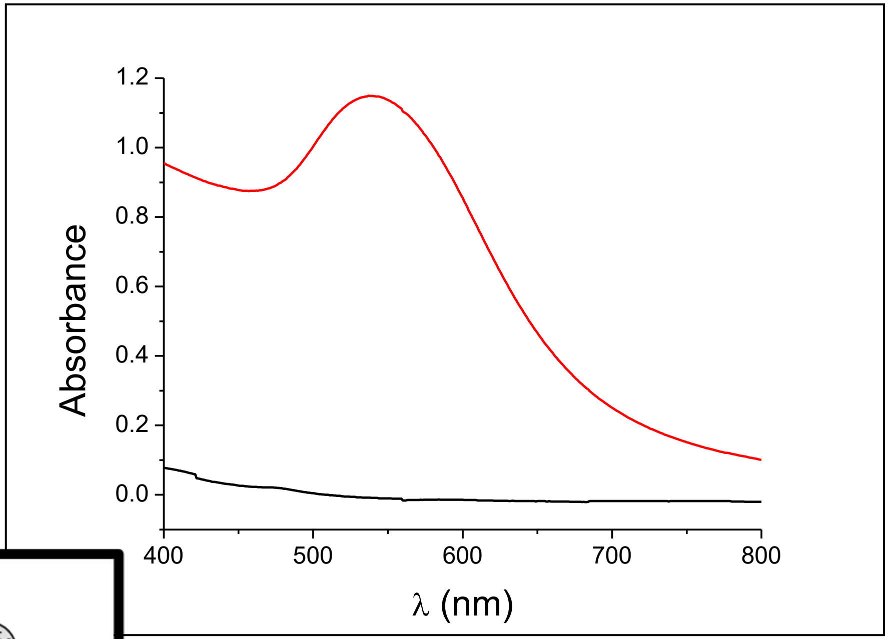



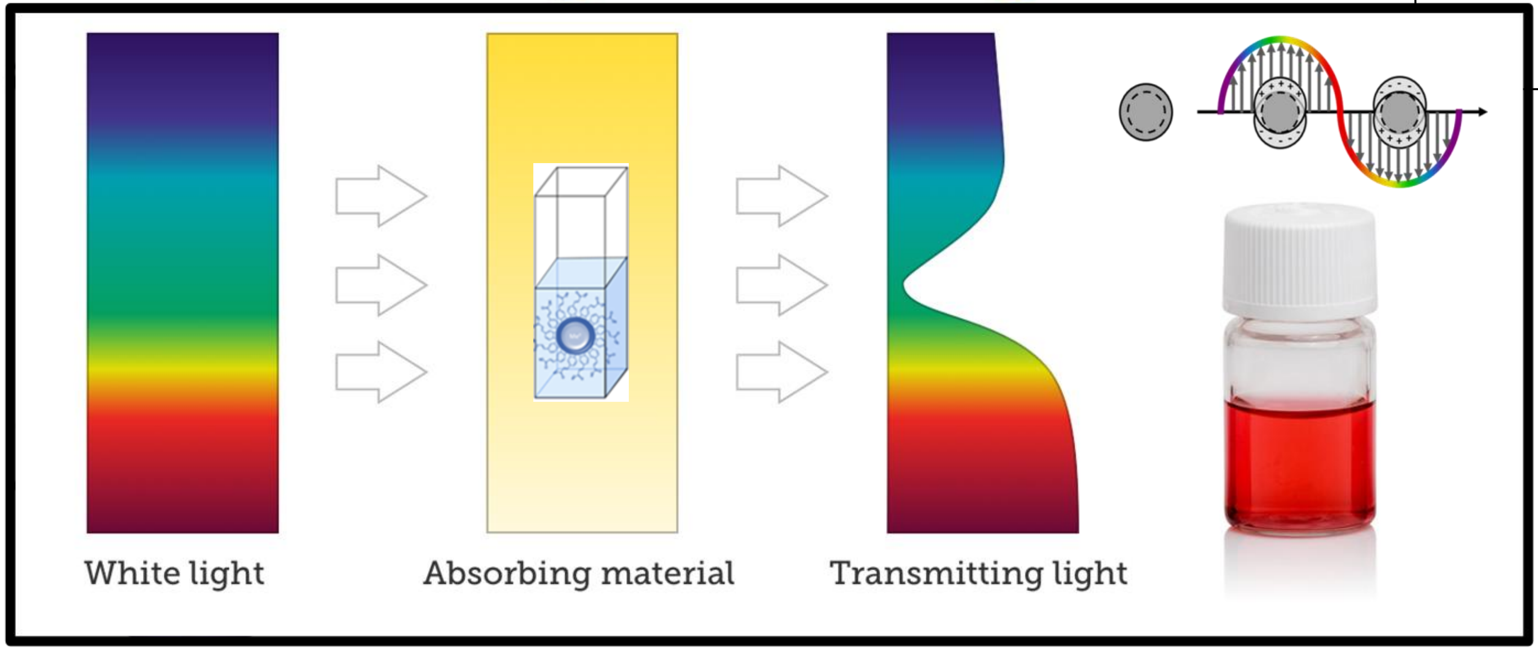

**Novoselov**, K. S., **Geim**, A. K., Morozov, S. V., Jiang, D. A., Zhang, Y., Dubonos, S. V., ... & Firsov, A. A. (**200**4). *science*, *306*(5696), 666-669.

# *Localized Surface Plasmon Resonance (LSPR)*

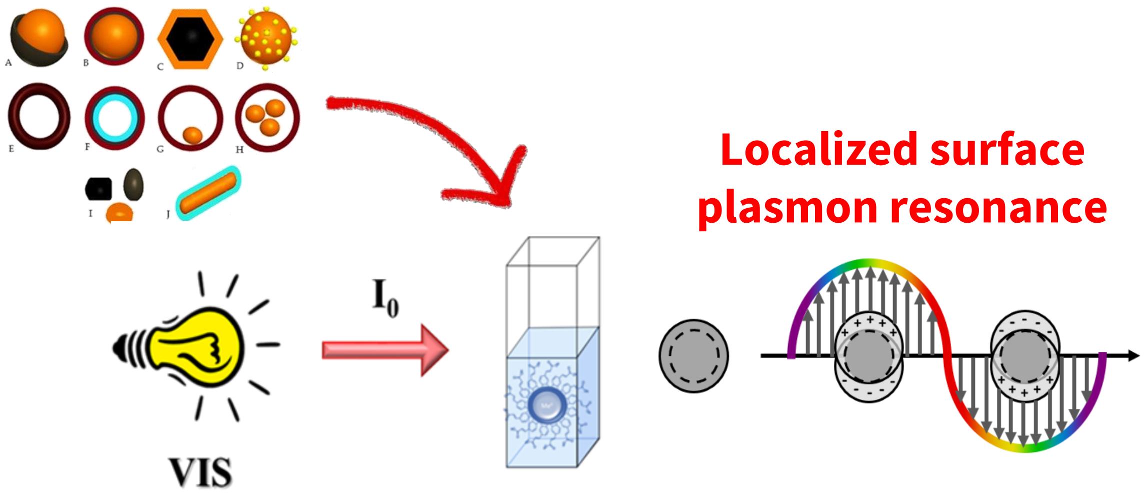


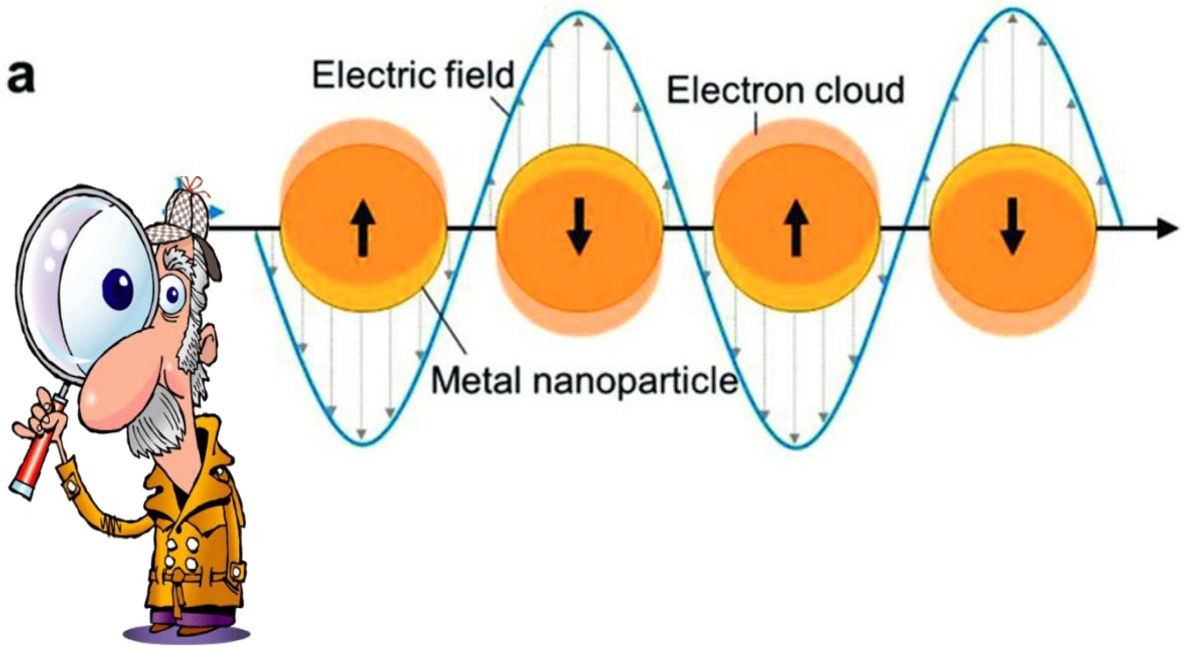


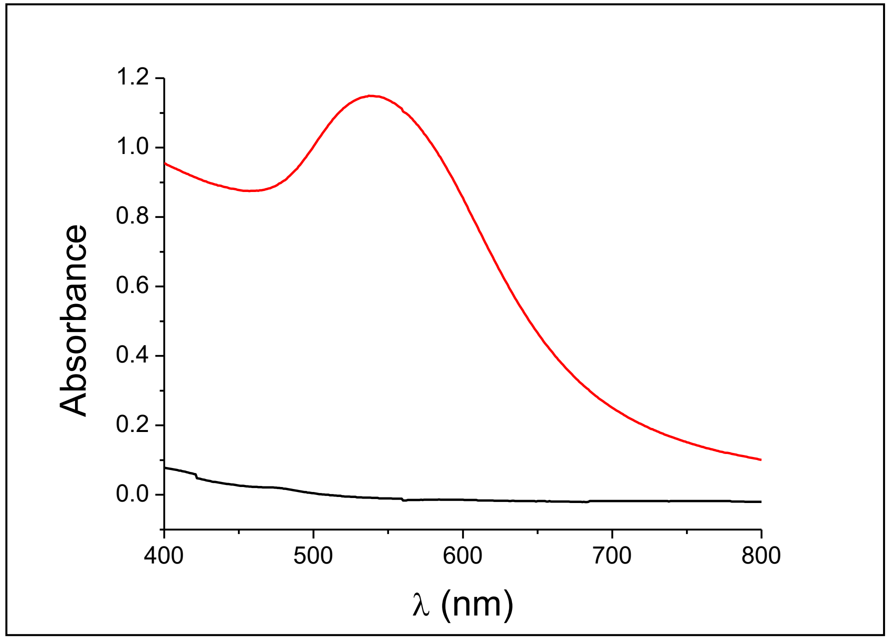



# Localized Surface Plasmon Resonance (LSPR)

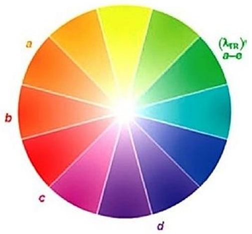


# MNPs and LSPR

## Metal nanoparticles: their camaleontic features

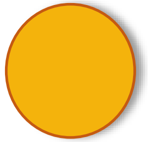


MNPs can interact in different ways with VIS-electromagnetic radiation depending on their shapes, sizes, and composition.

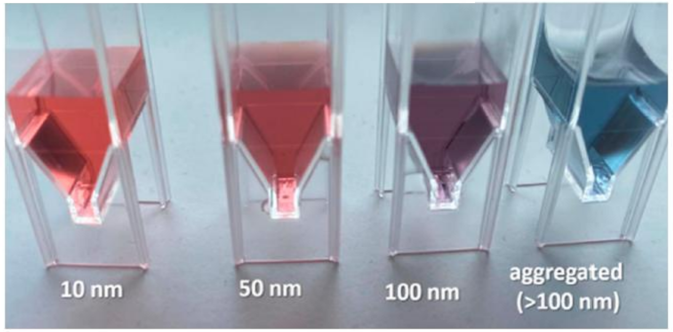
### Gold nanoparticles

Diameter

size



10 nm

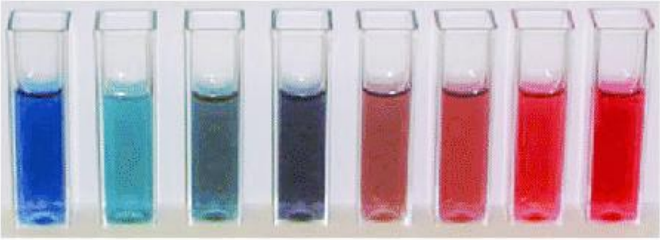



### Gold nanorods

Nanorods

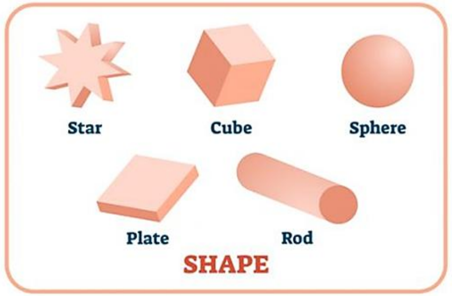
aspect ratio

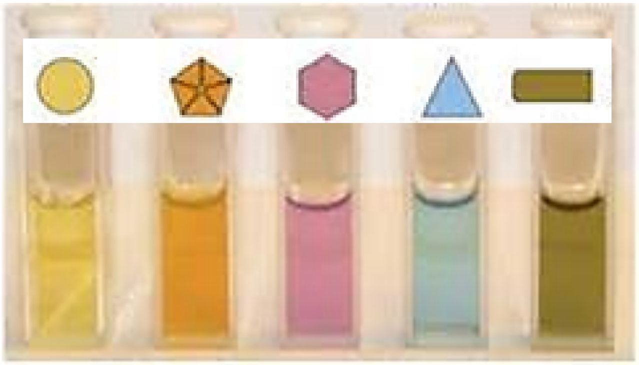
50 nm



### Silver nanoparticles

Shape



### Silica-gold core-shell nanoparticles

Nanoshells

shell thickness

140 nm

### Gold nanocages

Nanocages

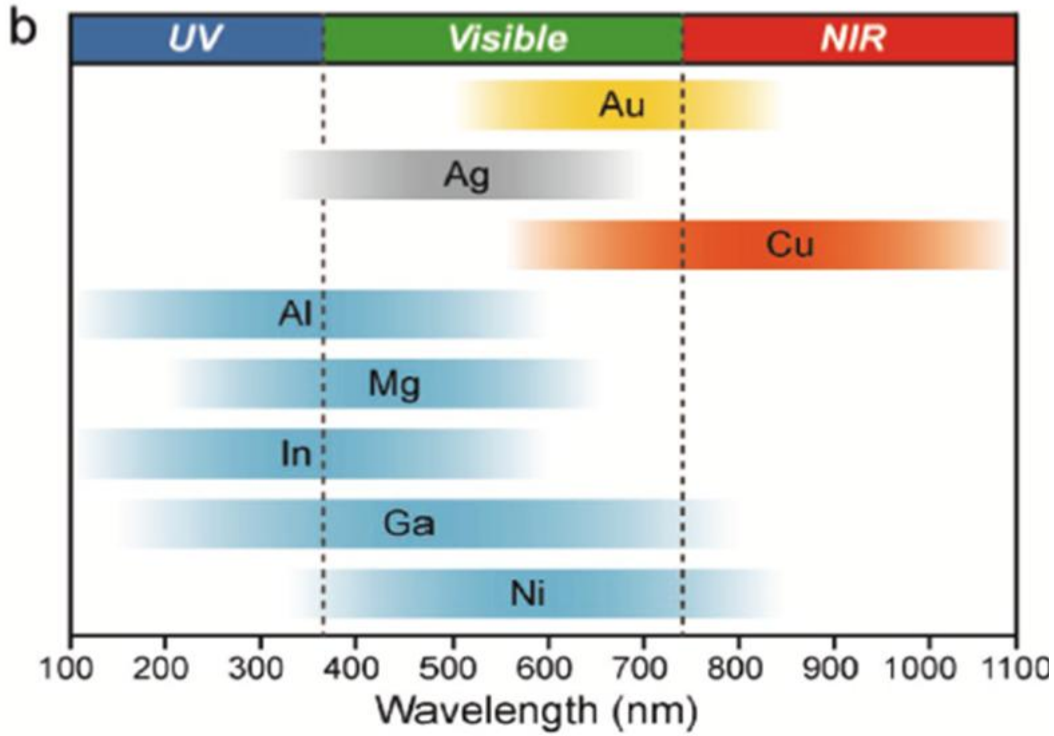
% gold

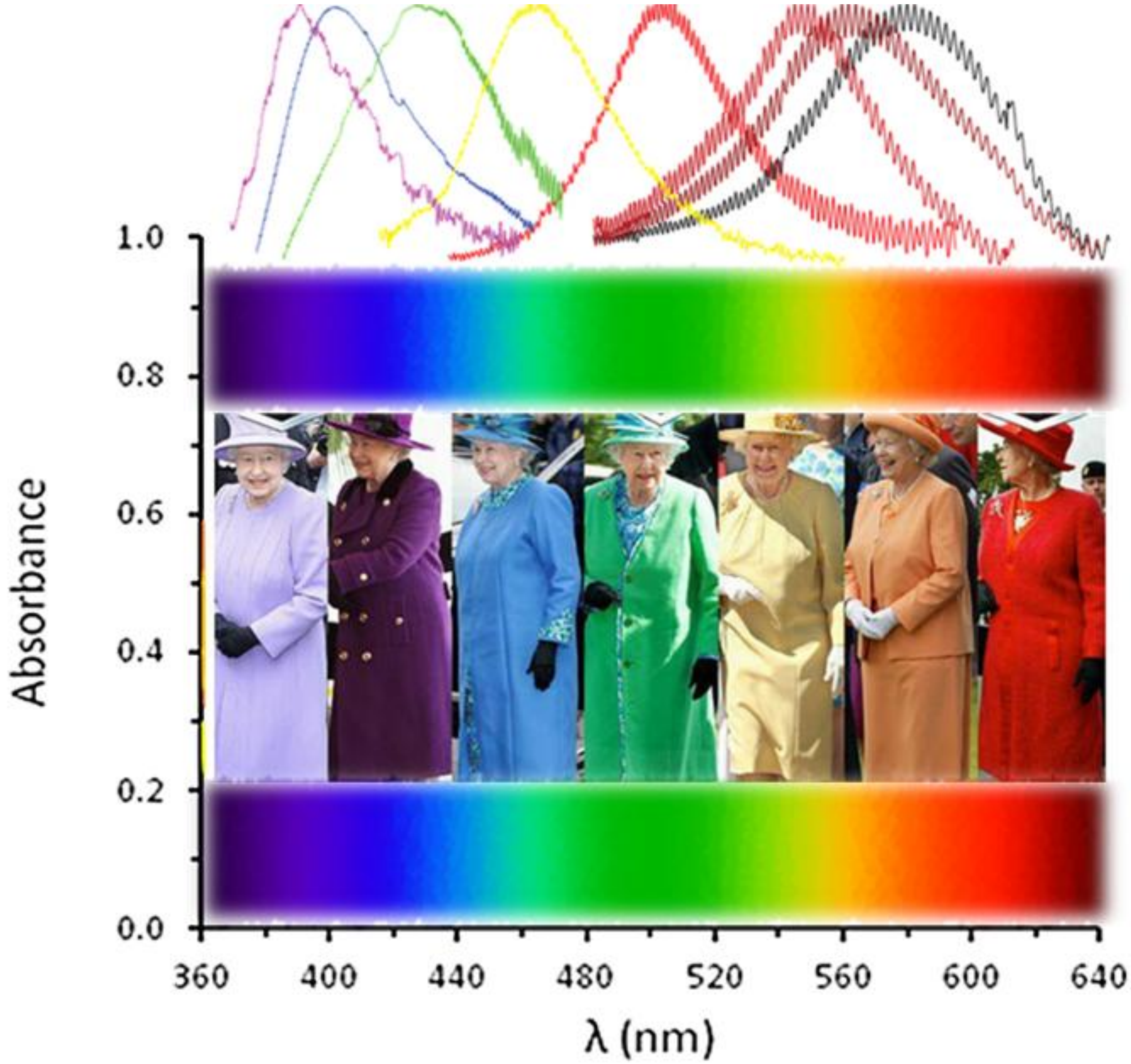
50 nm

# MNPs and LSPR



## Metal nanoparticles: their camaleontic features



# Plasmonic-active nanostructured materials for sensing and biosensing

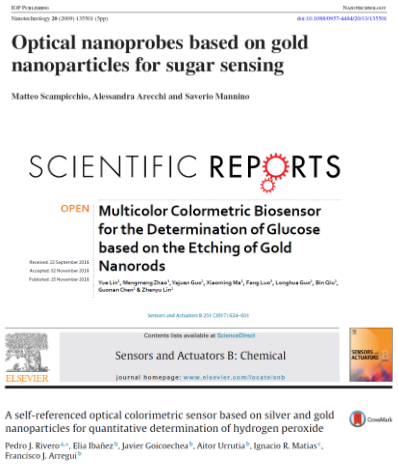
UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

Colloidal metal nanoparticles based assays


Biosensors and Bioelectronics
Plasmonic colorimetric sensors based on etching and growth of noble metal nanoparticles: Strategies and applications
Zhiyang Zhang, Han Wang, Zhaopeng Chen, Xiaoyan Wang, Jaebum Choo, Lingxin Chen

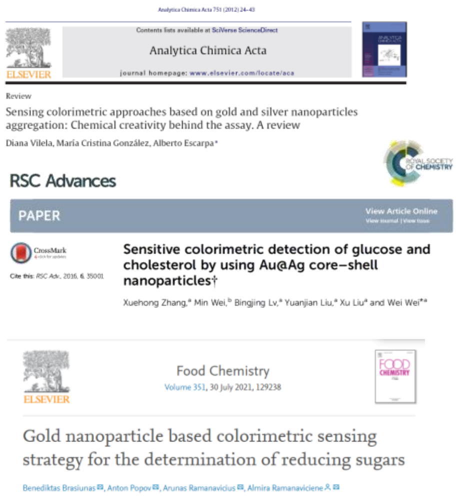
Sensors and Actuators B: Chemical
Colorimetric detection of sugars based on gold nanoparticle formation
Gerardo Palazzo, Laura Facchini, Antonia Mallardi

Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy
Colorimetric detection of glucose based on gold nanoparticles coupled with silver nanoparticles
Yan Gao, Yiting Wu, Junwei Di


Optical nanoprobes based on gold nanoparticles for sugar sensing
Matteo Scampicchio, Alessandra Arecchi and Saverio Mannino

SCIENTIFIC REPORTS
OPEN Multicolor Colormetric Biosensor for the Determination of Glucose based on the Etching of Gold Nanorods

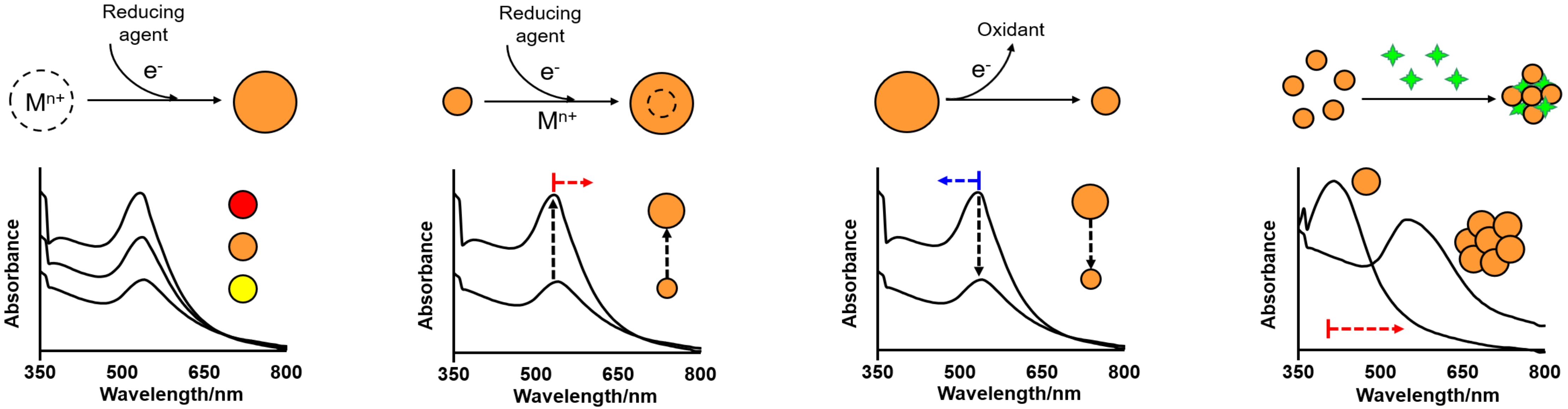
Sensors and Actuators B: Chemical
A self-referenced optical colorimetric sensor based on silver and gold nanoparticles for quantitative determination of hydrogen peroxide


Analytica Chimica Acta
Review
Sensing colorimetric approaches based on gold and silver nanoparticles aggregation: Chemical creativity behind the assay. A review
Diana Vilela, María Cristina González, Alberto Escarpa

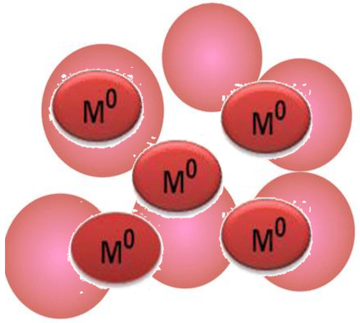
RSC Advances
PAPER
Sensitive colorimetric detection of glucose and cholesterol by using Au@Ag core–shell nanoparticles

Food Chemistry
Gold nanoparticle based colorimetric sensing strategy for the determination of reducing sugars

## Localized Surface Plasmon Resonance

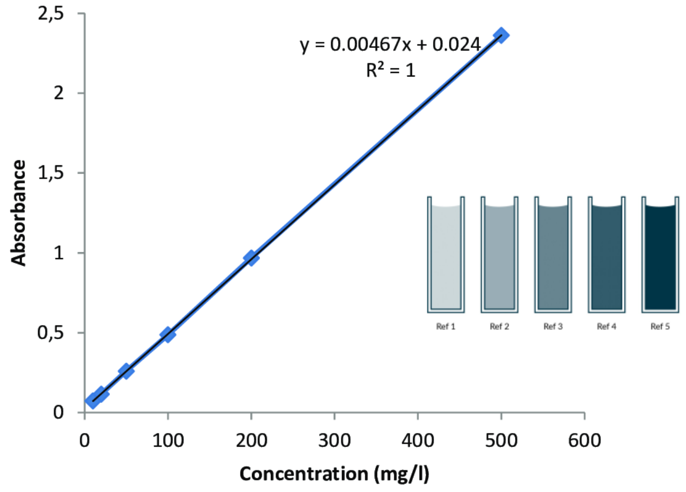


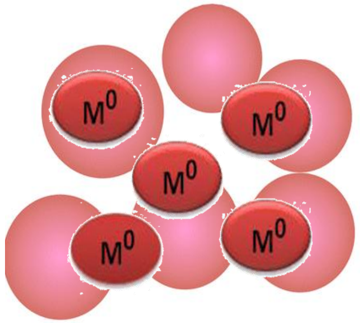
## Main pillar



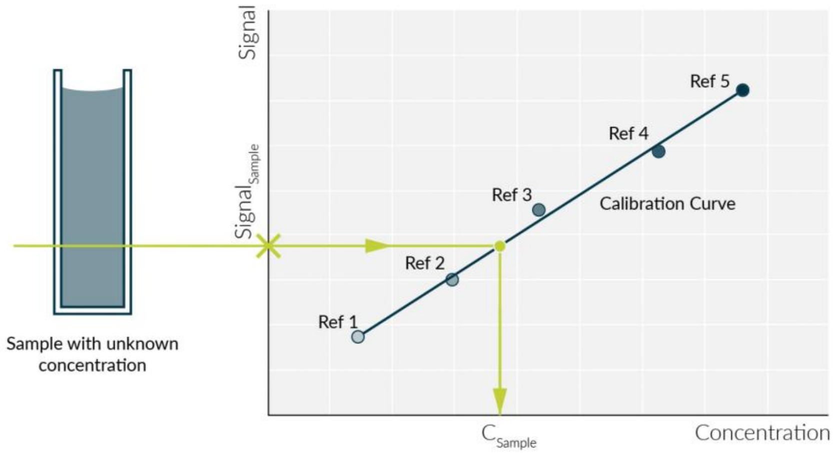

[C]=f(S)

**MODEL SYSTEM (STANDARD)**

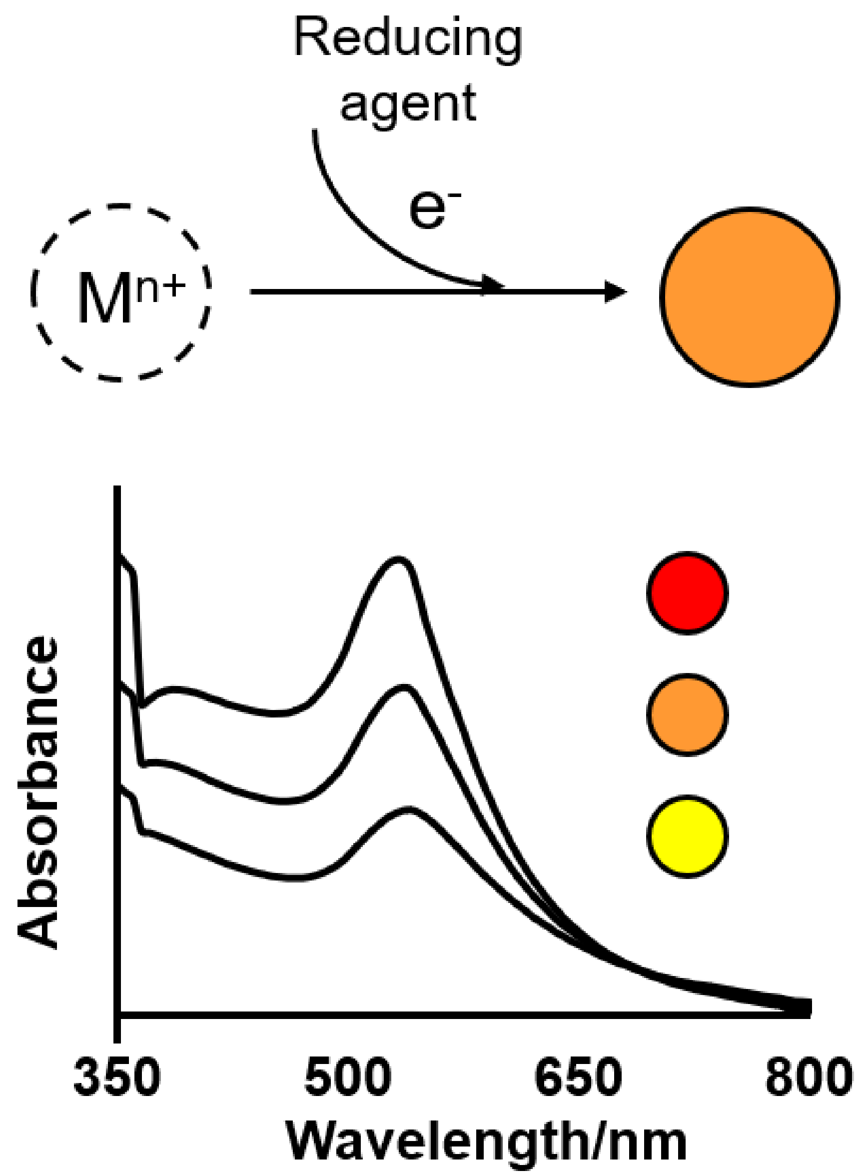



**SAMPLE**

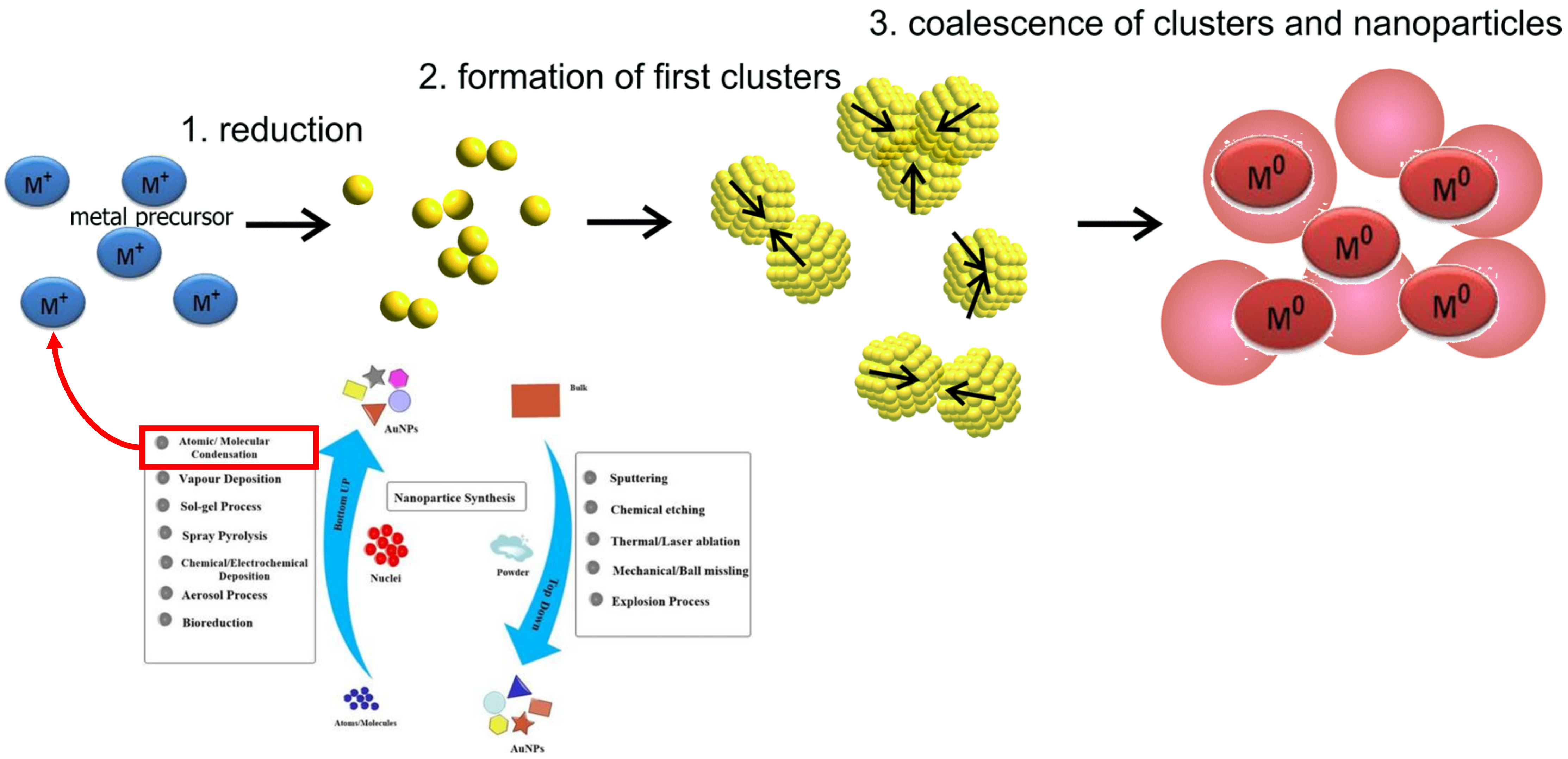


# Metal nanoparticles formation

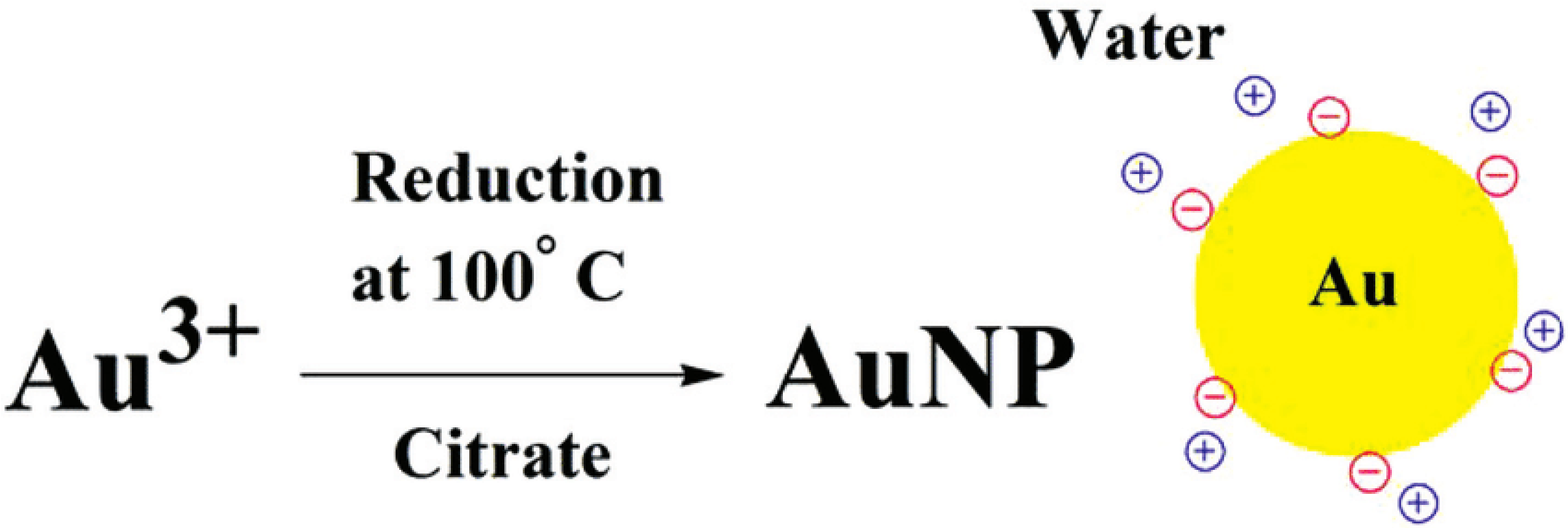


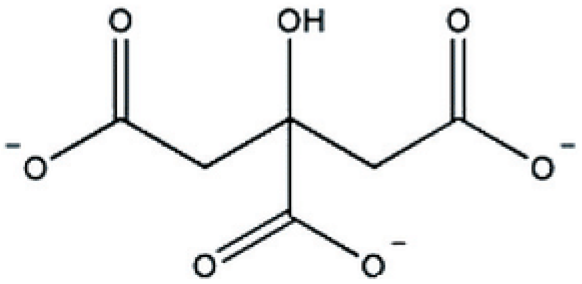
# Sintesi nanoparticelle

## Sintesi generica con riduzione del precursore metallico



# Metal nanoparticles formation.



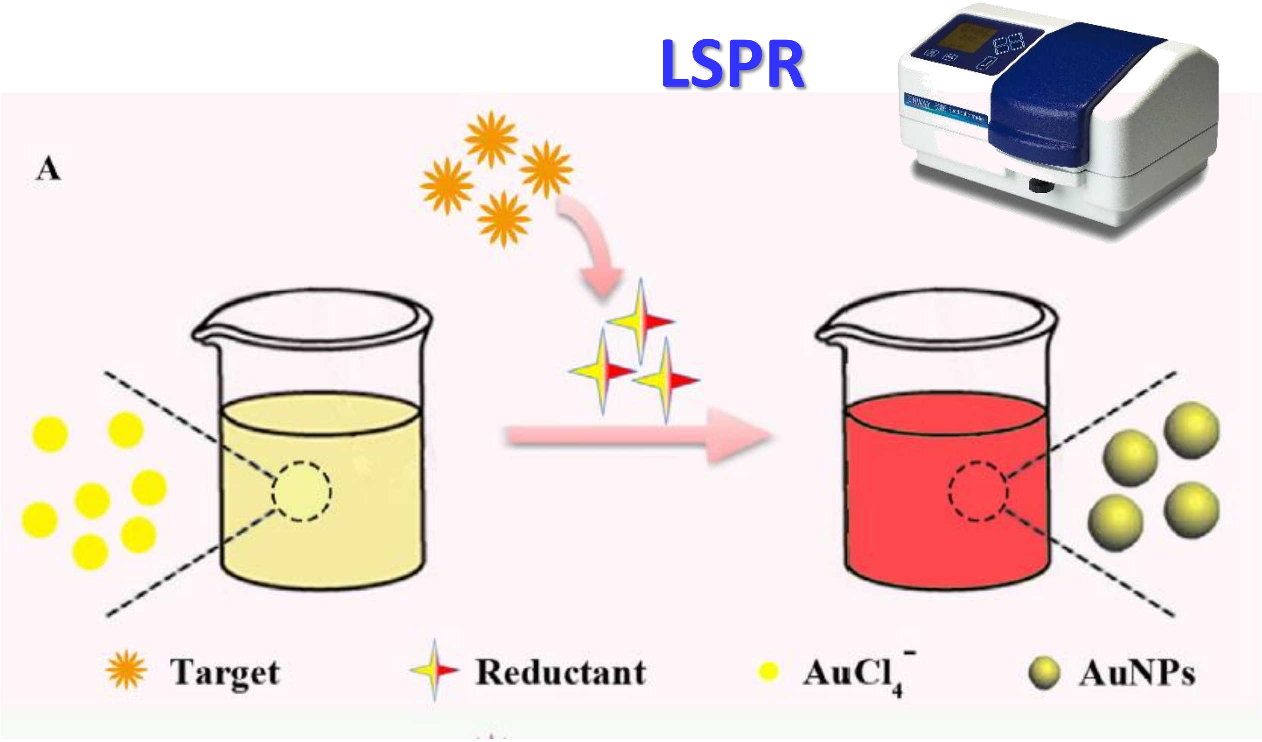





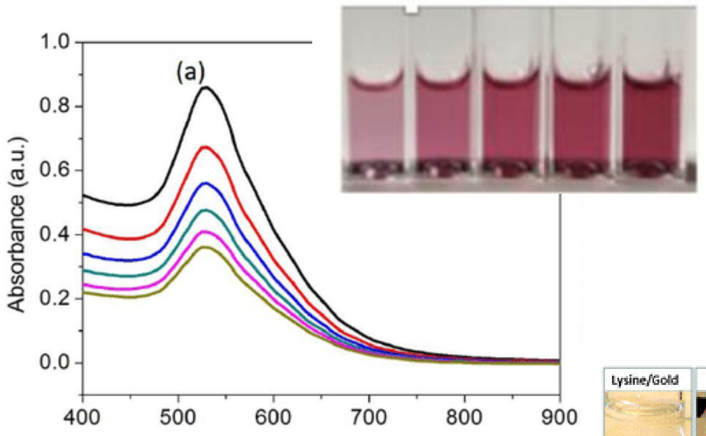
# Metal nanoparticles formation.

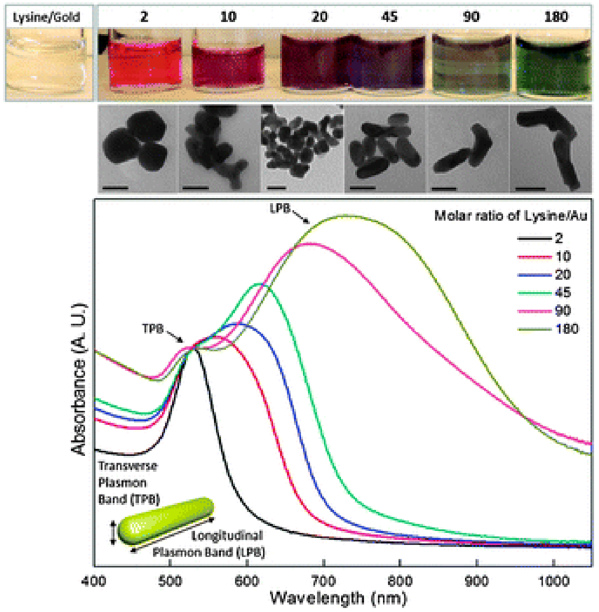
## Main strategy

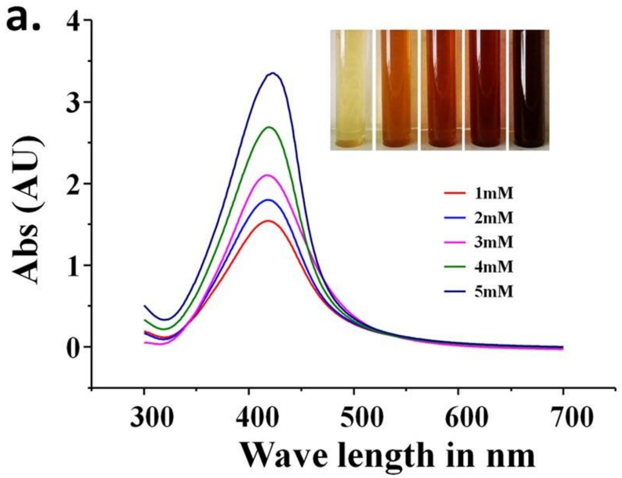
**LSPR**




## Analytical signal

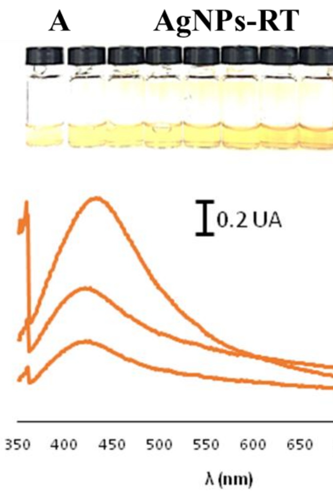


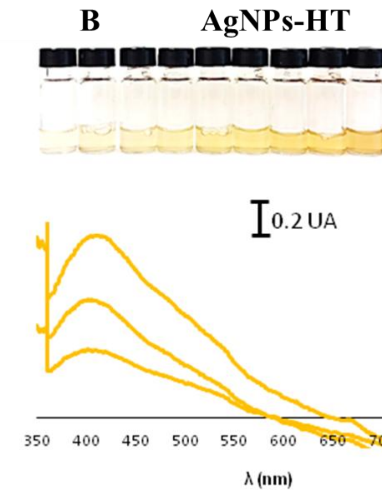



# Metal nanoparticles formation

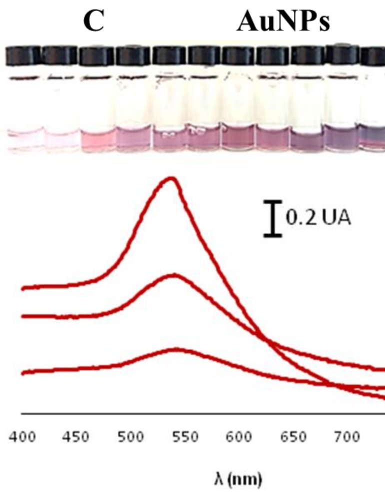
## Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation




pH 13
T 25°C




pH 8.4
T 45°C

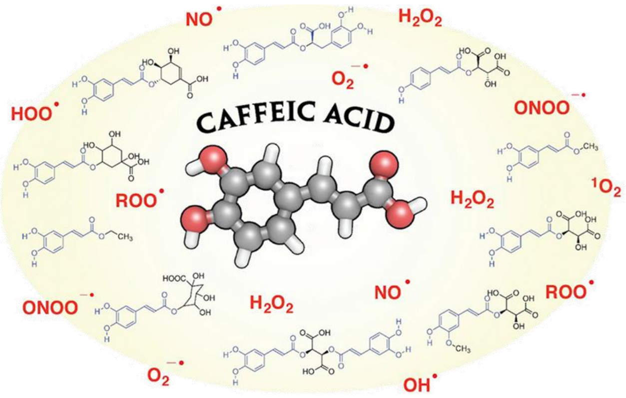


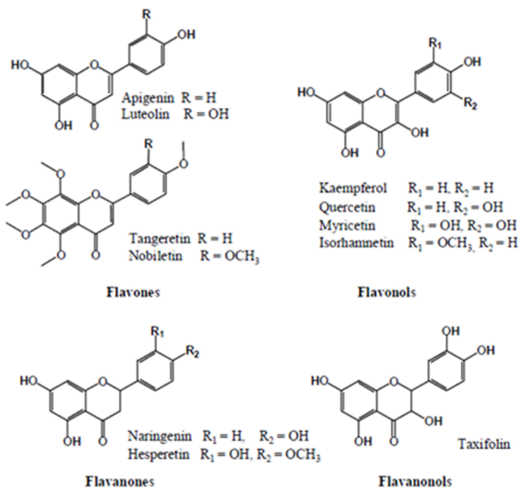

pH 8
T 45°C

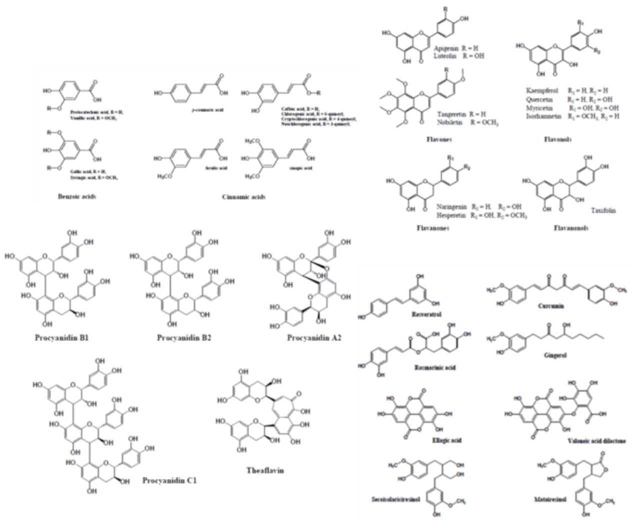
**Antioxidant Capacity**

**Class Selective**

**Total phenolic content**



# Metal nanoparticles formation

## Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation

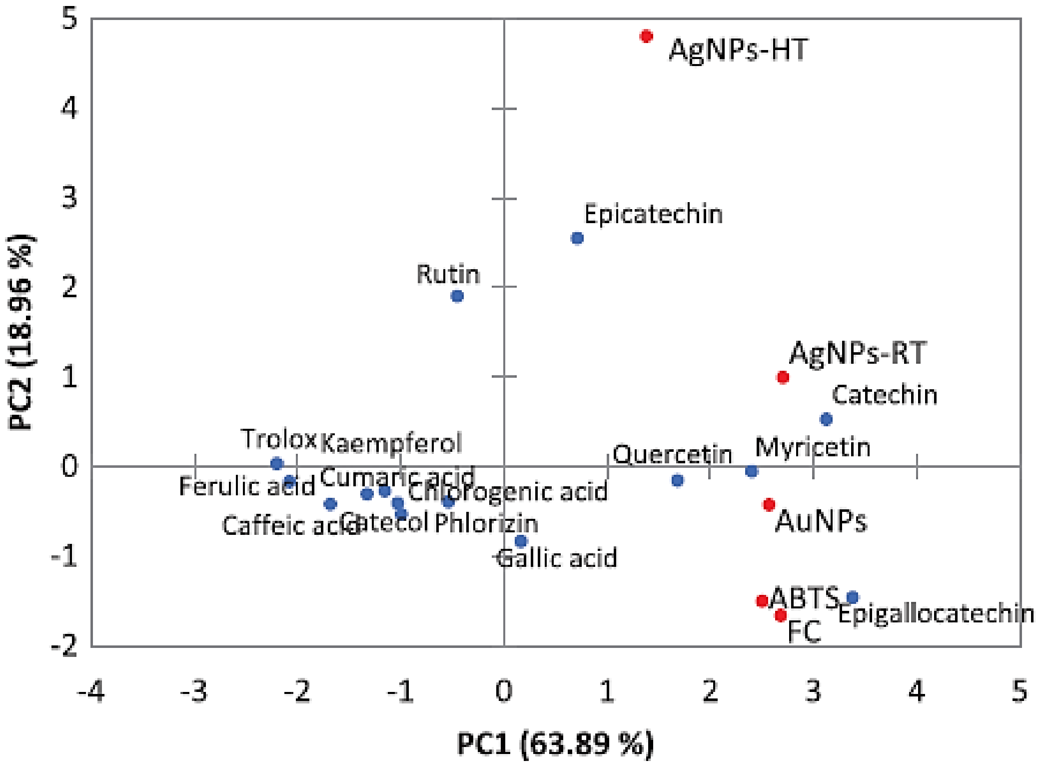
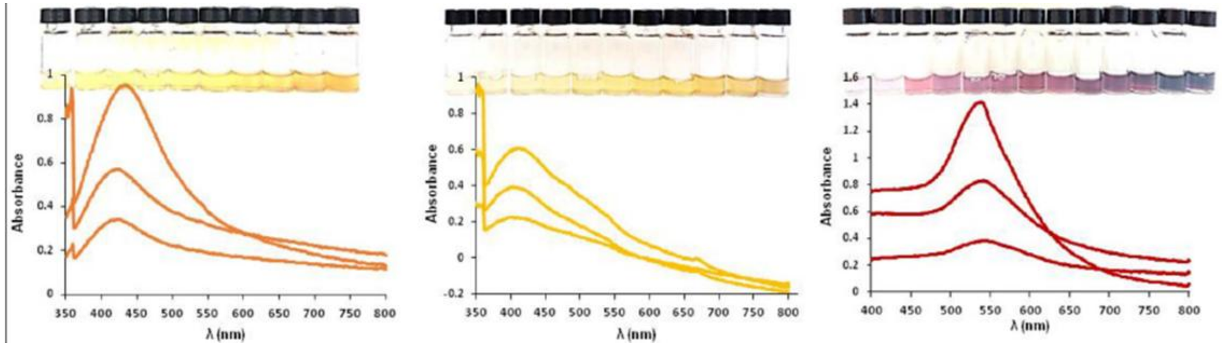



**Fig. 2.** PCA of the ABTS, FC, AuNPs and the proposed AgNPs-based methods reactivity vs. polyphenolic compounds. The biplot (Score and loading) of the first two principal components showed 82.85% of the cumulative variance. Rows normalization were applied to the dataset. Data were autoscaled before PCA.

| R | ABTS | FC | AgNPs-HT | AgNPs-RT | AuNPs |
|---|---|---|---|---|---|
| ABTS | 1 | 0.876 | 0.891 | 0.956 | 0.977 |
| FC | 0.876 | 1 | 0.733 | 0.913 | 0.801 |
| AgNPs-HT | 0.891 | 0.733 | 1 | 0.770 | 0.826 |
| AgNPs-RT | 0.956 | 0.913 | 0.770 | 1 | 0.950 |
| AuNPs | 0.977 | 0.801 | 0.826 | 0.950 | 1 |



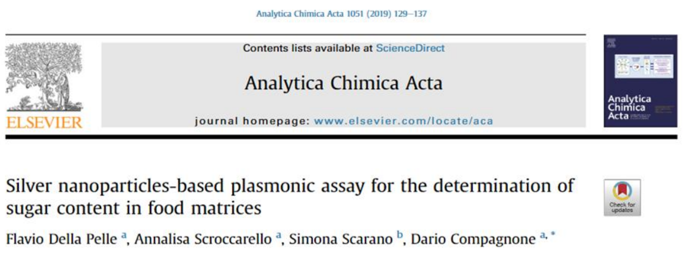

**VT**: Vanilla Tea
**TG**: Green Tea
**TC**: Classic Tea
**SD**: sogni d'oro infused
**RE**: Relax infused

**RB**: Rosa di bosco Infused
**LT**: Lemon Tea
**IN**: Finocchio infused
**DIG**: Digestiva infused

# Metal nanoparticles formation



## Sugars content evaluation trough AgNPs formation


Analytica Chimica Acta 1051 (2019) 129–137

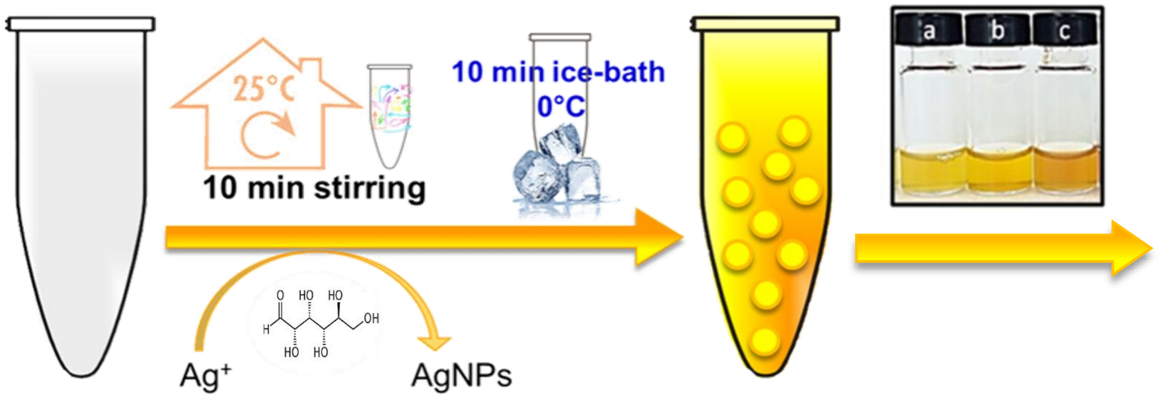
Contents lists available at ScienceDirect

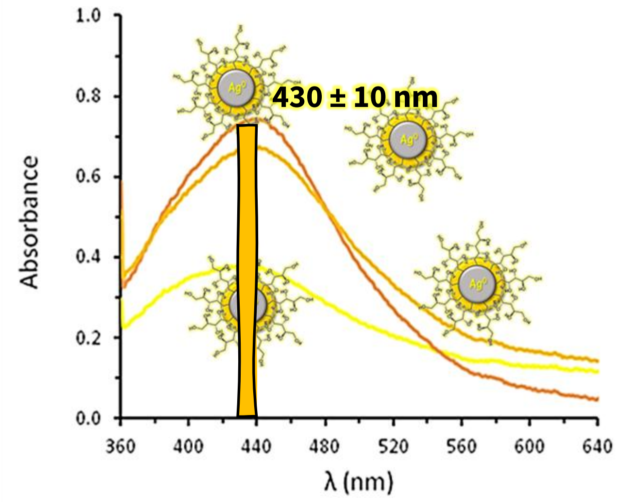
Analytica Chimica Acta

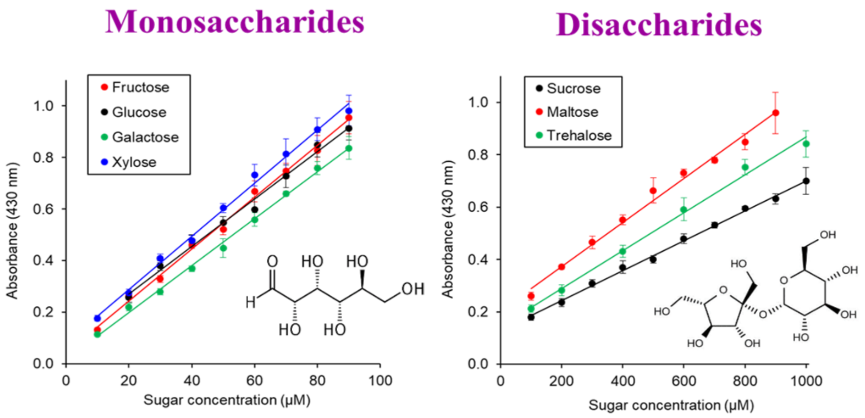
journal homepage: www.elsevier.com/locate/aca

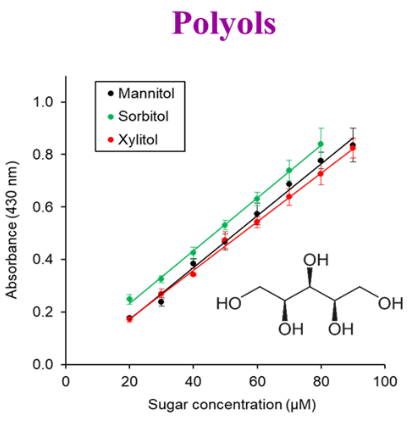
Silver nanoparticles-based plasmonic assay for the determination of sugar content in food matrices

Flavio Della Pelle [a], Annalisa Scroccarello [a], Simona Scarano [b], Dario Compagnone [a, *]




| Sample | AgNPs assay (g 100 mL$^{-1}$, Glu. Eq.) | RSD (%, n = 5) | Ion chromatography (g 100 mL$^{-1}$, Glu + Fru) | RSD (%, n = 3) | Rel. error (%) |
|---|---|---|---|---|---|
| Peach tea | 2.98 ± 0.14 | 4.74 | 3.13 ± 0.08 | 2.71 | + 5.0 |
| Black tea | 3.56 ± 0.23 | 6.51 | 3.05 ± 0.11 | 3.56 | - 14.3 |
| Coconut water | 4.72 ± 0.13 | 2.84 | 4.93 ± 0.05 | 0.98 | + 4.4 |
| Gaseous | 3.50 ± 0.25 | 7.23 | 3.53 ± 0.04 | 1.21 | + 0.9 |
| Cedrata | 9.36 ± 0.27 | 2.85 | 8.74 ± 0.78 | 8.9 | - 6.6 |
| Tonic water | 6.11 ± 0.07 | 1.15 | 5.62 ± 0.12 | 2.11 | - 8.0 |
| Apple 1 | 1.67 ± 0.02 | 1.12 | 1.50 ± 0.02 | 1.11 | - 10.2 |
| Apple 2 | 1.14 ± 0.04 | 3.41 | 1.14 ± 0.02 | 1.78 | 0.0 |
| Apple 3 | 3.27 ± 0.04 | 1.30 | 3.12 ± 0.10 | 3.10 | - 4.6 |
| Apple 4 | 2.43 ± 0.23 | 9.42 | 2.67 ± 0.11 | 4.10 | + 9.9 |
| Apple 5 | 2.43 ± 0.02 | 0.74 | 2.31 ± 0.9 | 3.80 | - 5.0 |

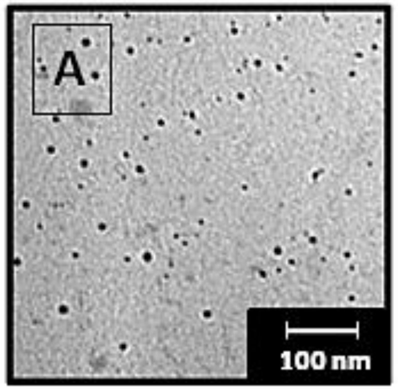
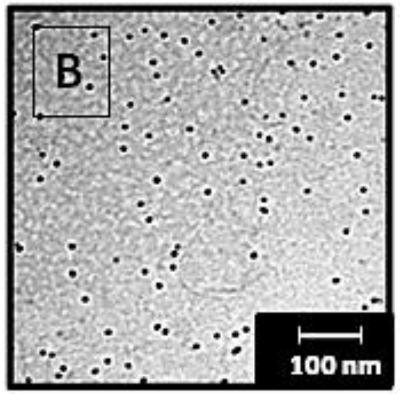
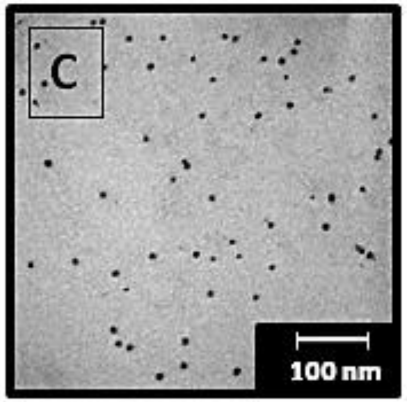
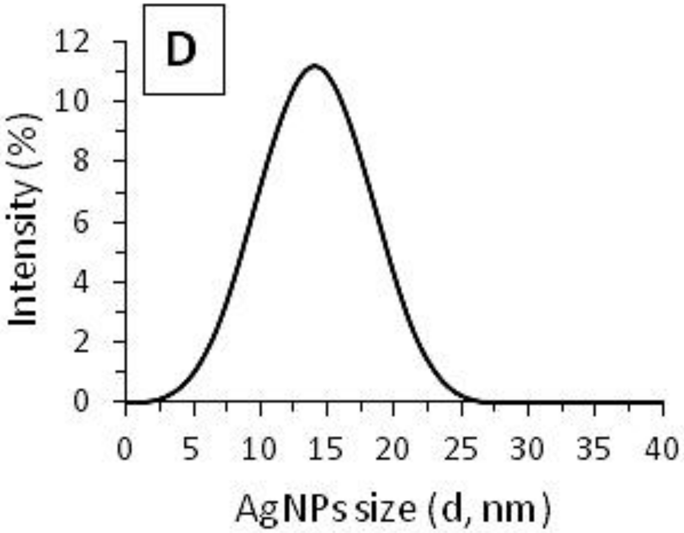
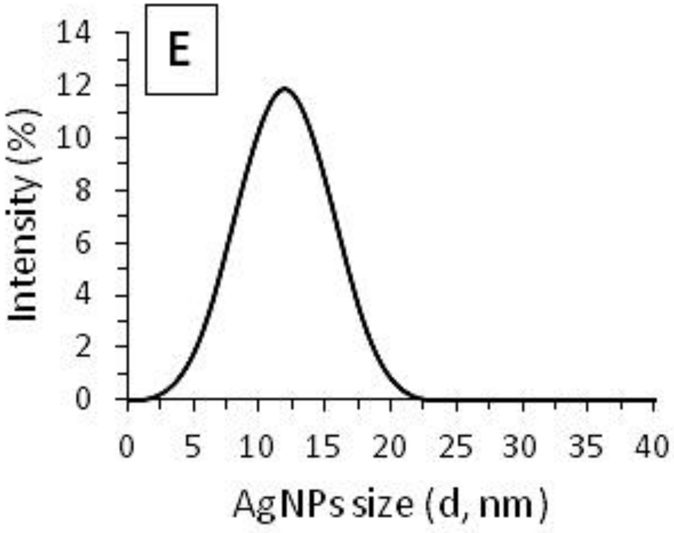
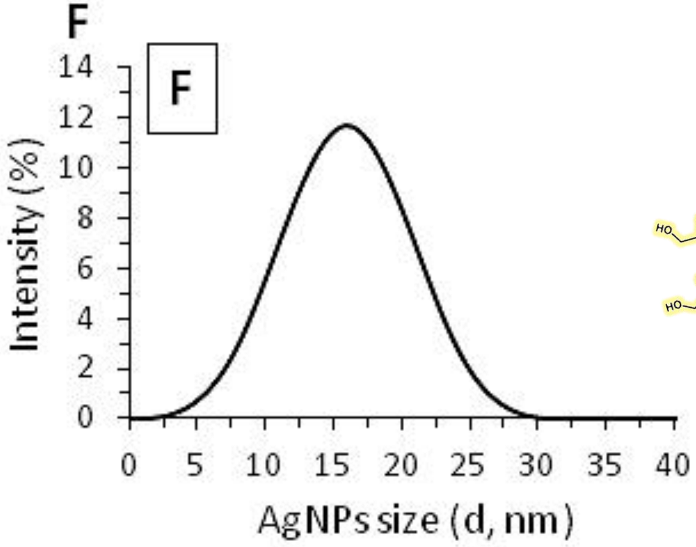
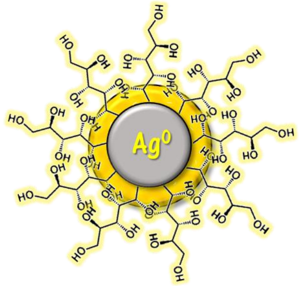
**Recovery: 86-118%**

**$R^2 \geq 0.991$**
**Monosaccharides and polyols LOD= 8.7 ± 0.4 μM**
**Disaccharides average LOD= 120 ± 0.1 μM**
**RSD≤ 8%**

# Metal nanoparticles formation

## AgNPs Morphological study

**SURFACE FUNCTIONALIZATION!!!**

| | Glucose | Sucrose | Xylitol | |
|---|---|---|---|---|
| TEM |  |  |  |  |
| DLS |  |  |  |  |

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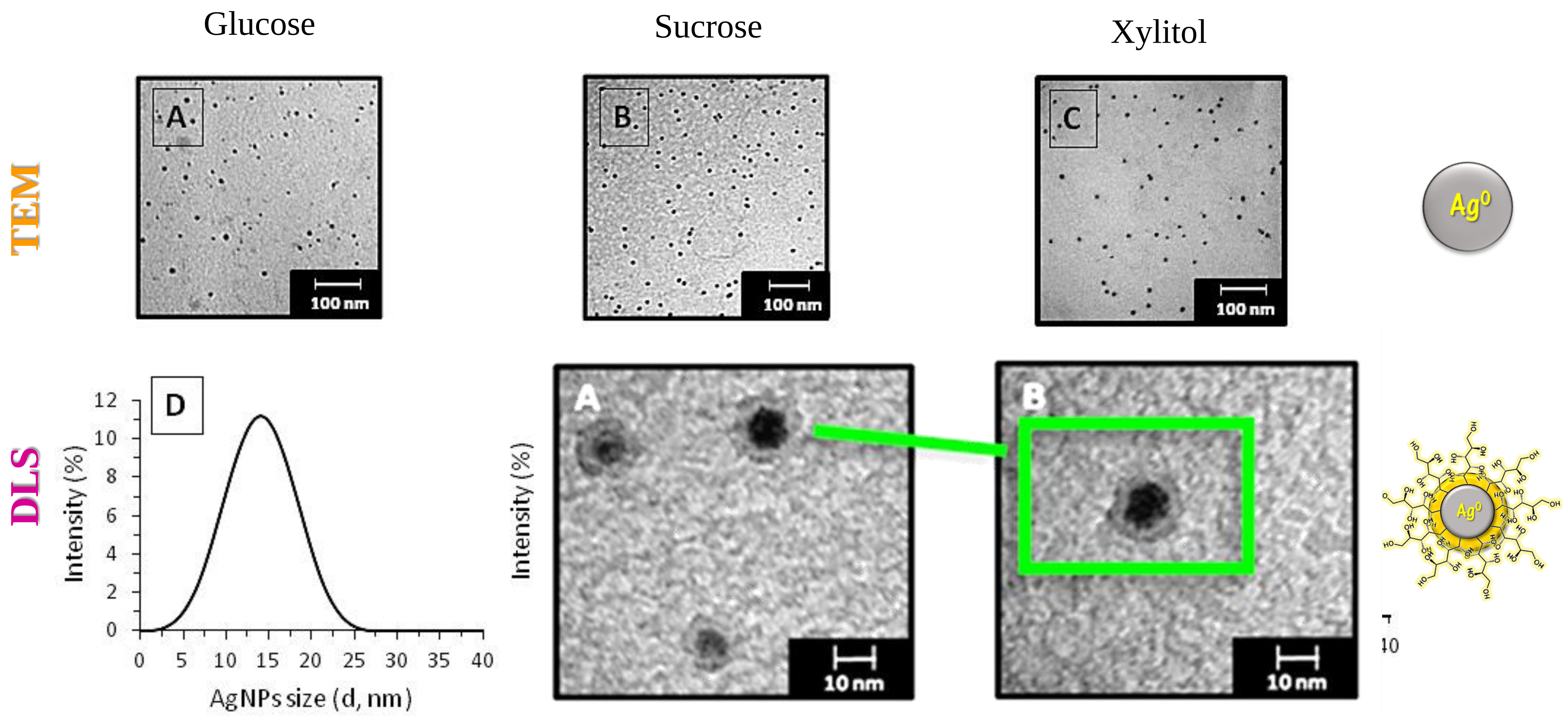
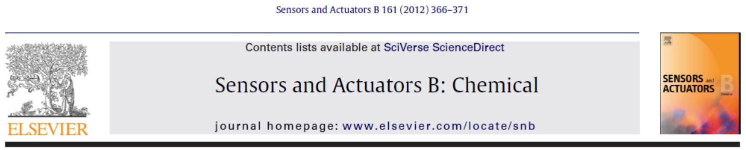
## AgNPs Morphological study

**SURFACE FUNCTIONALIZATION!!!**



# Metal nanoparticles formation

## Sugars content evaluation trough AuNPs formation


Sensors and Actuators B 161 (2012) 366–371
Contents lists available at SciVerse ScienceDirect
Sensors and Actuators B: Chemical
journal homepage: www.elsevier.com/locate/snb

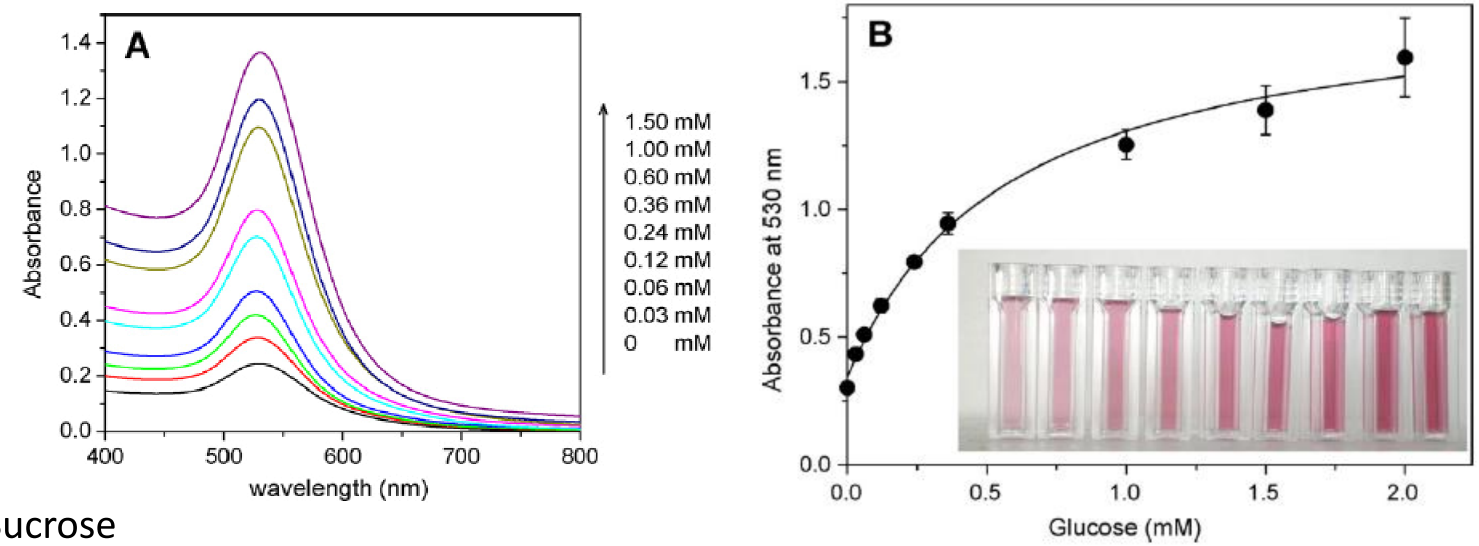
Colorimetric detection of sugars based on gold nanoparticle formation

Gerardo Palazzo[a], Laura Facchini[a], Antonia Mallardi[b,*]

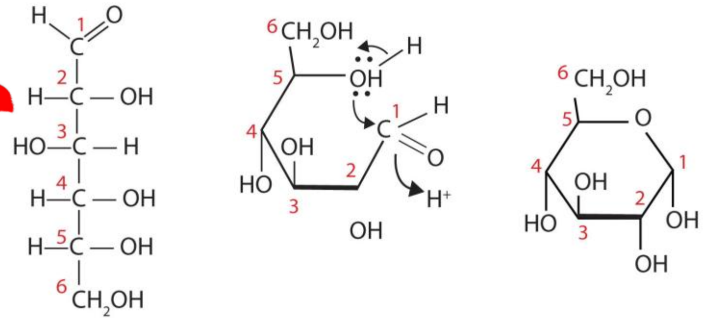
### STRATEGY 1

The “pink assay” is based on the sugar assisted chemical synthesis of NPs and it represents a simple one-step colorimetric approach to the quantification of all potentially reducing sugars (**sucrose included**) with a LOD of 10 M.

Sugars sensing

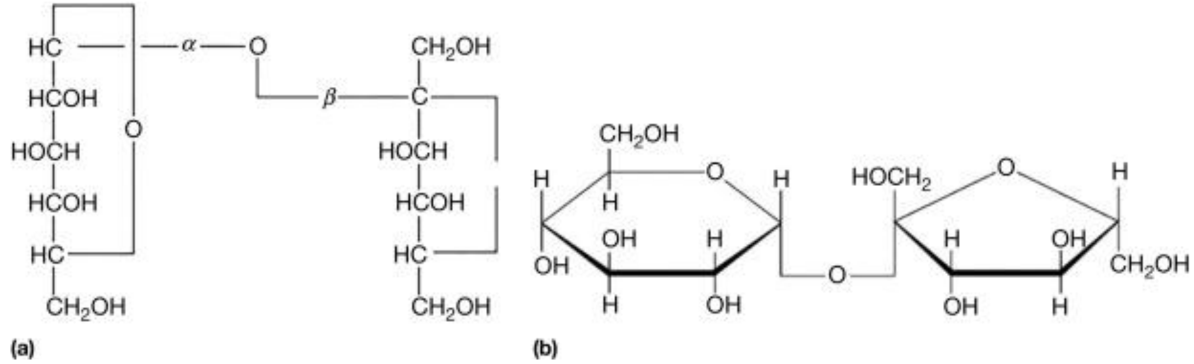



Glucose



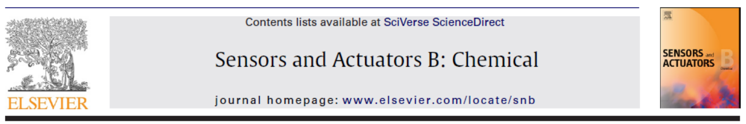

(a) Fischer projection (b) Three-dimensional representantion (c) Cyclic monosaccharide

Sucrose



# Metal nanoparticles formation

## Sugars content evaluation trough AuNPs formation


Sensors and Actuators B 161 (2012) 366–371
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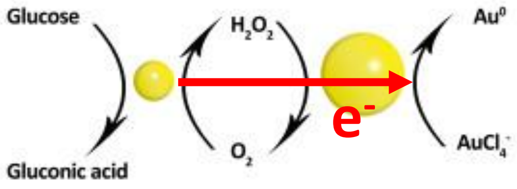
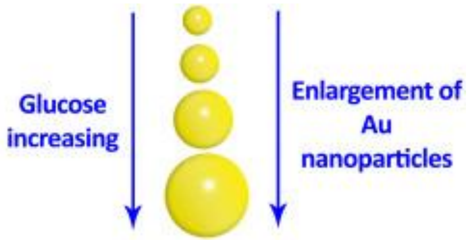
Colorimetric detection of sugars based on gold nanoparticle formation

Gerardo Palazzo[a], Laura Facchini[a], Antonia Mallardi[b,*]

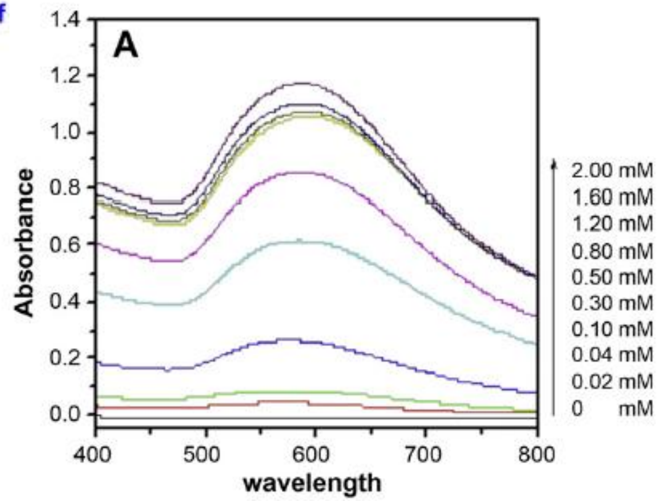
**STRATEGY 2**

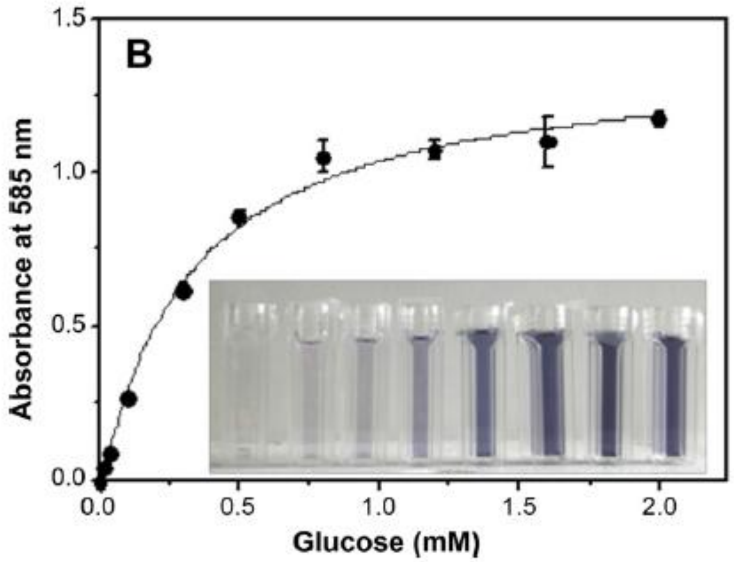
The "blue assay" is based on the Au-NP synthesis catalysed by the enzyme glucose oxidase and it is specific for glucose, with a LOD of 5 M.
This enzyme catalyses the **glucose oxidation** to gluconic acid **by a final electron acceptor, usually molecular oxygen**. Recently, the ability of glucose oxidase to reduce, in presence of glucose, $Au^{3+}$ ions to $Au^0$ has been reported and proposed as a route to the synthesis of Au-NPs of controlled size. Here we exploit this reaction to selectively quantify the glucose. Au-NP synthesis was achieved by adding the enzyme GOD to a buffered solution (pH = 7.0) of $HAuCl_4$ and glucose, and incubating at 37 °C for 90 min. Blue NPs (see picture) **were obtained while the reaction does not take place in absence of glucose or glucose oxidase**.



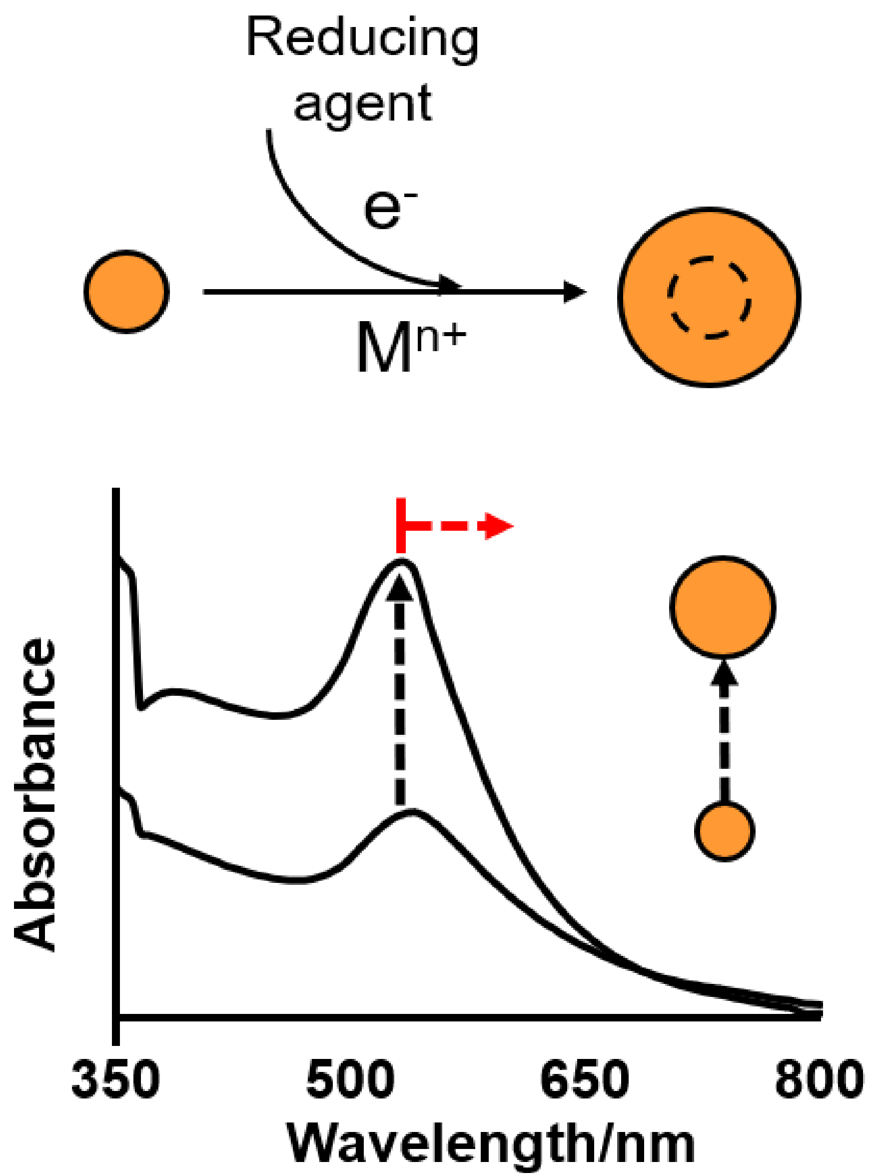




Glucose biosensing



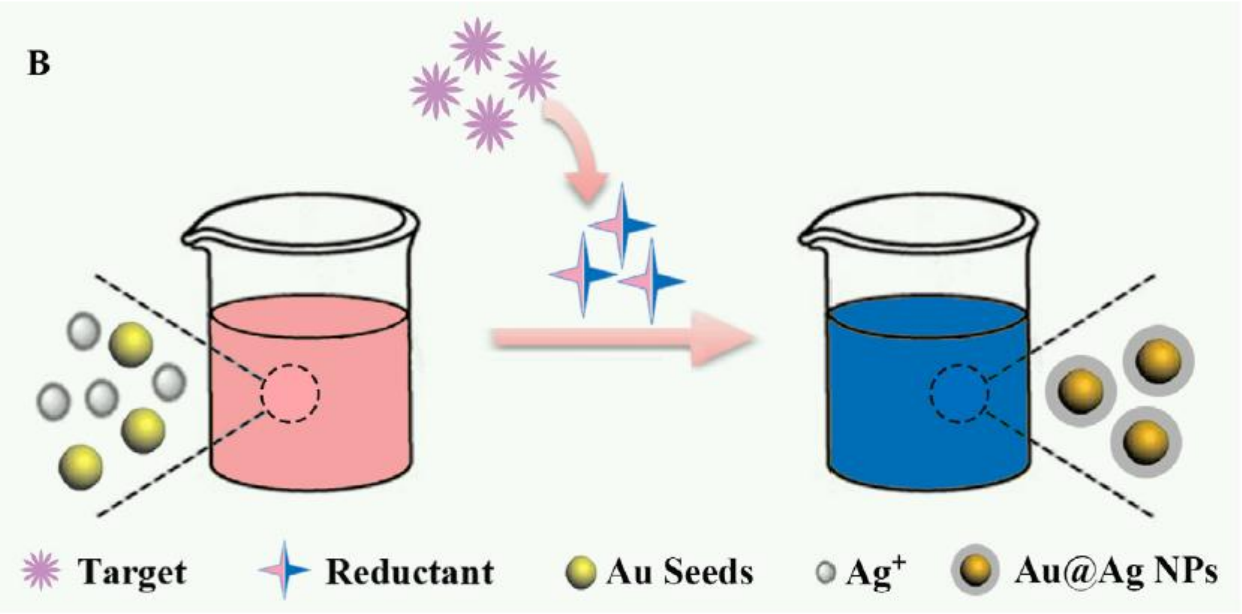
# Metal nanoparticle-based seed-growth strategies



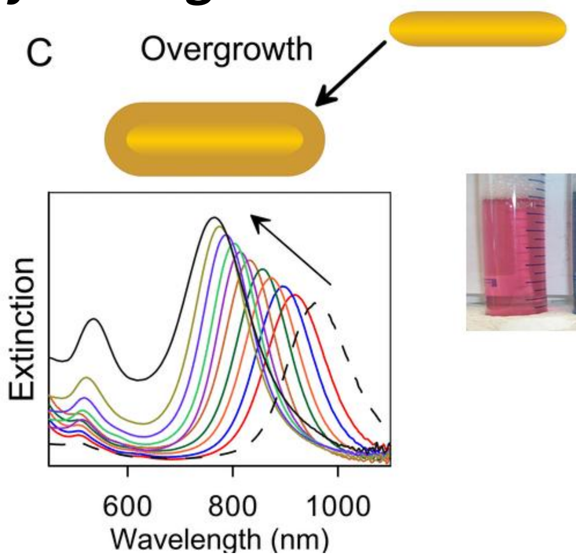
# Metal nanoparticles growth

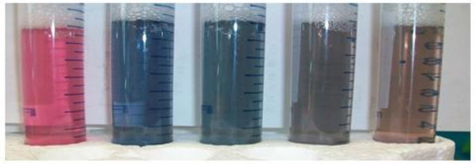


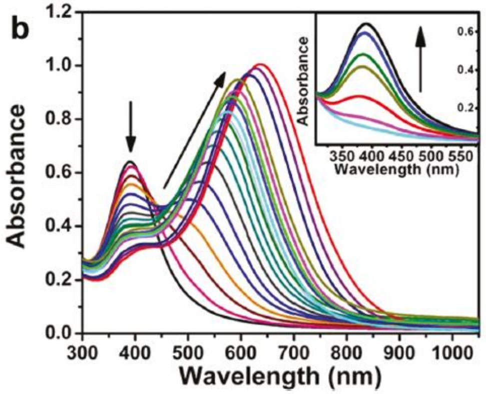
## Main strategy

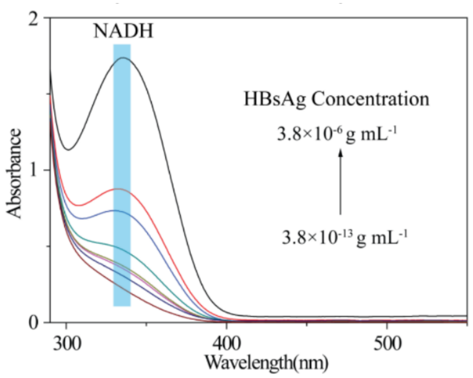



## Analytical signal





# Metal nanoparticles growth

## Reducing sugars monitoring trough AgNPs growth

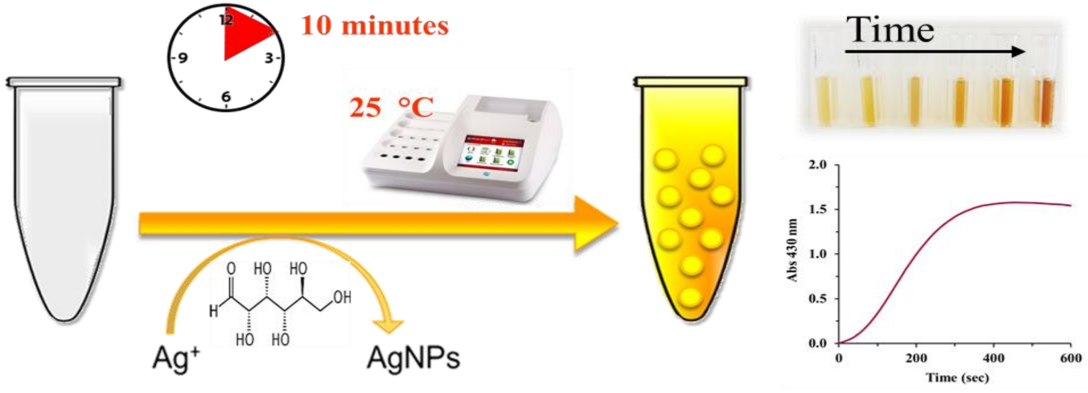

**Studies on Silver Nanoparticles Production Mediated by Sugars**

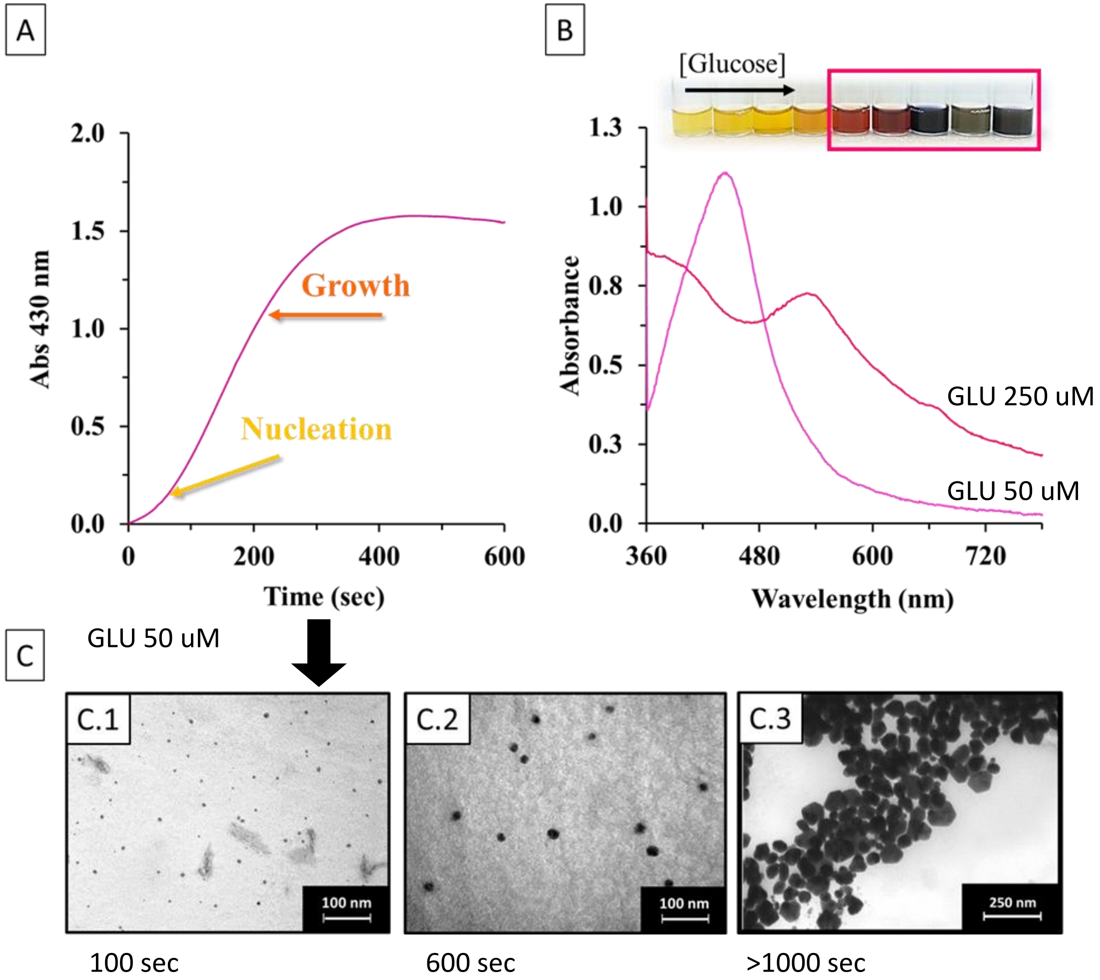

**Annalisa Scroccarello, Flavio Della Pelle, Simona Scarano and Dario Compagnone**

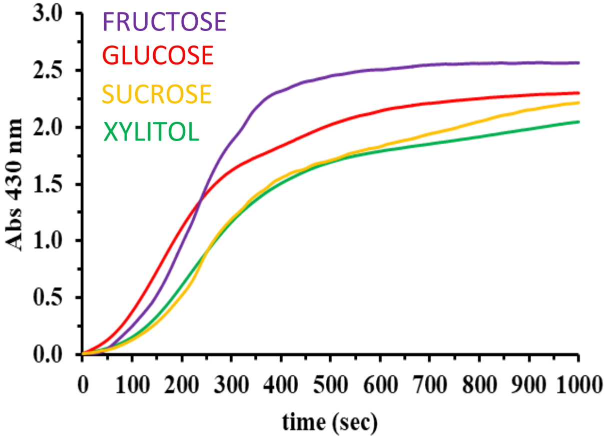


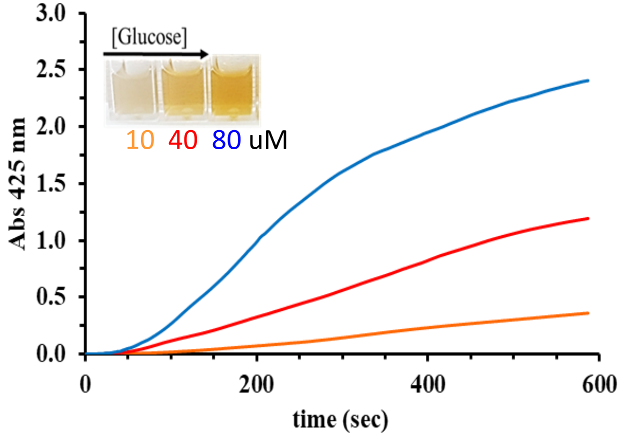


G. Di Francia et al. (eds.), *Sensors and Microsystems*, Lecture Notes in Electrical Engineering 629, https://doi.org/10.1007/978-3-030-37558-4_5

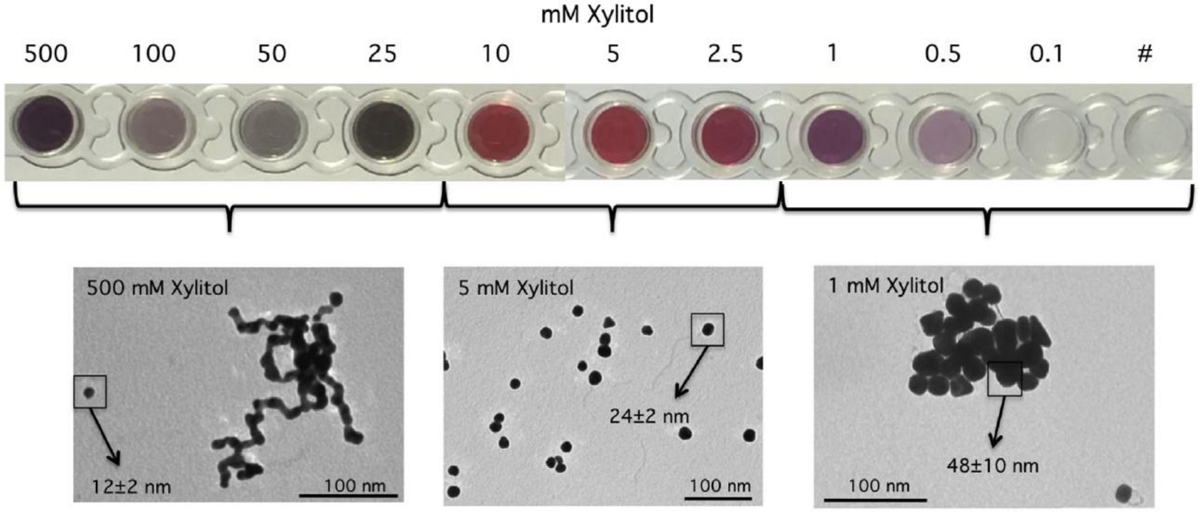



# Metal nanoparticles growth



## Xylitol monitoring trough AuNPs growth

### Seed formation and growth phenomena study




Analytica Chimica Acta xxx (2017) 1–8
Contents lists available at ScienceDirect
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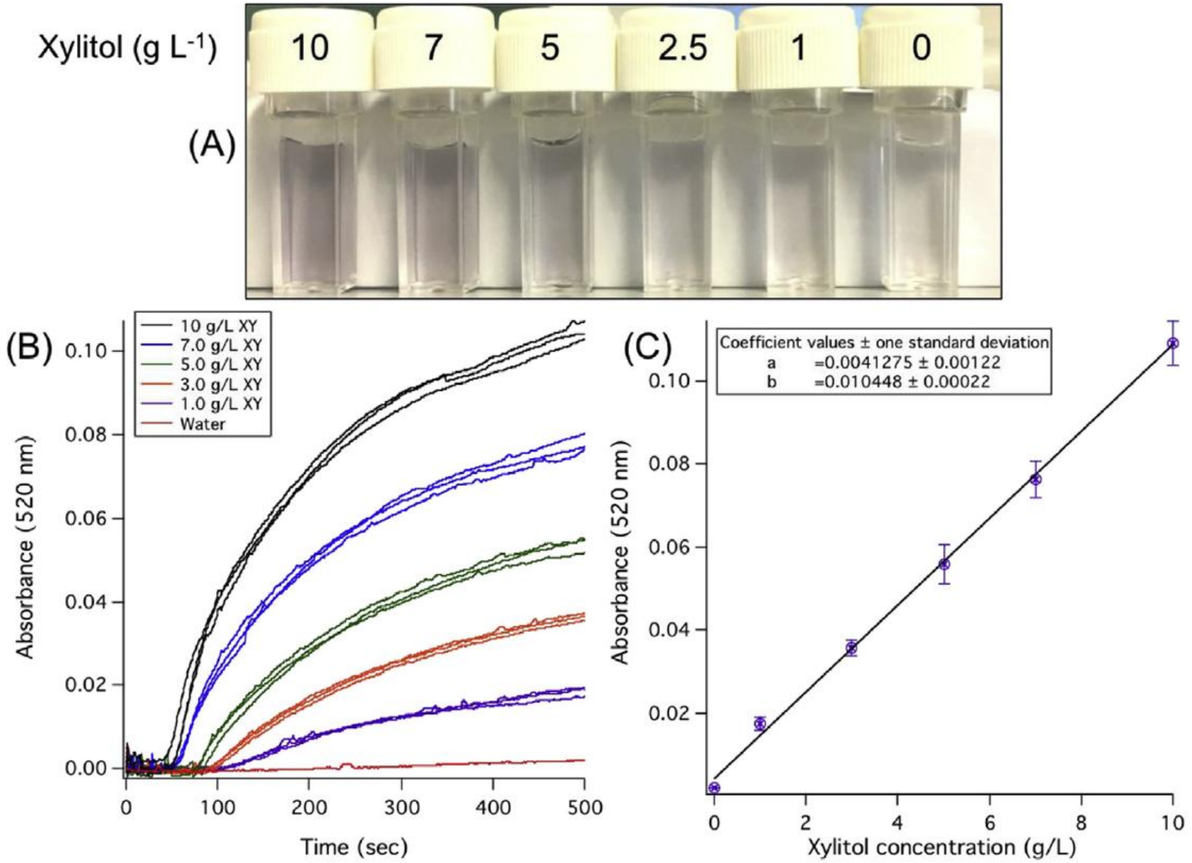
The early nucleation stage of gold nanoparticles formation in solution as powerful tool for the colorimetric determination of reducing agents: The case of xylitol and total polyols in oral fluid

S. Scarano*, E. Pascale, M. Minunni

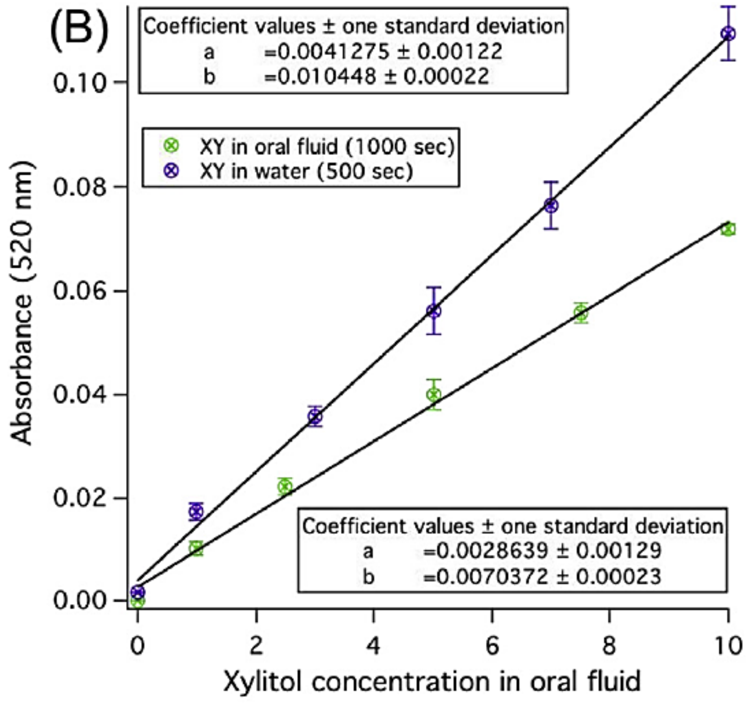
### Dose-response kinetic and curve



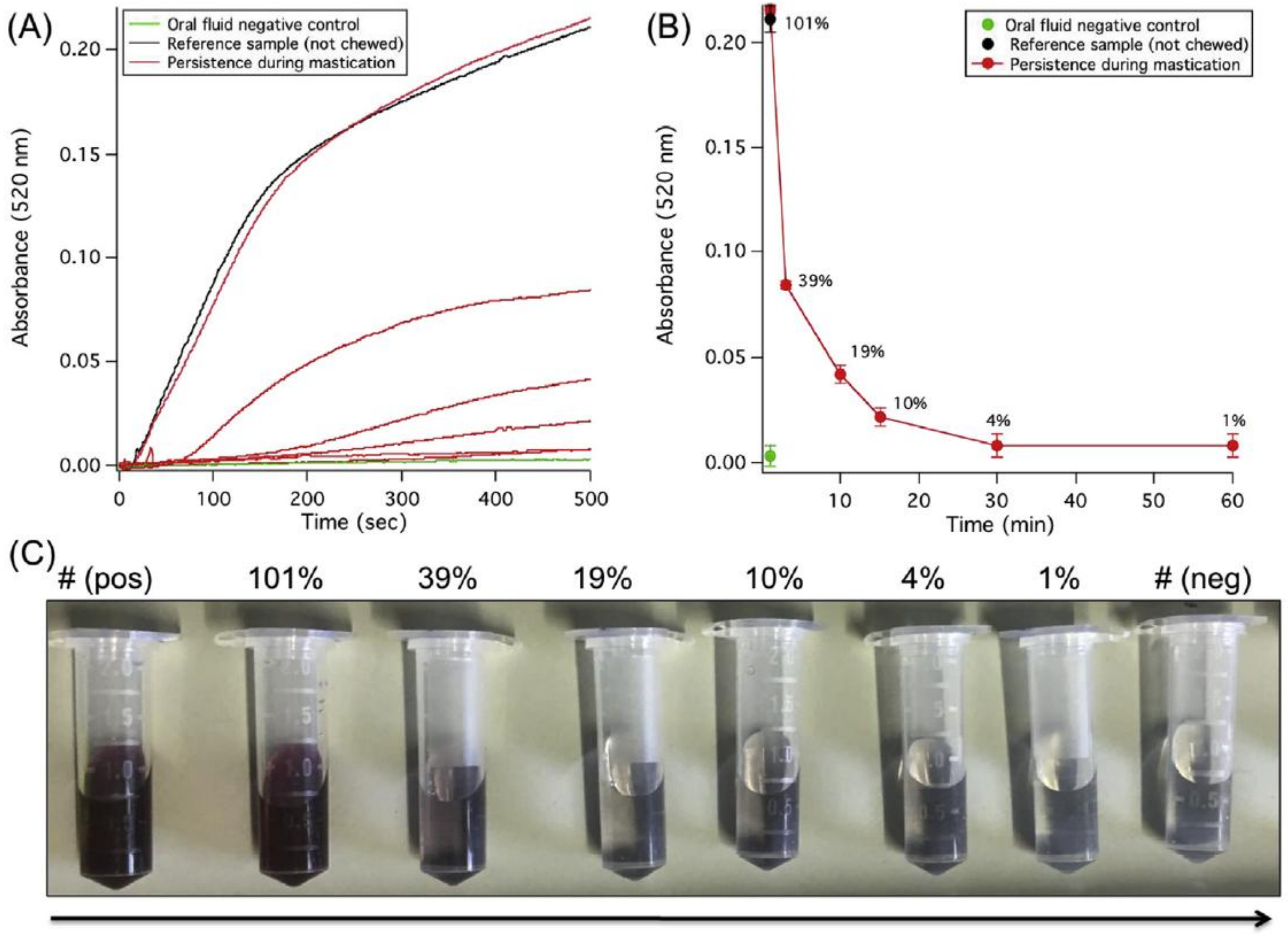
## Xylitol monitoring in human saliva trough AuNPs growth

### Recovery study

Methods evalutaion  for sample analysis

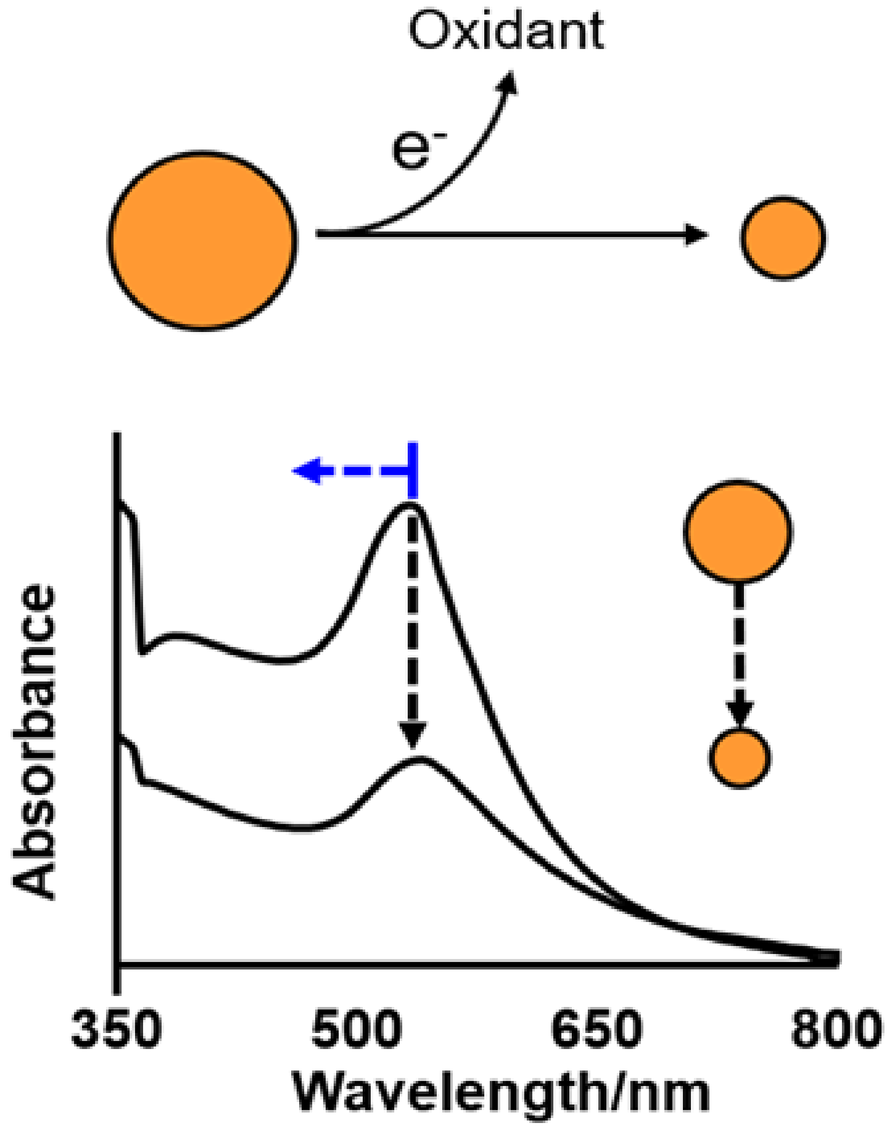



### Xylitol montoring along 1 hours of chewin-gum mastication




Xylitol decay

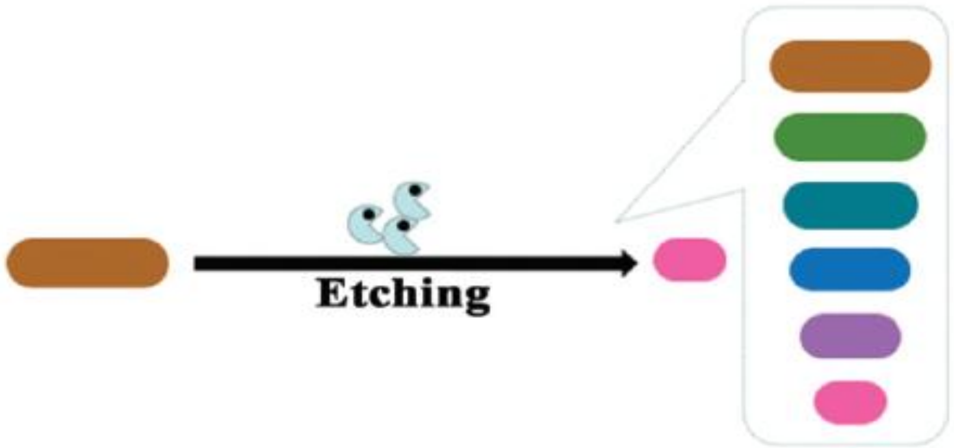
# Metal nanoparticle etching



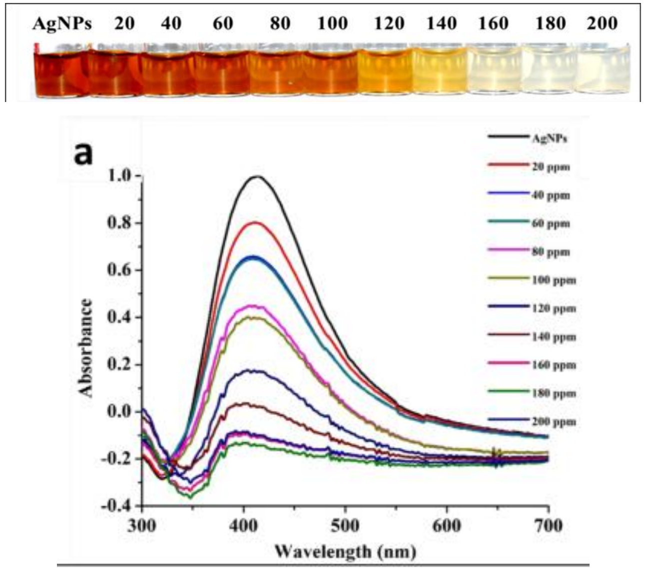
# Metal nanoparticles etching

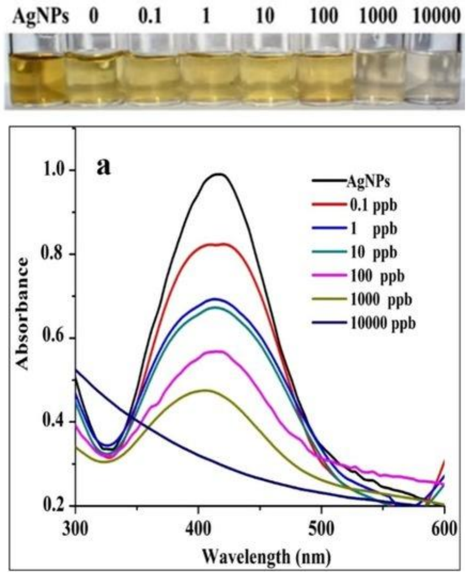


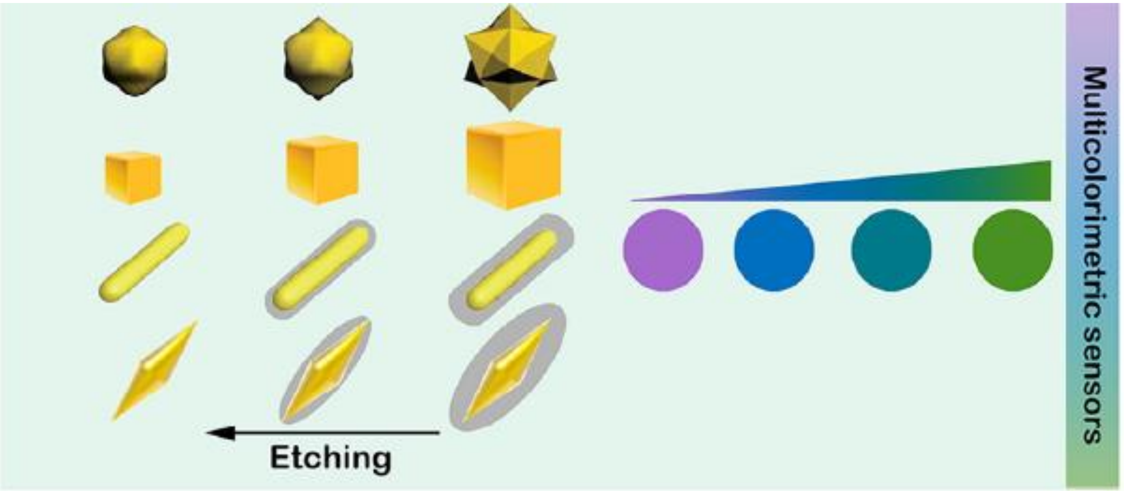
## Main strategy

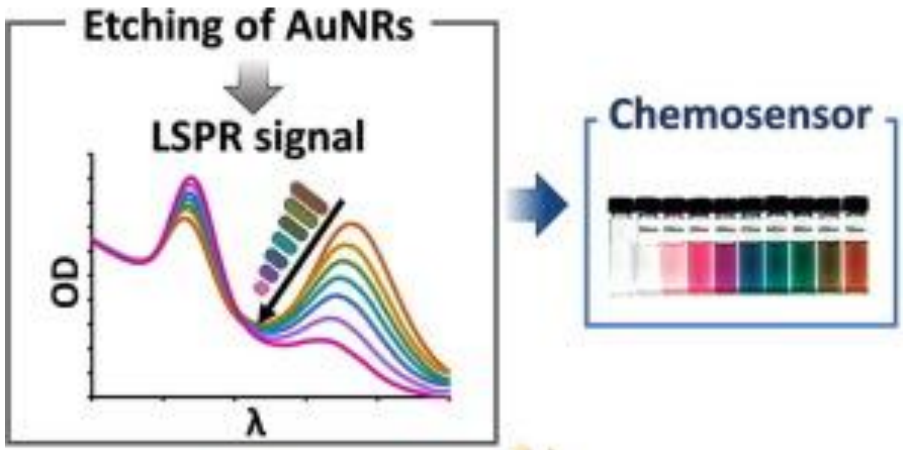


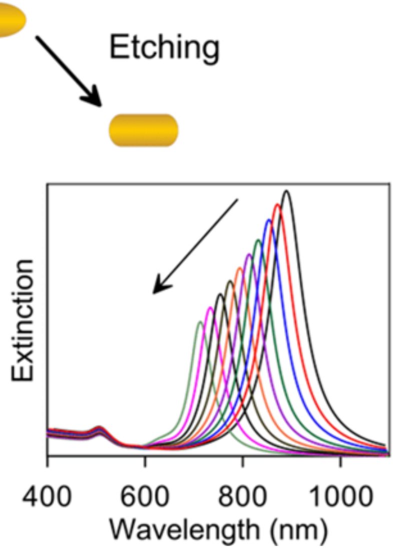

## Analytical signal



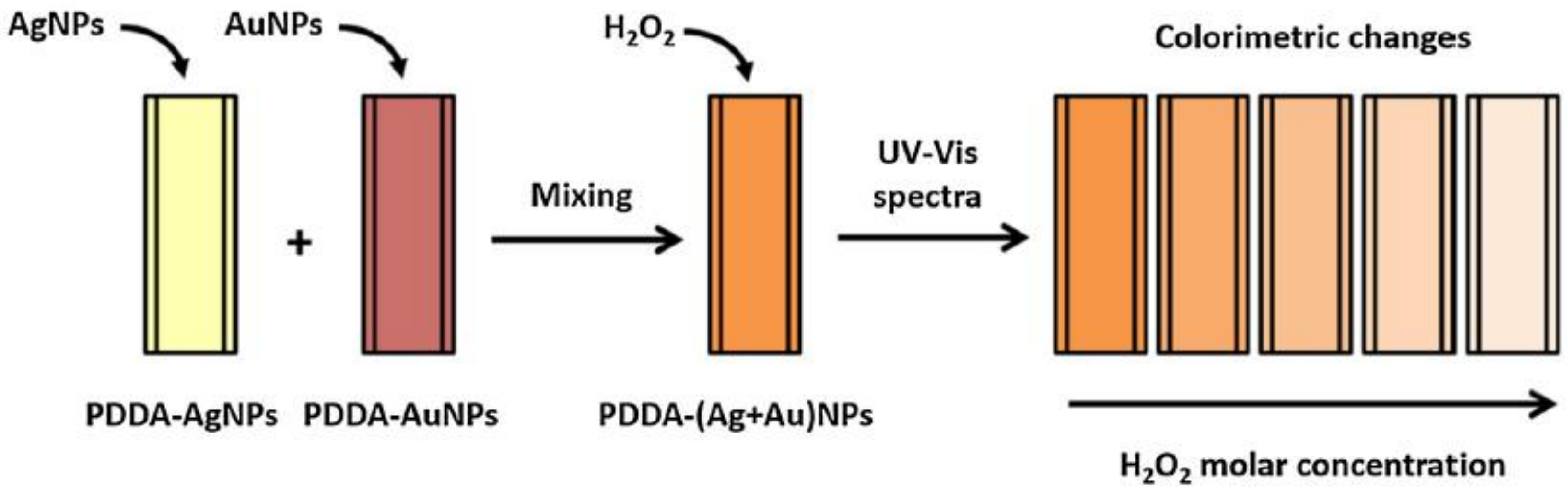



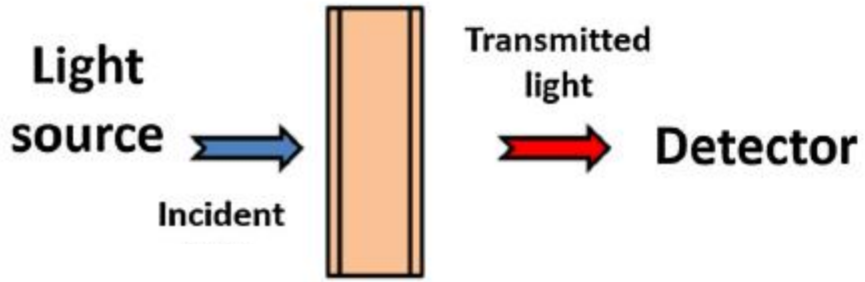



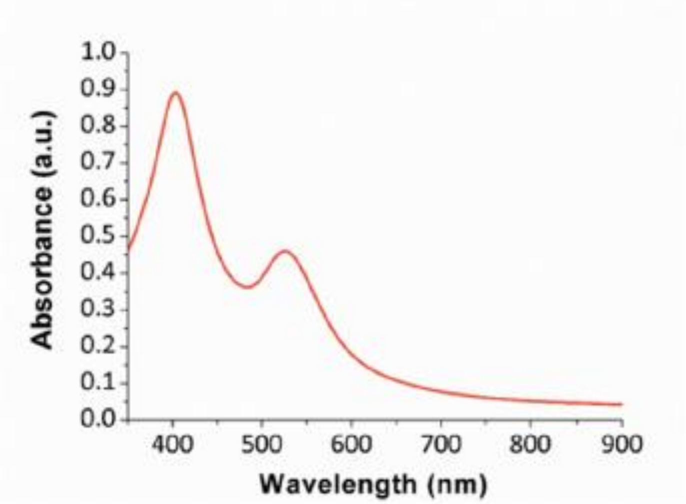



# Metal nanoparticles etching

## $H_2O_2$ determination trough MNPs etching





Sensors and Actuators B 251 (2017) 624–631

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

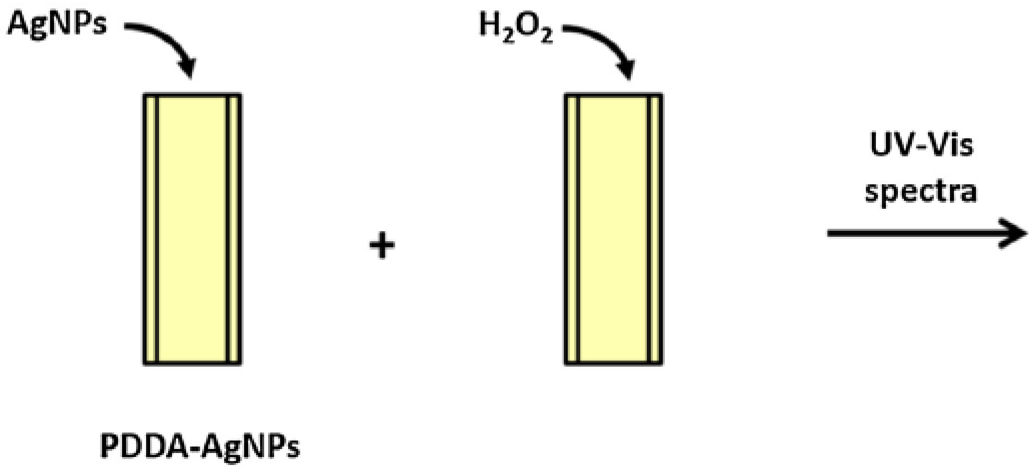
journal homepage: www.elsevier.com/locate/snb

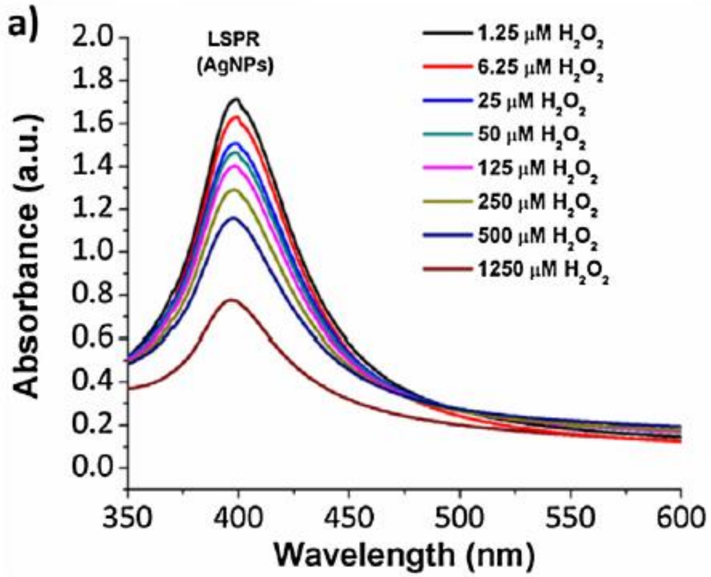

A self-referenced optical colorimetric sensor based on silver and gold nanoparticles for quantitative determination of hydrogen peroxide

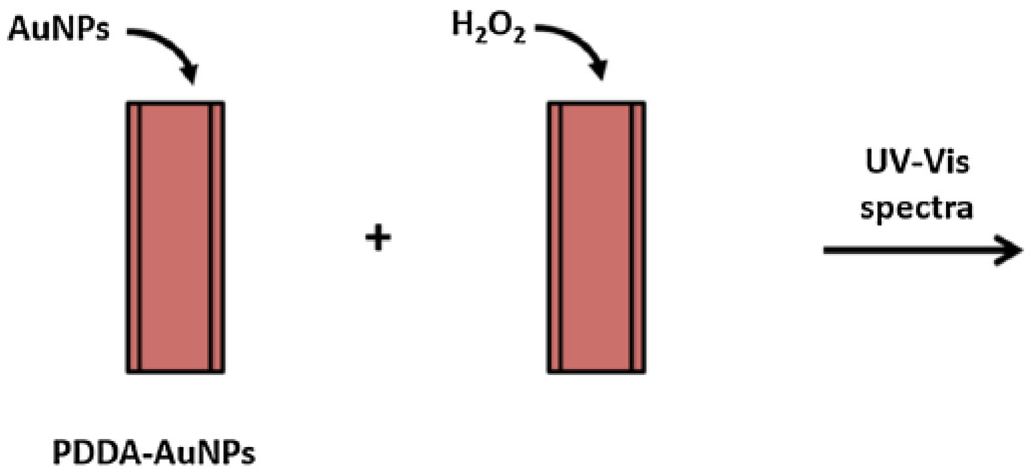

Pedro J. Rivero[a,*], Elia Ibañez[b], Javier Goicoechea[b], Aitor Urrutia[b], Ignacio R. Matias[c], Francisco J. Arregui[b]

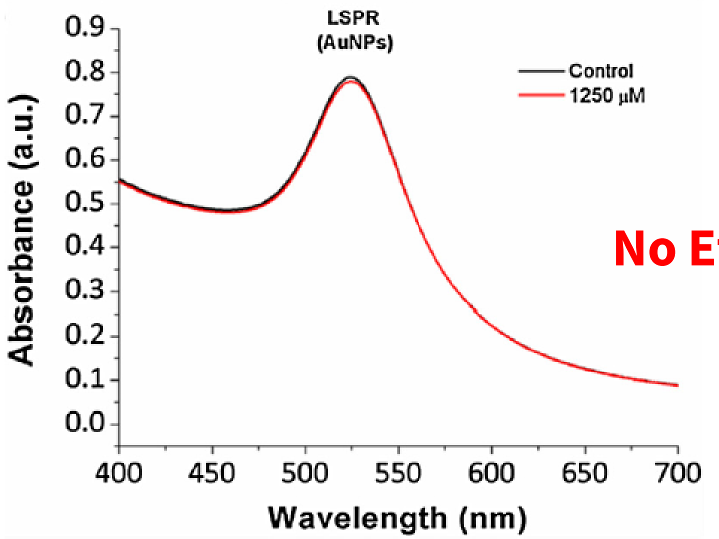
# Metal nanoparticles etching

## Etching phenomena study



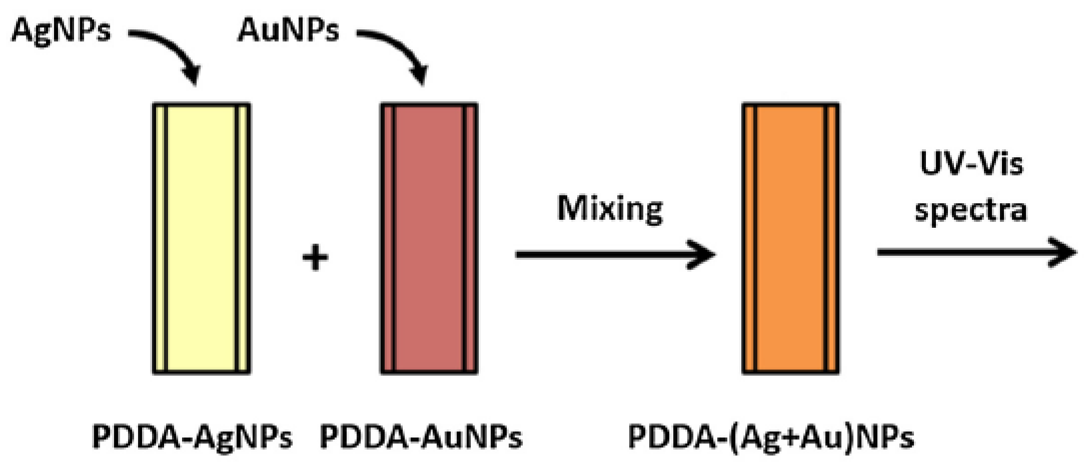



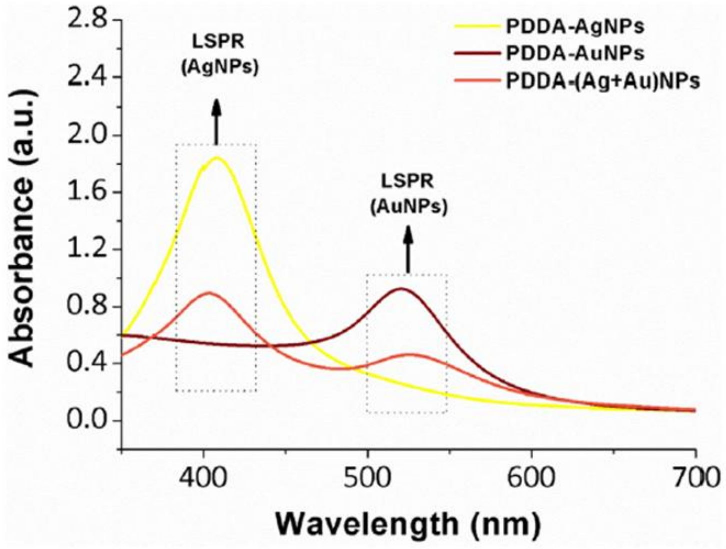

**No Etching phenomena**

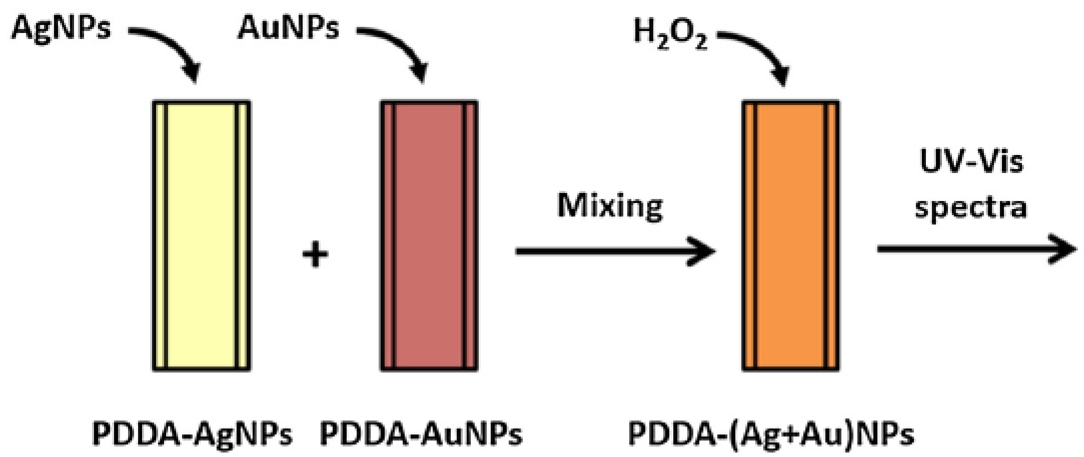
# Metal nanoparticles etching

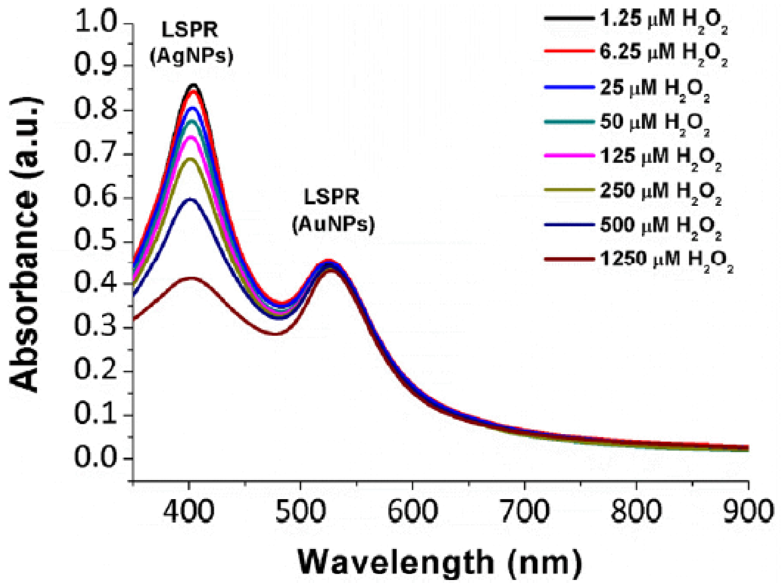


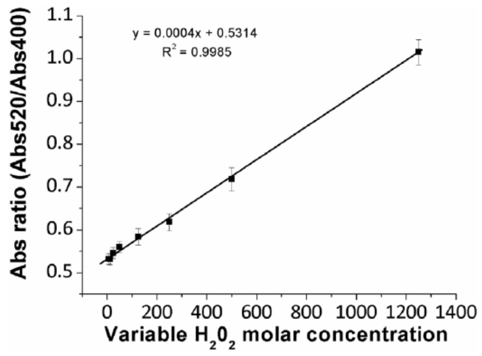
## Etching phenomena study. $H_2O_2$ determination

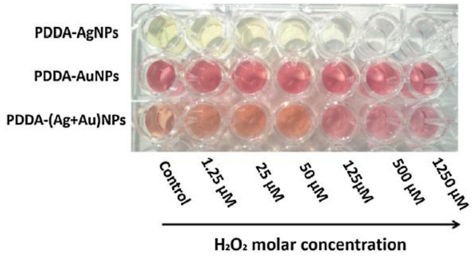


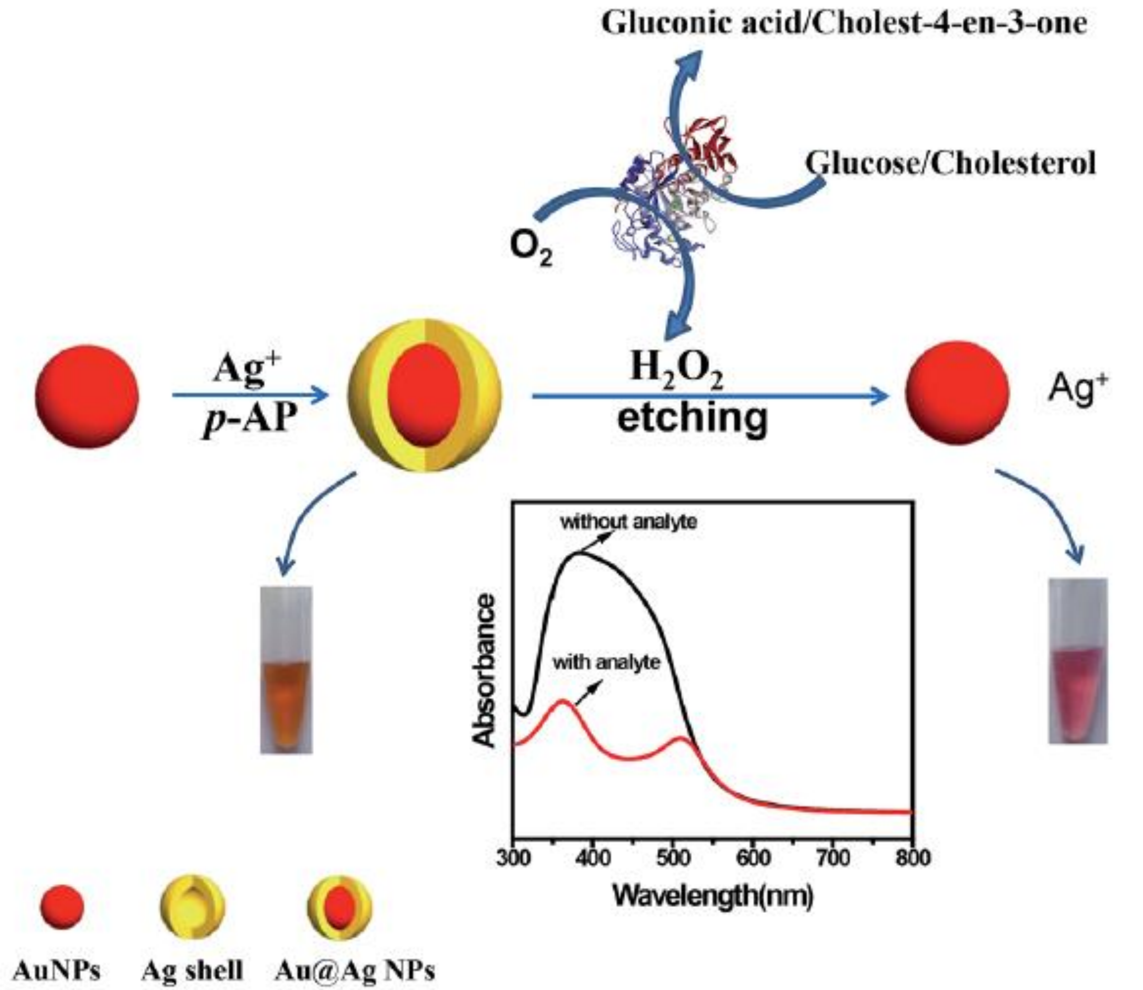



# Metal nanoparticles etching

## Glucose and cholesterol evaluation trough MNPs etching

$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{GOx}} \text{gluconic acid} + H_2O_2$$

$$\text{Cholesterol} + O_2 + H_2O \xrightarrow{\text{ChOx}} \text{cholest-4-en-3-one} + H_2O_2$$




Scheme 1 Schematic illustration of the formation of Au@Ag NPs and its application for the colorimetric detection of $H_2O_2$ and glucose/cholesterol.

RSC Advances
ROYAL SOCIETY OF CHEMISTRY
PAPER
View Article Online
View Journal | View Issue
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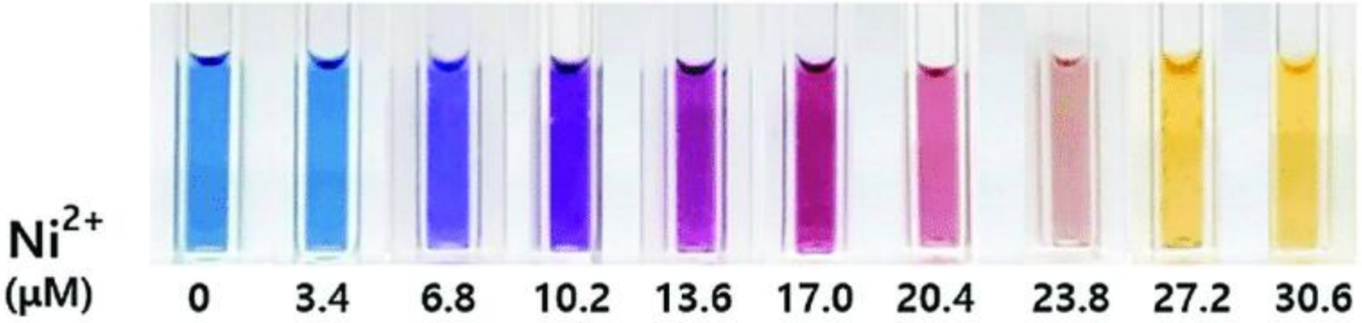
Cite this: RSC Adv., 2016, 6, 35001

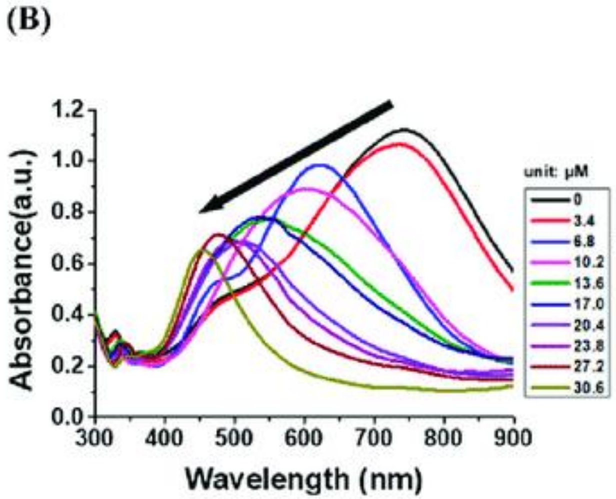
**Sensitive colorimetric detection of glucose and cholesterol by using Au@Ag core–shell nanoparticles†**

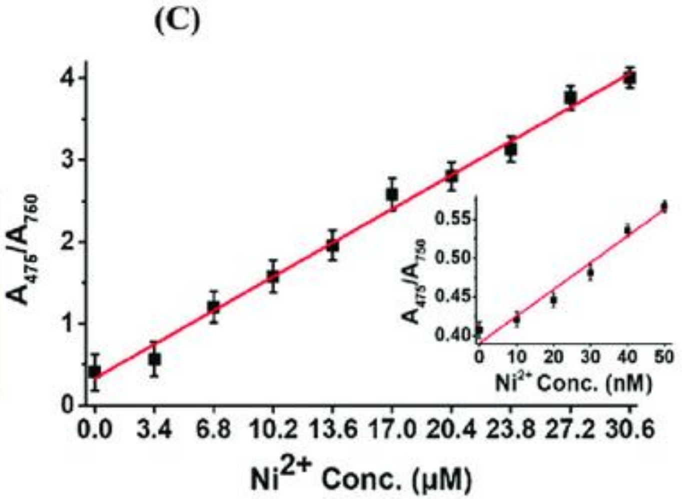
Xuehong Zhang,[a] Min Wei,[b] Bingjing Lv,[a] Yuanjian Liu,[a] Xu Liu[a] and Wei Wei*[a]

# Metal nanoparticles etching

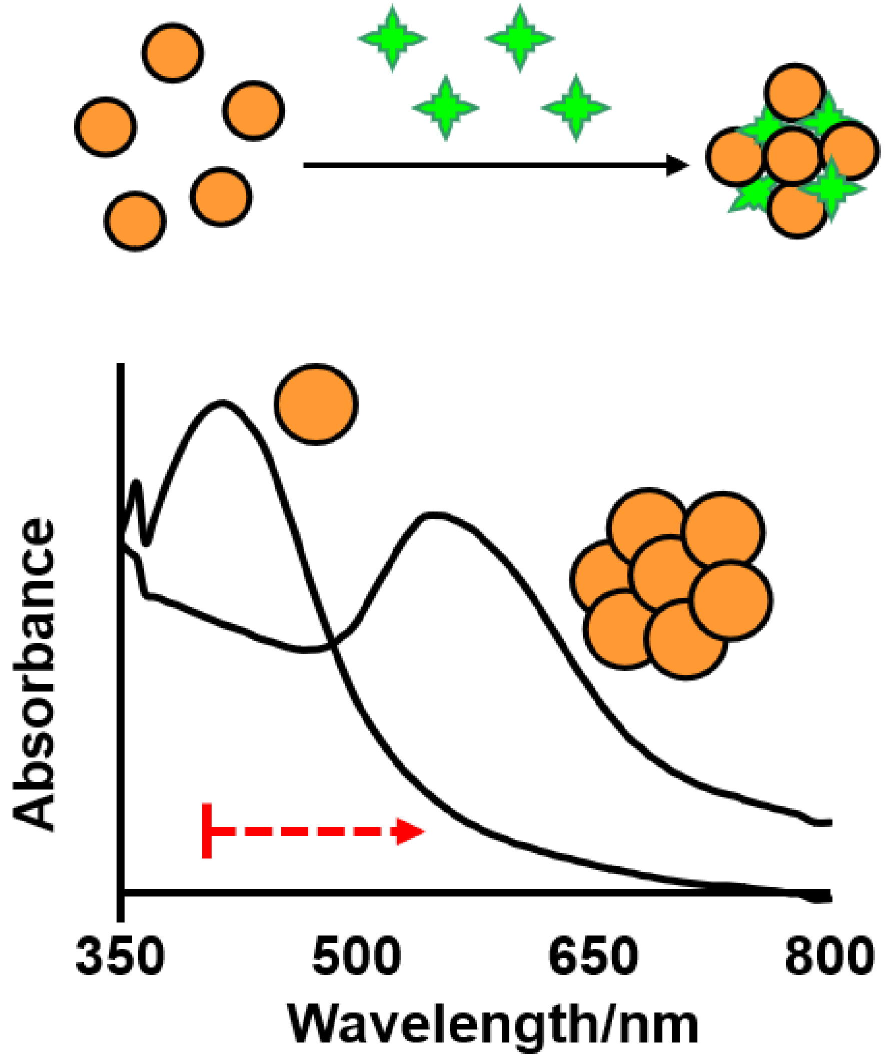
## Nickel determination

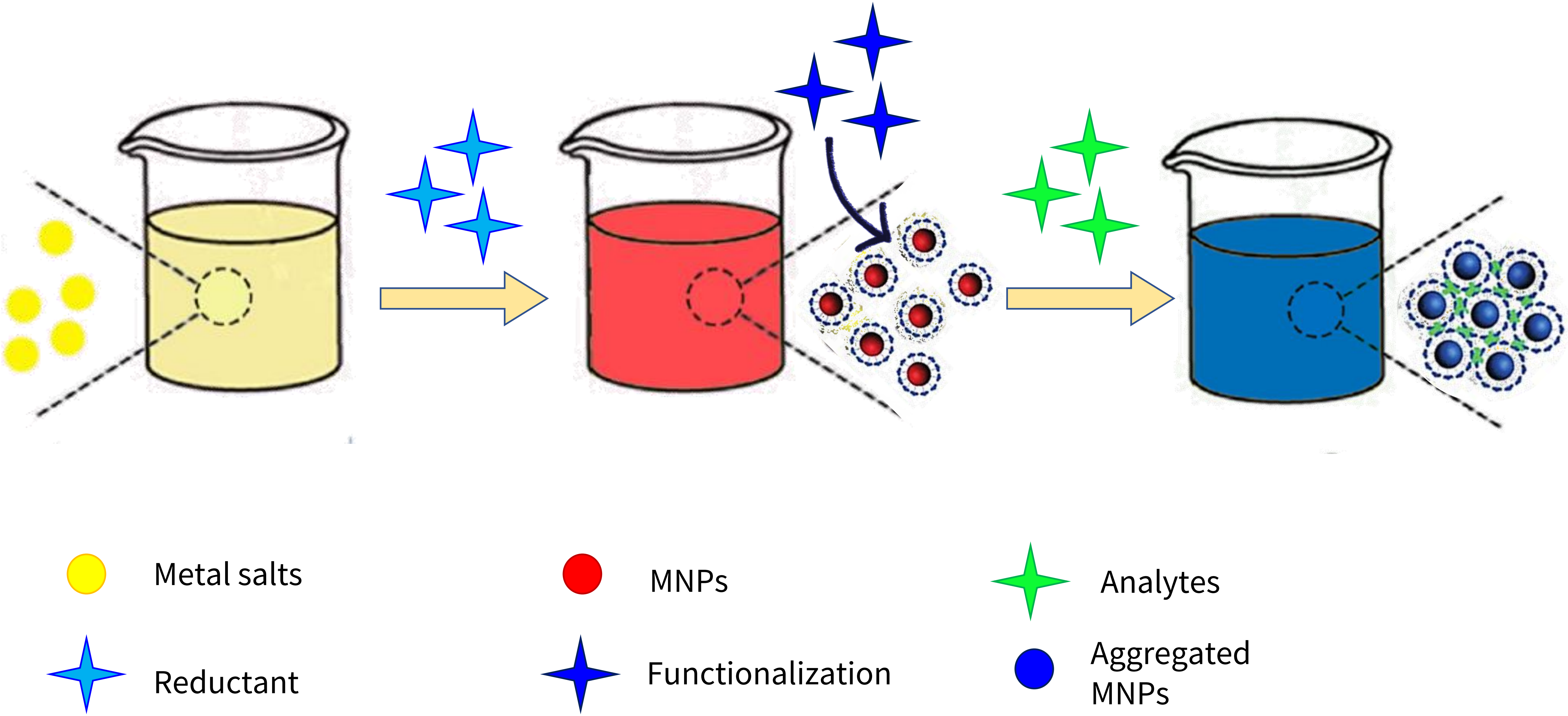
# Metal nanoparticle aggregation



# Metal nanoparticles aggregation



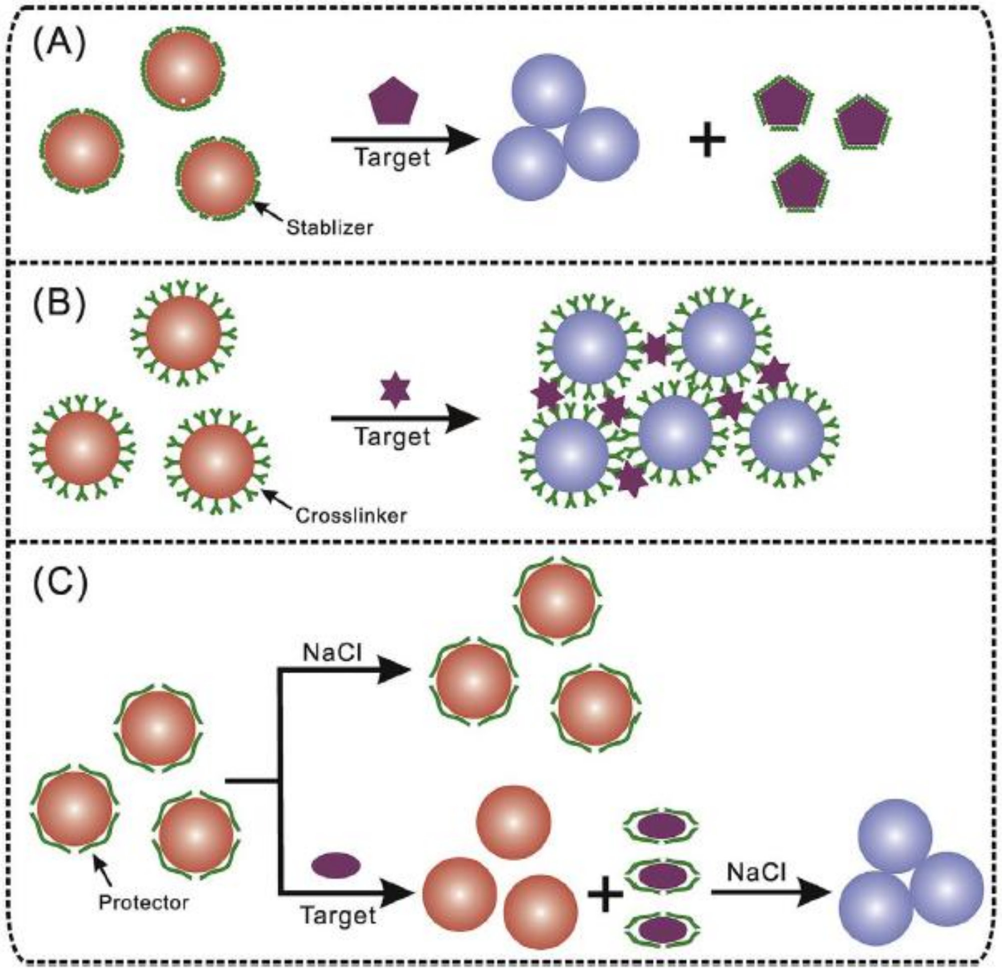
## Main strategy



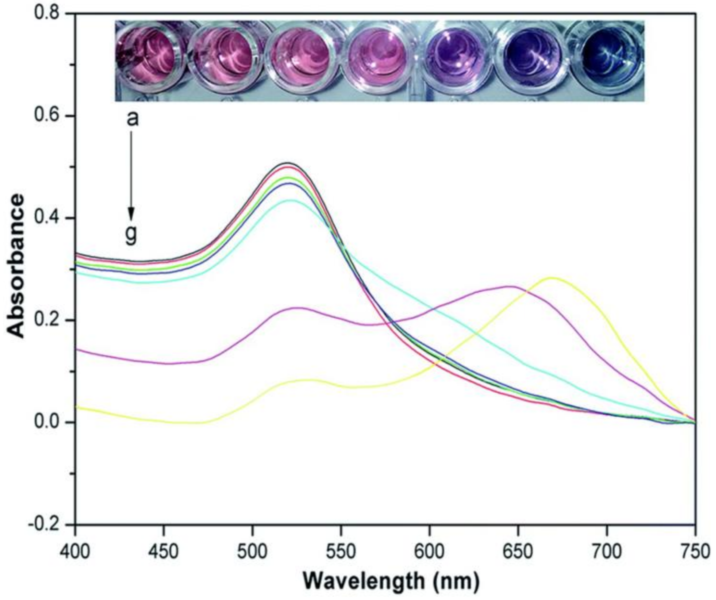
# Metal nanoparticles aggregation

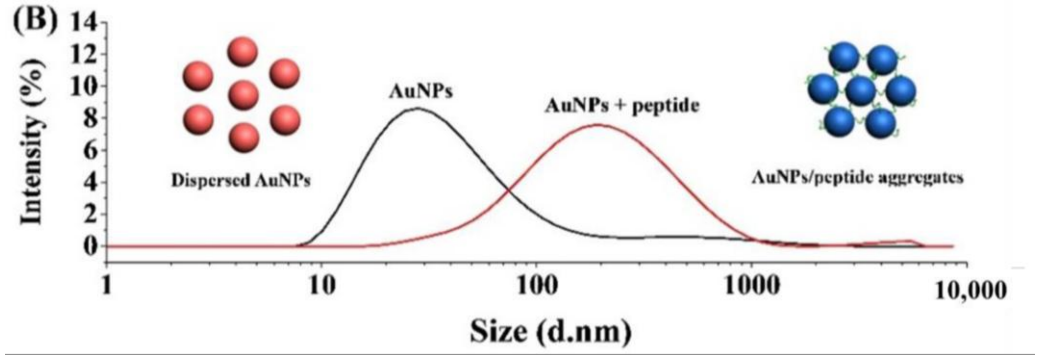


## Main strategy



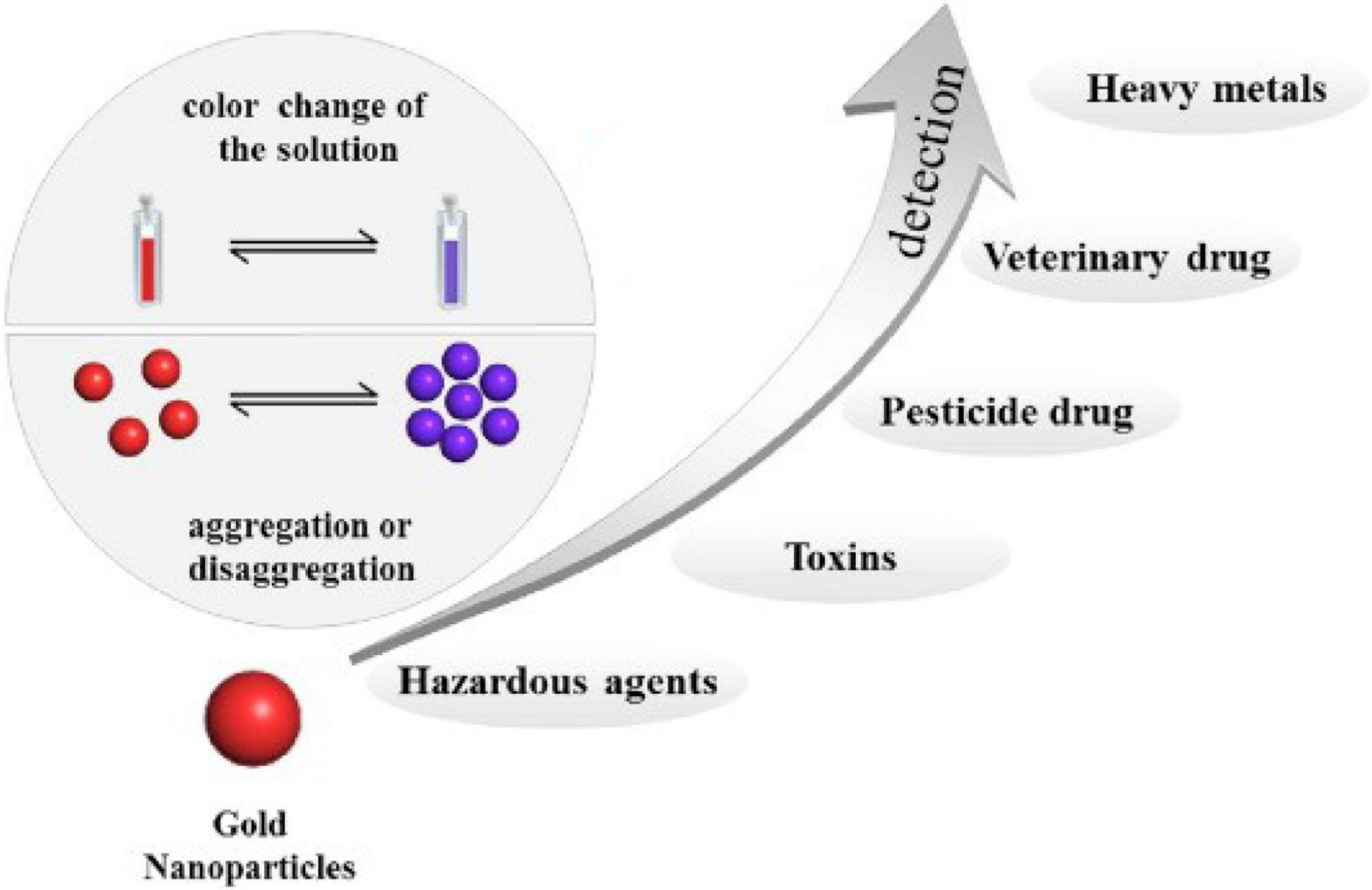

## Analytical signal



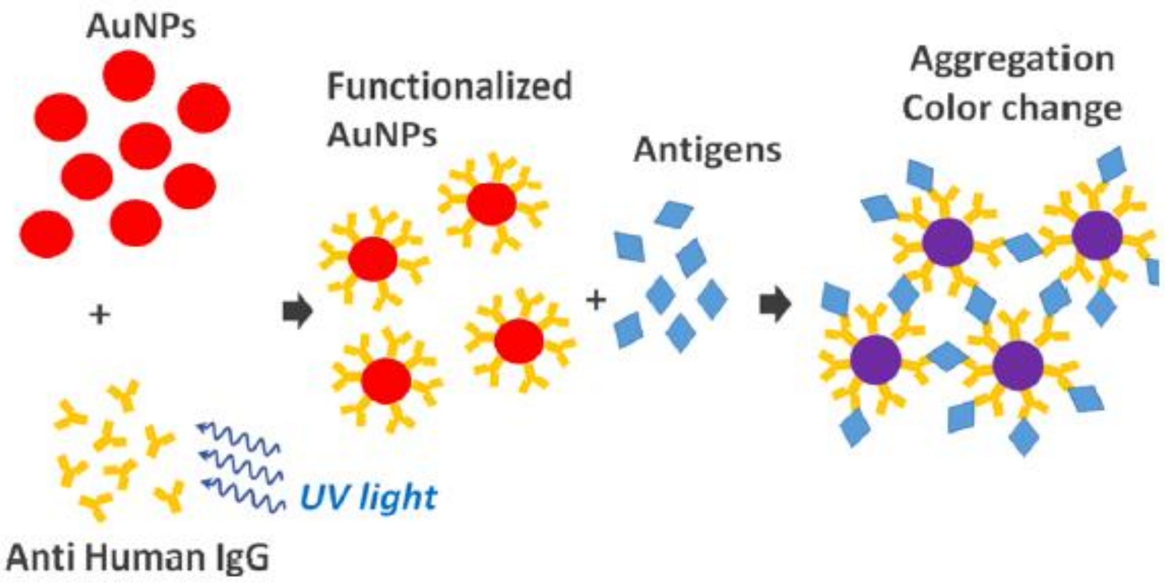
# Metal nanoparticles aggregation

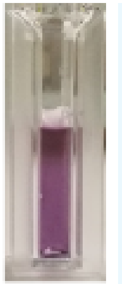
## Main strategy

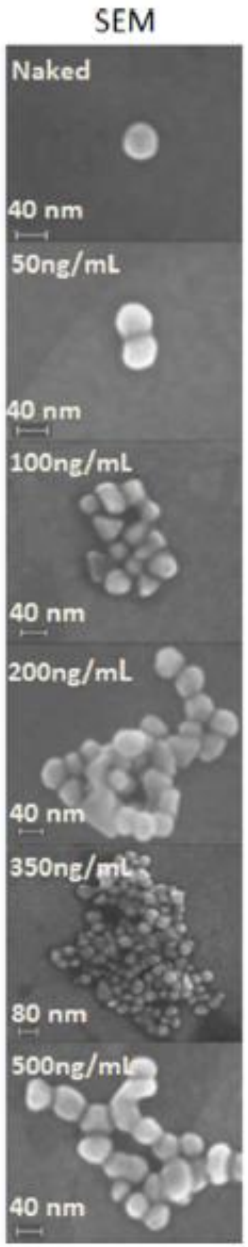


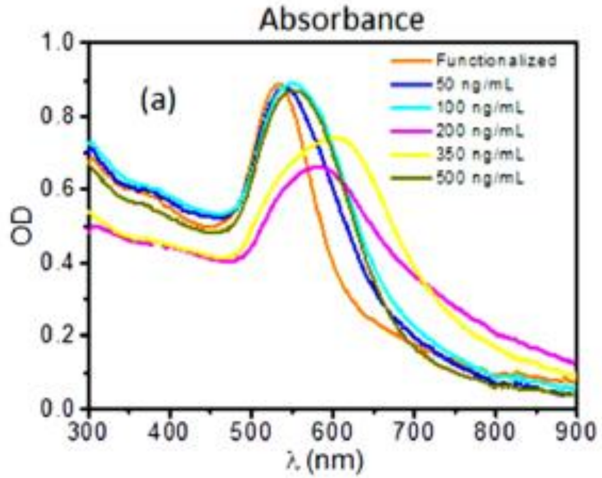
# Metal nanoparticles aggregation

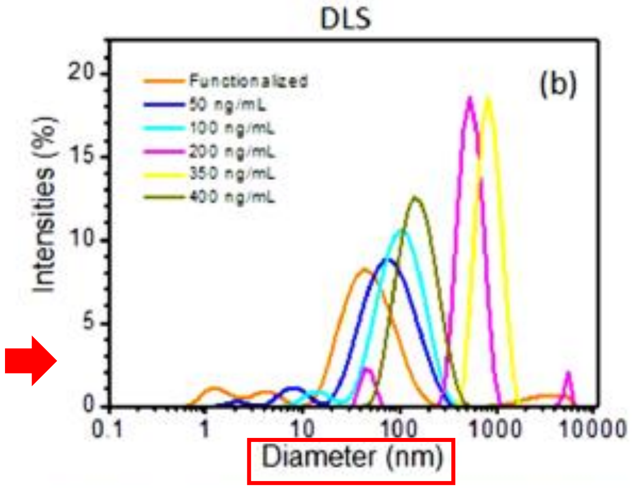
## Immuno-based determination of HIgG

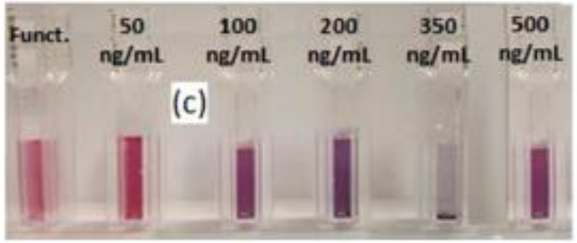






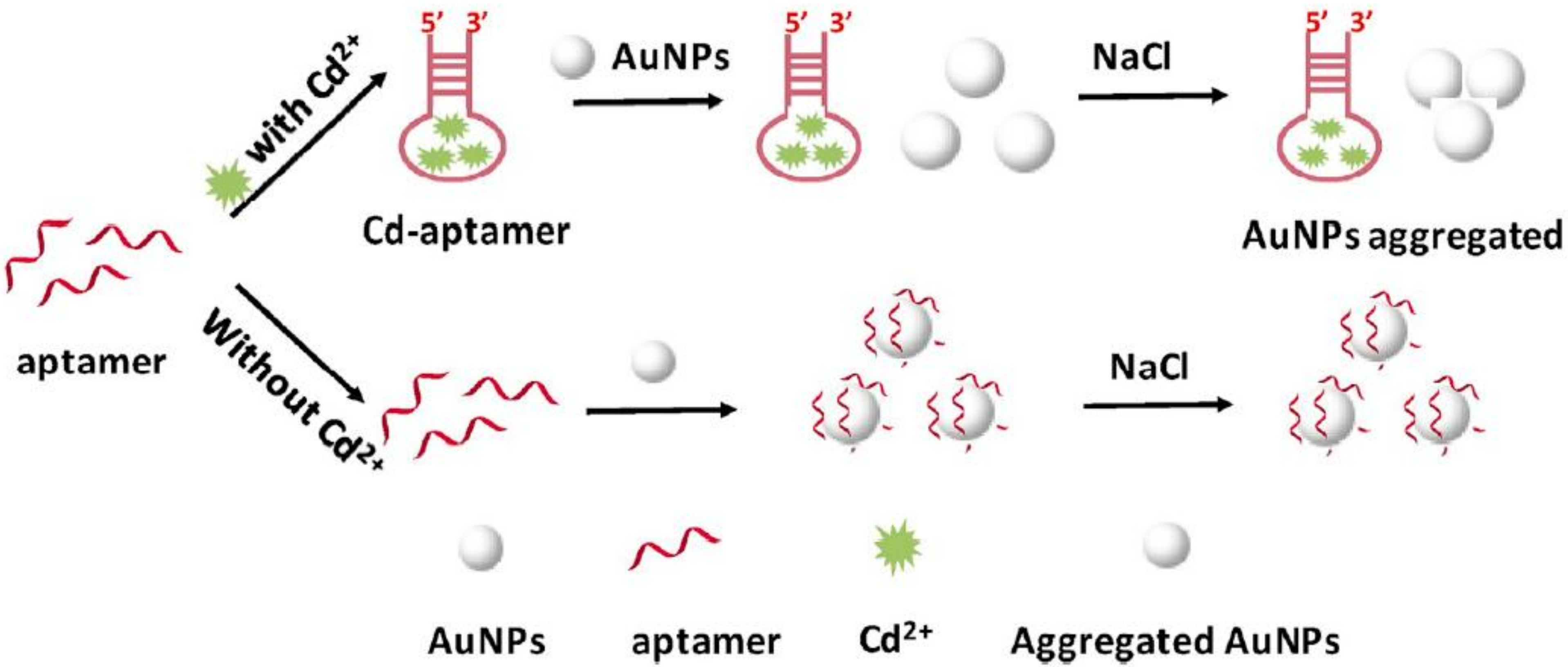

ACS OMEGA
Article
Cite This: ACS Omega 2018, 3, 3805−3812

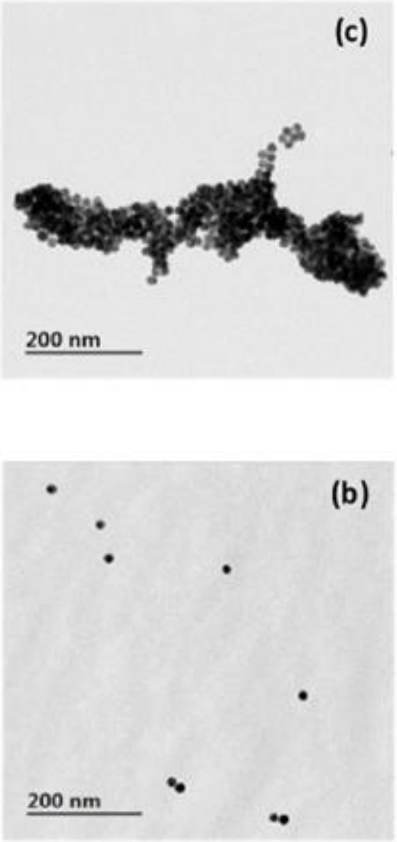
**Colorimetric Immunosensor by Aggregation of Photochemically Functionalized Gold Nanoparticles**

Marzia Iarossi,[†,∥] Chiara Schiattarella,[†,‡] Ilaria Rea,[‡] Luca De Stefano,[‡] Rosalba Fittipaldi,[§] Antonio Vecchione,[§] Raffaele Velotta,[*,†] and Bartolomeo Della Ventura[†]

# Metal nanoparticles aggregation

## $Cd^{2+}$ indirect determination trough AuNPs aggregation





Talanta 208 (2020) 120231
Contents lists available at ScienceDirect
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journal homepage: www.elsevier.com/locate/talanta


In-situ detection of cadmium with aptamer functionalized gold nanoparticles based on smartphone-based colorimetric system


Ying Gan[a,b], Tao Liang[a], Qiongwen Hu[a], Longjie Zhong[a], Xinyi Wang[a], Hao Wan[a,b,**], Ping Wang[a,b,*]

UNIVERSITÀ DEGLI STUDI DI TERAMO UNITE

## $Cd^{2+}$ indirect determination assay format

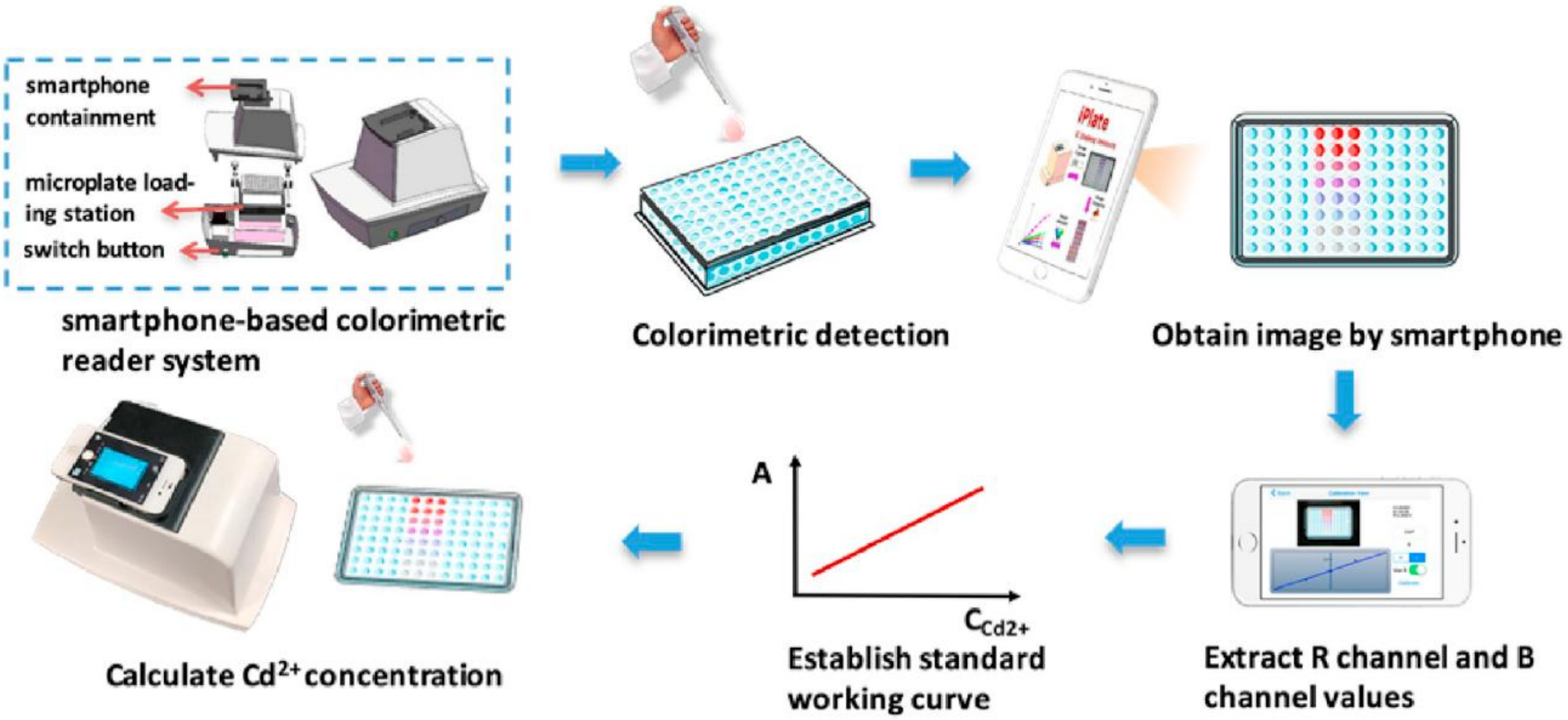
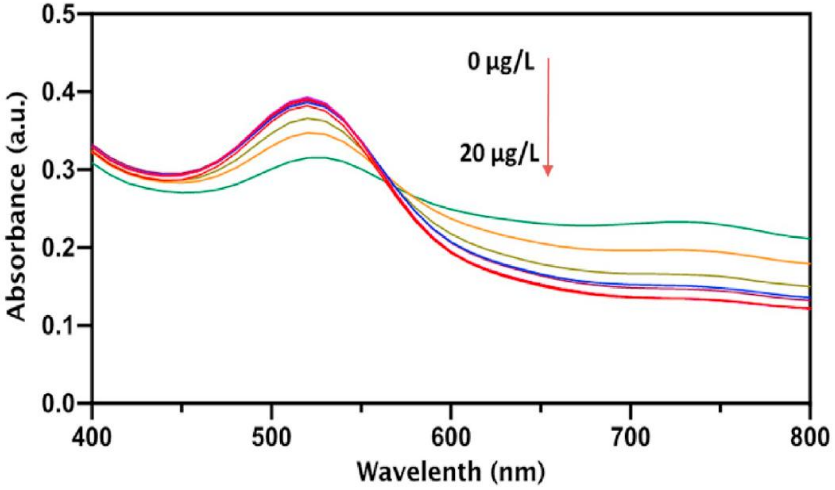


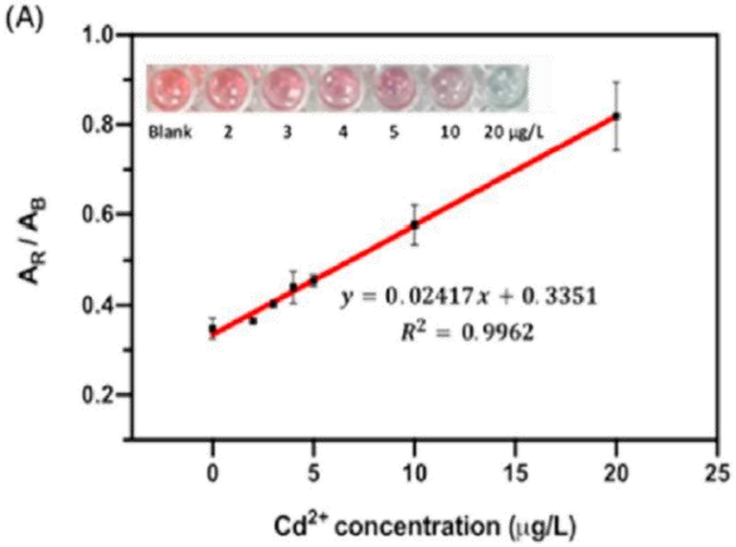

Fig. 2. Detection process of smartphone based colorimetric reader system.

# Metal nanoparticles aggregation

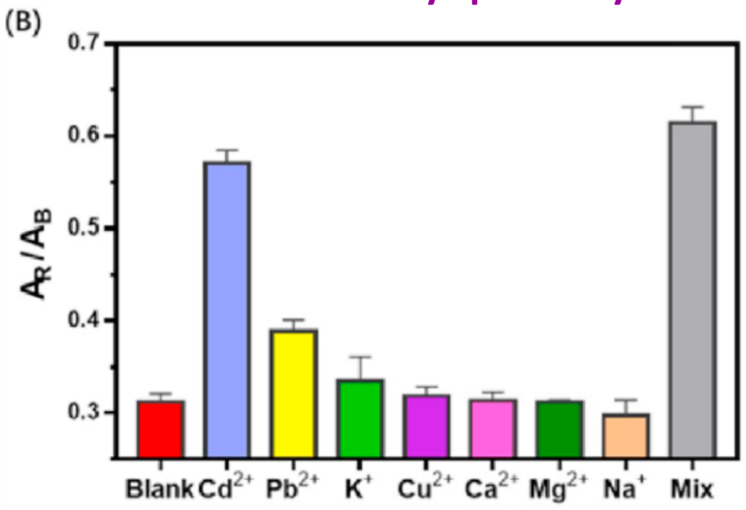
## $Cd^{2+}$ indirect determination

### Dose-response curve




### Colorimetric assay specificity



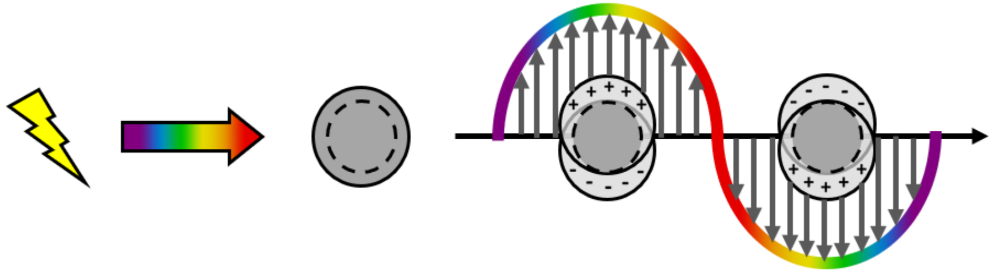

### Recovery study

Determination of $Cd^{2+}$ in tap water samples using the proposed method.

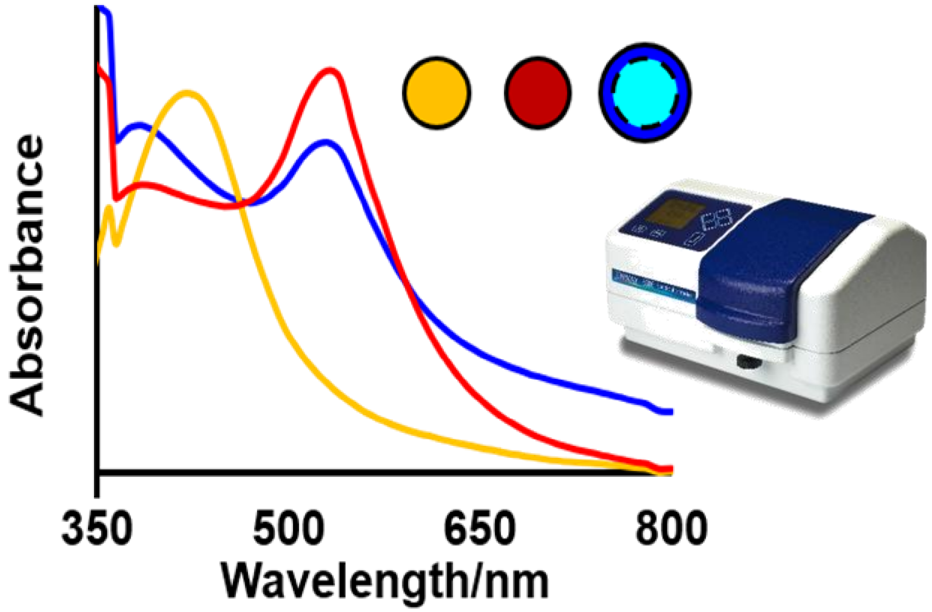
| Samples | Spiked concentration (µg/L) | This colorimetric system | | Microplate reader | |
|---|---|---|---|---|---|
| | | Determined conc. (µg/L) | Recovery% | Determined conc. (µg/L) | Recovery% |
| 1 | 5 | 5.18 | 116.4 | 5.21 | 104.3 |
| 2 | 10 | 11.32 | 113.2 | 10.96 | 109.6 |
| 3 | 10 | 11.61 | 116.1 | 10.83 | 108.3 |
| 4 | 20 | 21.63 | 108.15 | 20.12 | 100.6 |
| 5 | 20 | 23.56 | 117.8 | 22.15 | 110.8 |

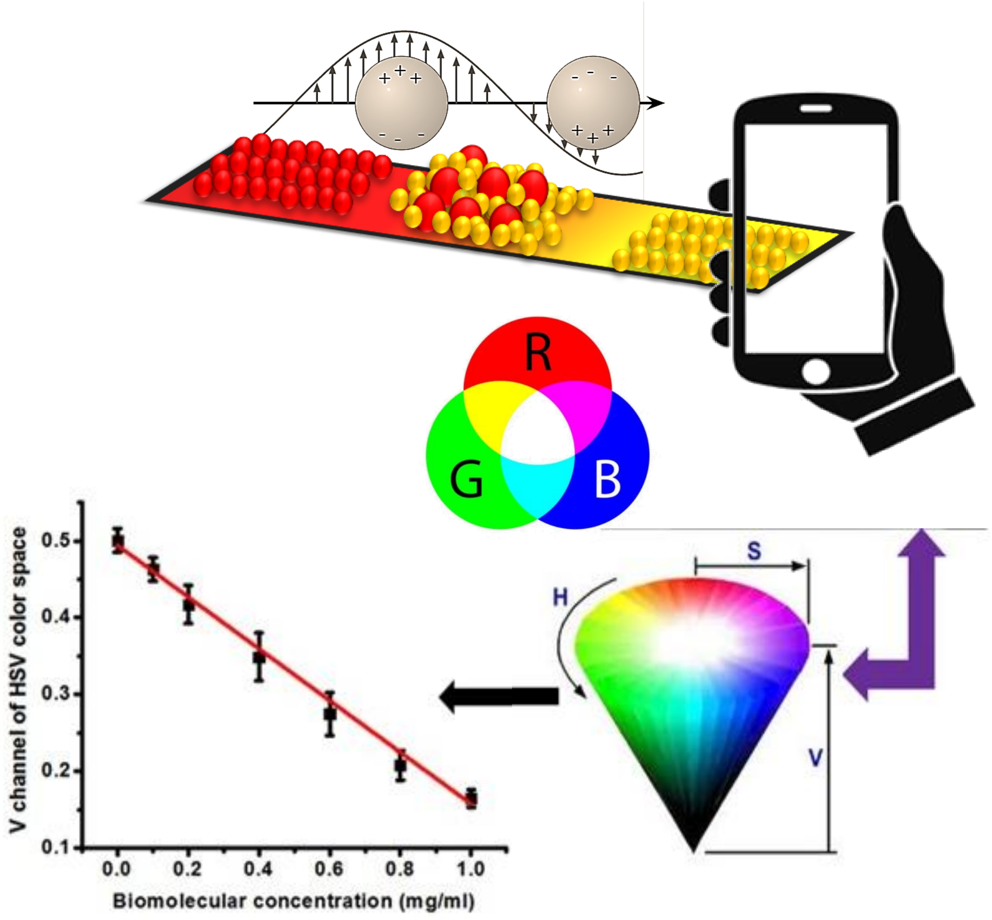
# Colorimetric approach

## From plasmonic… Towards colorimetric strategies



**Localized Surface Plasmon Resonance**



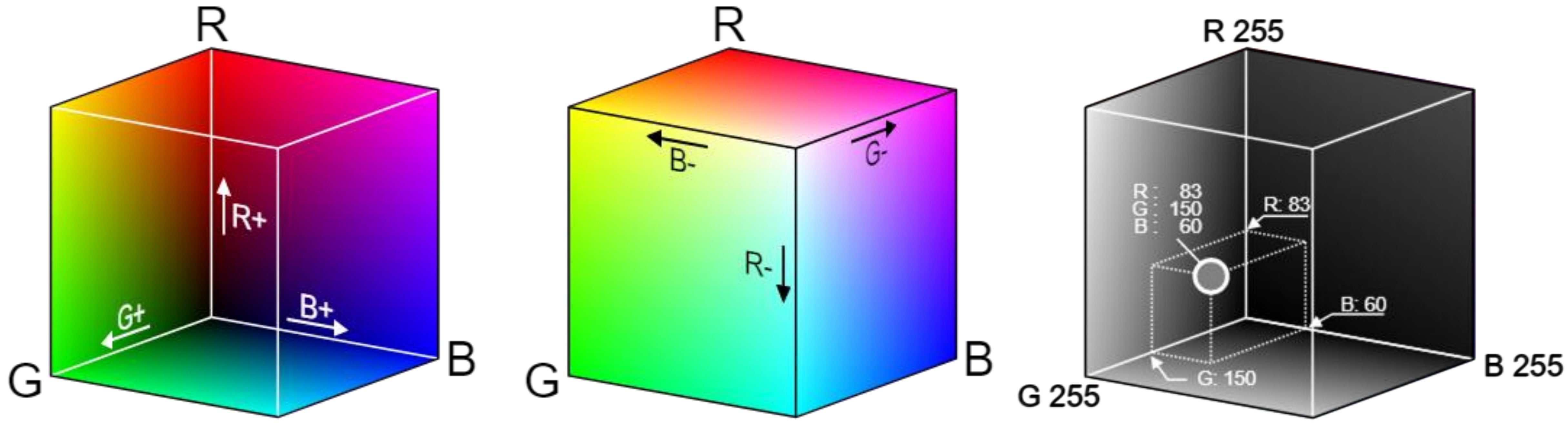
## Optical spectroscopic methods/ Spectrochemical methods.

## WHICH COLOR I PERCEIVE?

The Visible Spectrum

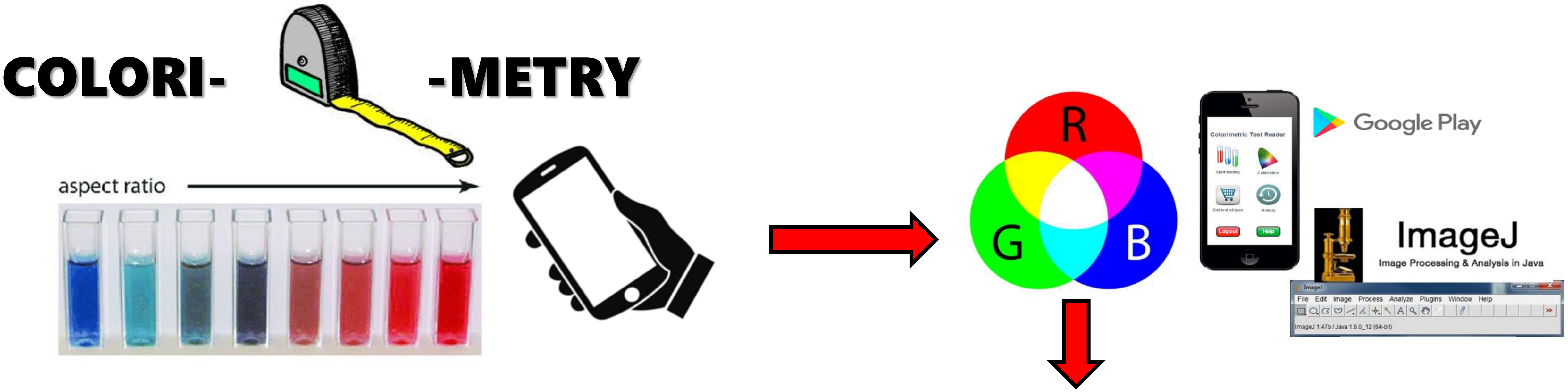
| Wavelength Region Absorbed, nm | Color of Light Absorbed | Complementary Color Transmitted |
|---|---|---|
| 400–435 | Violet | Yellow-green |
| 435–480 | Blue | Yellow |
| 480–490 | Blue-green | Orange |
| 490–500 | Green-blue | Red |
| 500–560 | Green | Purple |
| 560–580 | Yellow-green | Violet |
| 580–595 | Yellow | Blue |
| 595–650 | Orange | Blue-green |
| 650–750 | Red | Green-blue |

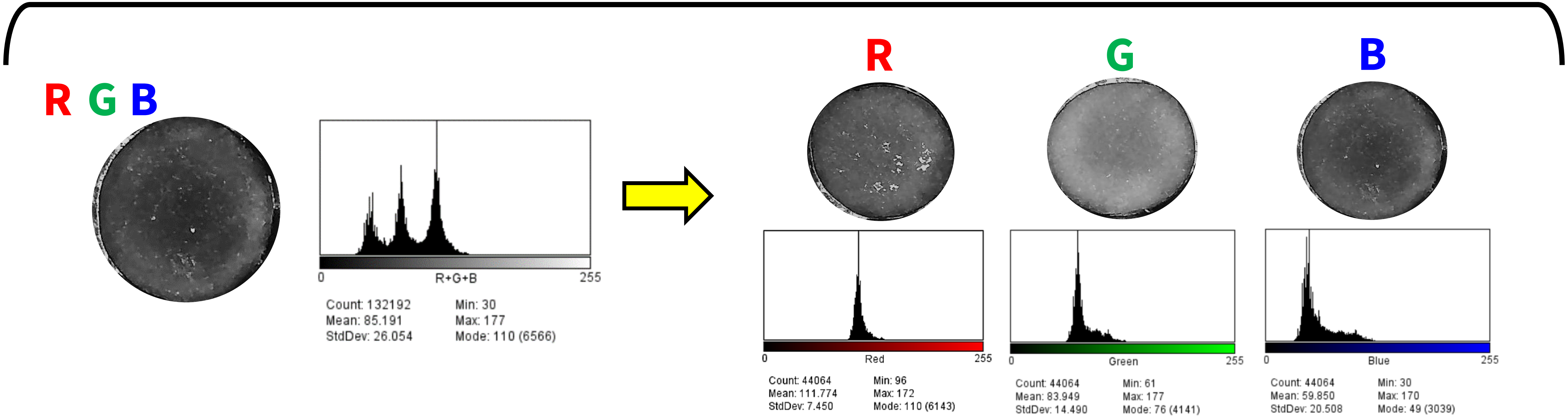
## RGB COLORIMETRIC SPACE



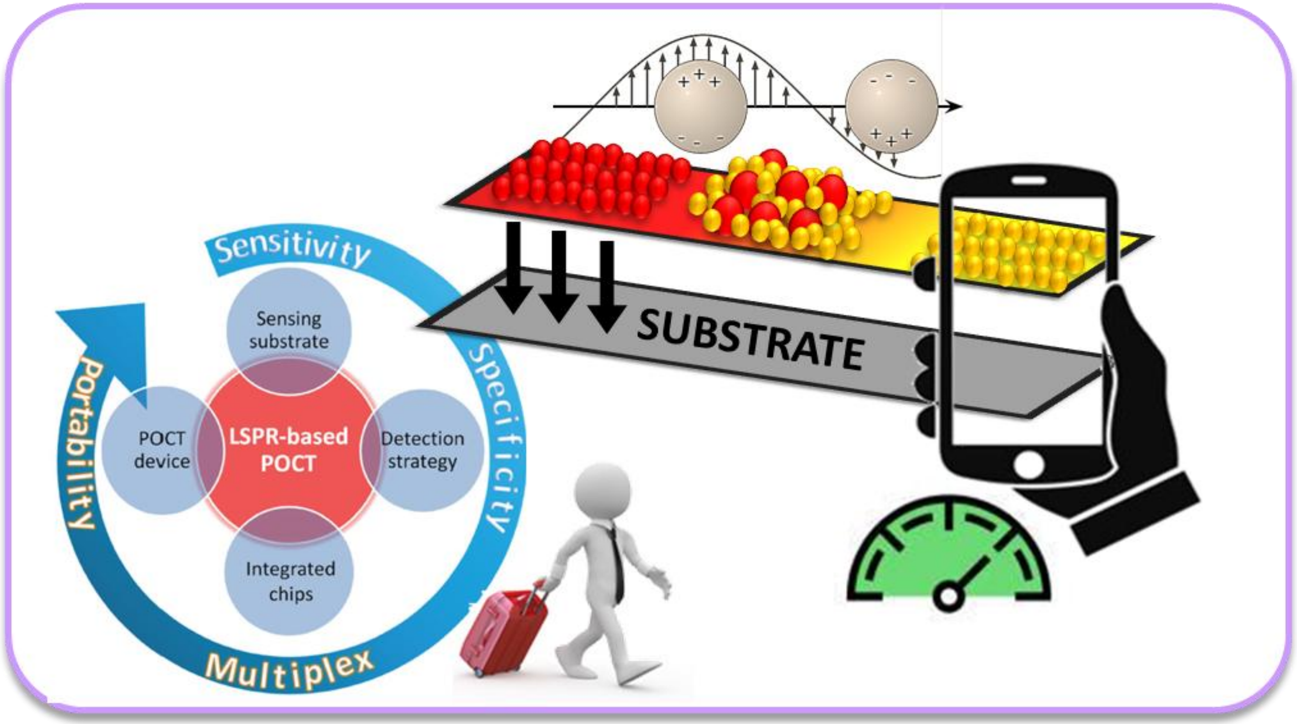
# COLORIMETRY PILLAR





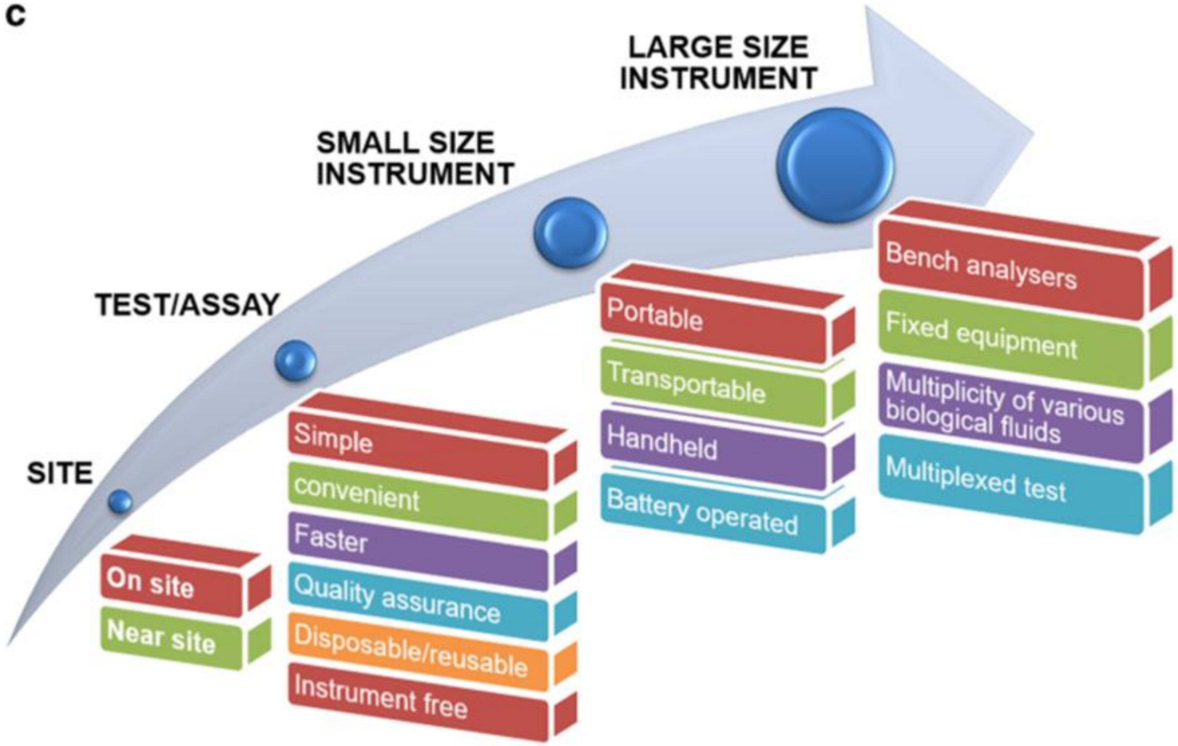



# Metal nanoparticles integration onto solid substrates




***!!! Lab-on-a-strip Device !!!***

***To satisfy…***




**Cost performance**

**Manufacturing**

**Mass production**

***Which substrate?***

# Paper as elective substrate

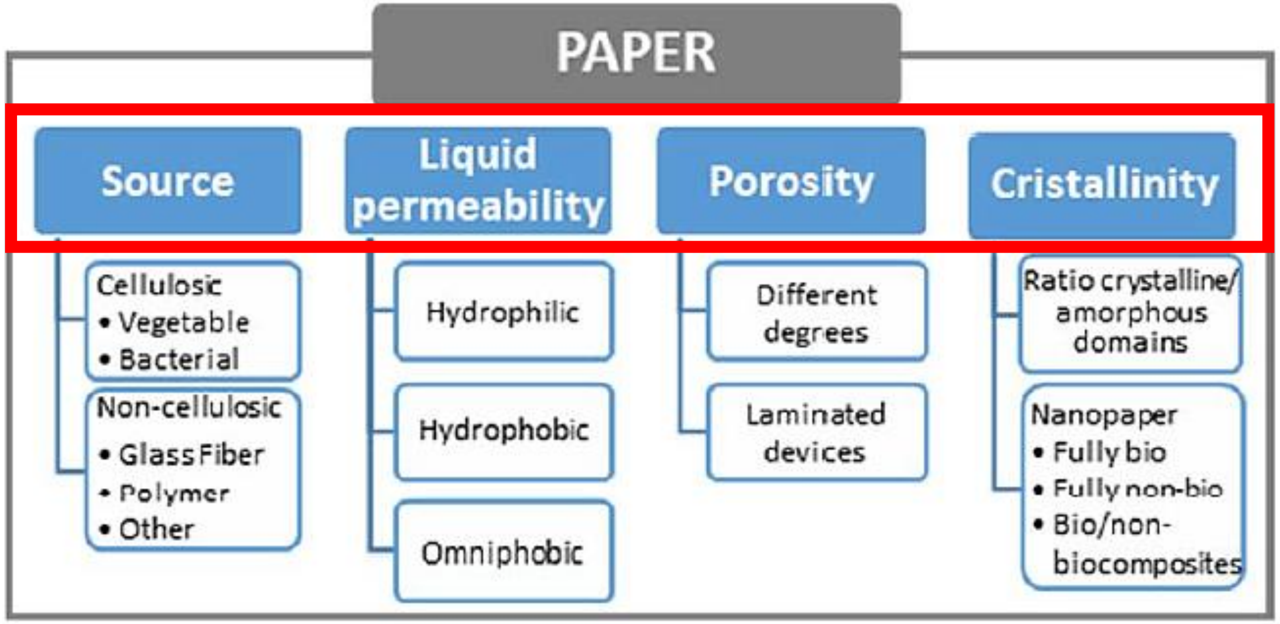
## Paper as substrate



Paper can…
Store
Filter
React

Drawbacks…
Reagents diffusion…
Electrical noise! ☹

An hydrophobic barrier is needed…



# Paper as elective substrate

## Paper tailorability

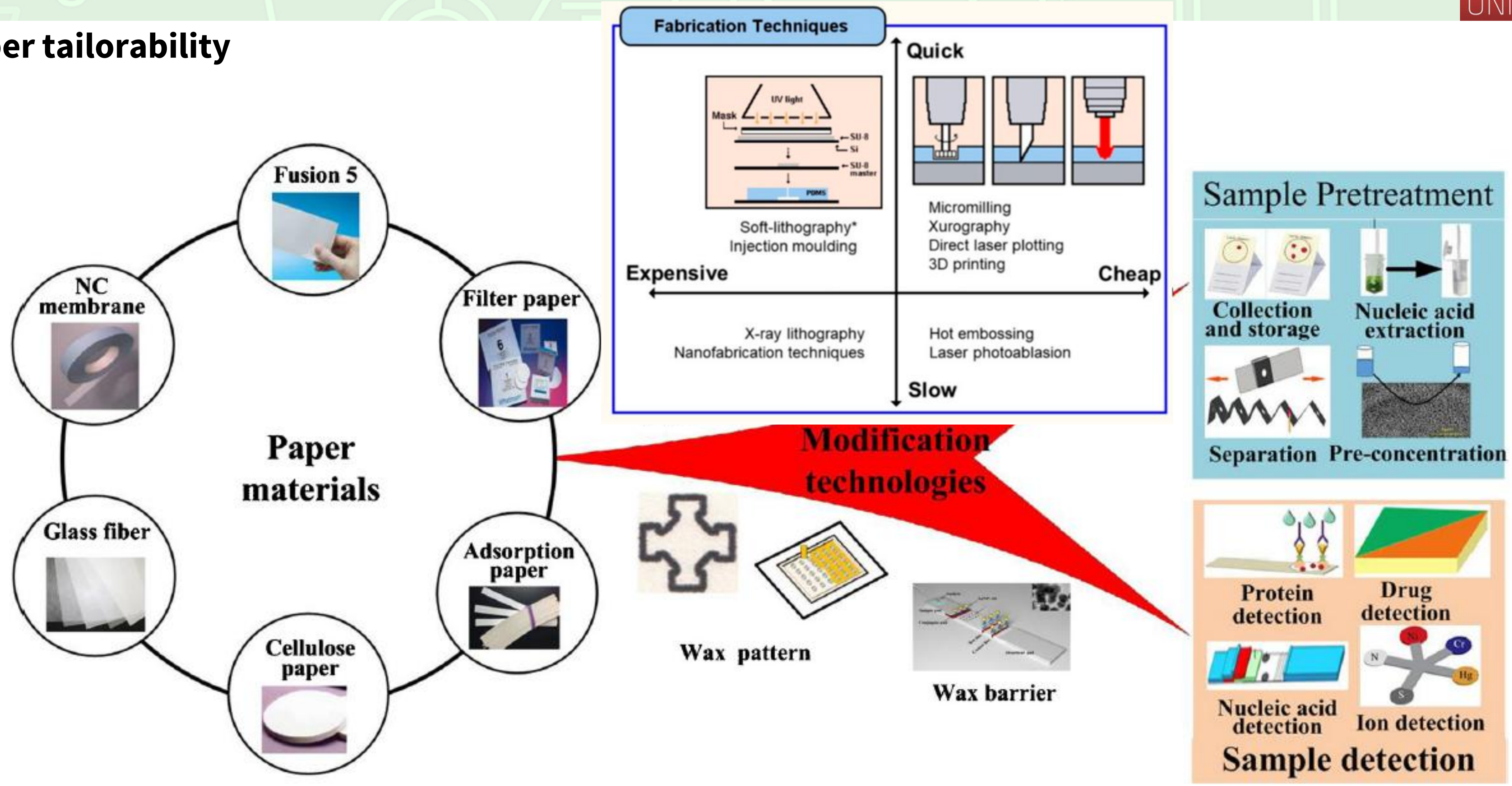



**Fig. 1** Existing paper modification approaches for paper-based POCT. Different paper materials, including Fusion 5, filter paper, chromatography paper, cellulose paper, Whatman® No.1 filter paper and NC membrane, have been modified with various reagents for paper-based sample pretreatment and paper-based detection

# Paper as elective substrate

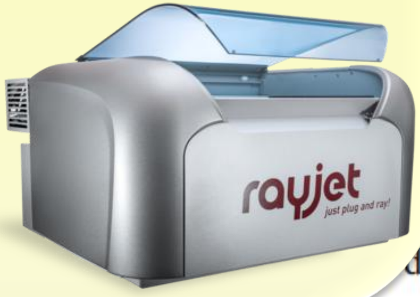
## Paper tailorability


### Office grade instruments

- Cutting plotter

- Wax printer

- Thermal-roll laminator




- $CO_2$-Laser Plotter ($\lambda$= 10.6 μm)

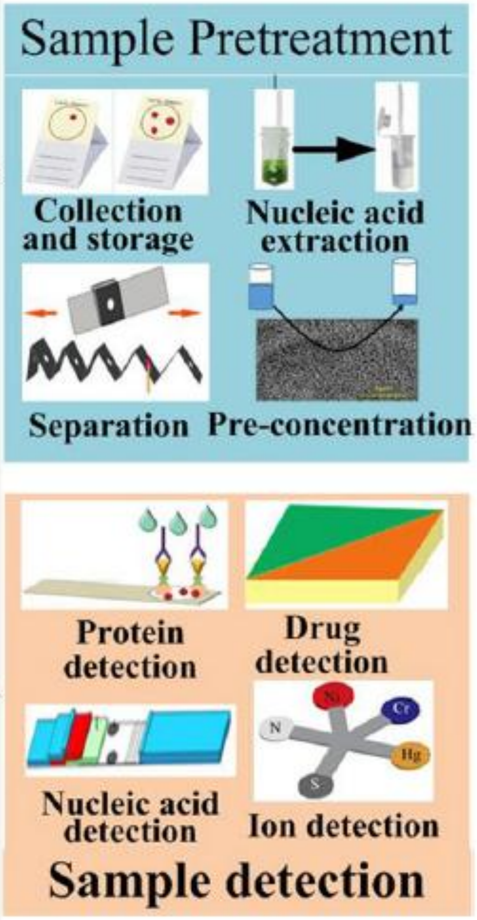



Fig. 1 Existing paper modification approaches for paper-b ... arious reagents for paper-based Different paper materials, including Fusion 5, filter paper, ch ... detection phy paper, cellulose paper, Whatman® No.1 filter paper an...

# MNPs as colorimetric probe

Analytica Chimica Acta 1183 (2021) 338971

Contents lists available at ScienceDirect

Analytica Chimica Acta

journal homepage: www.elsevier.com/locate/aca

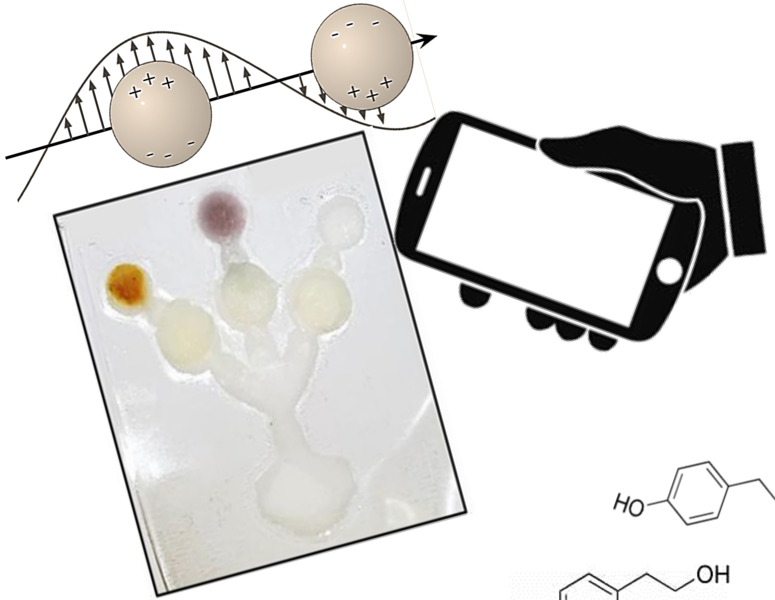
Metal nanoparticles based lab-on-paper for phenolic compounds evaluation with no sample pretreatment. Application to extra virgin olive oil samples

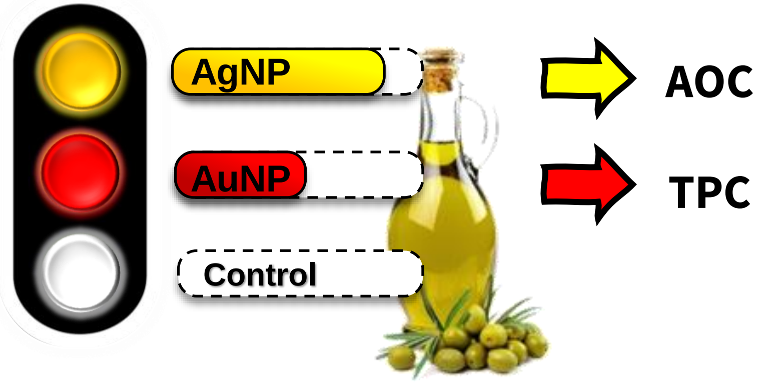
Annalisa Scroccarello [a], Flavio Della Pelle [a, *], Daniel Rojas [a], Giovanni Ferraro [b], Emiliano Fratini [b], Sara Gaggiotti [c], Angelo Cichelli [c], Dario Compagnone [a, **]

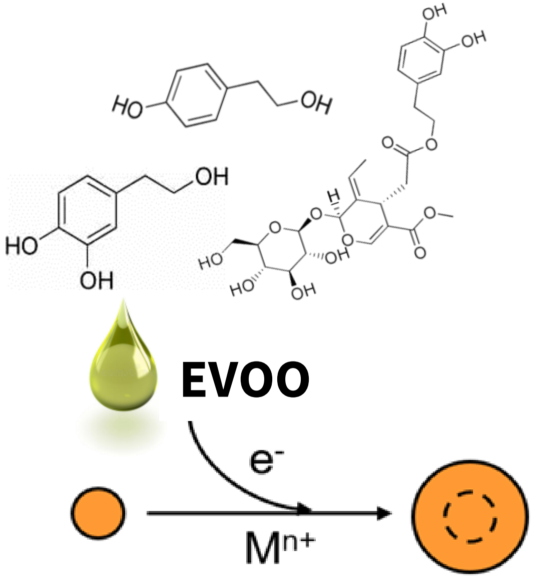
**Office grade instruments**

Thermal-roll laminator

## *Lab-on-paper device*



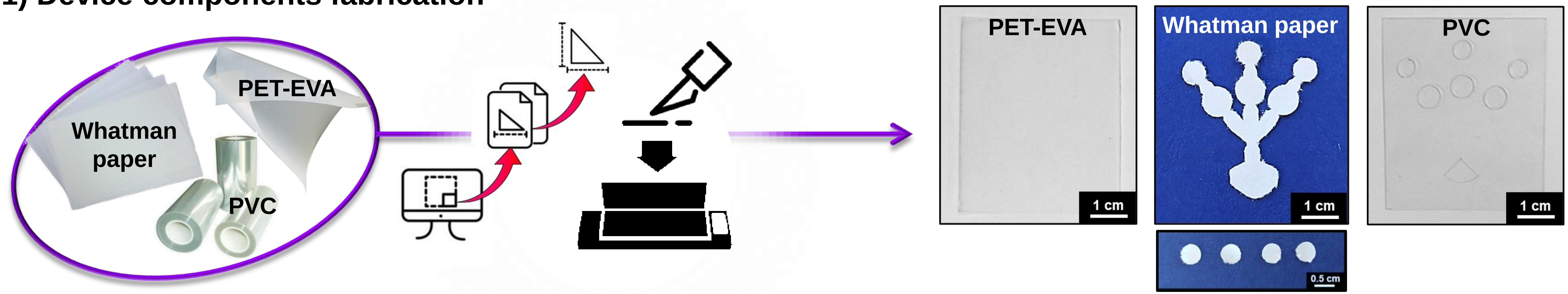


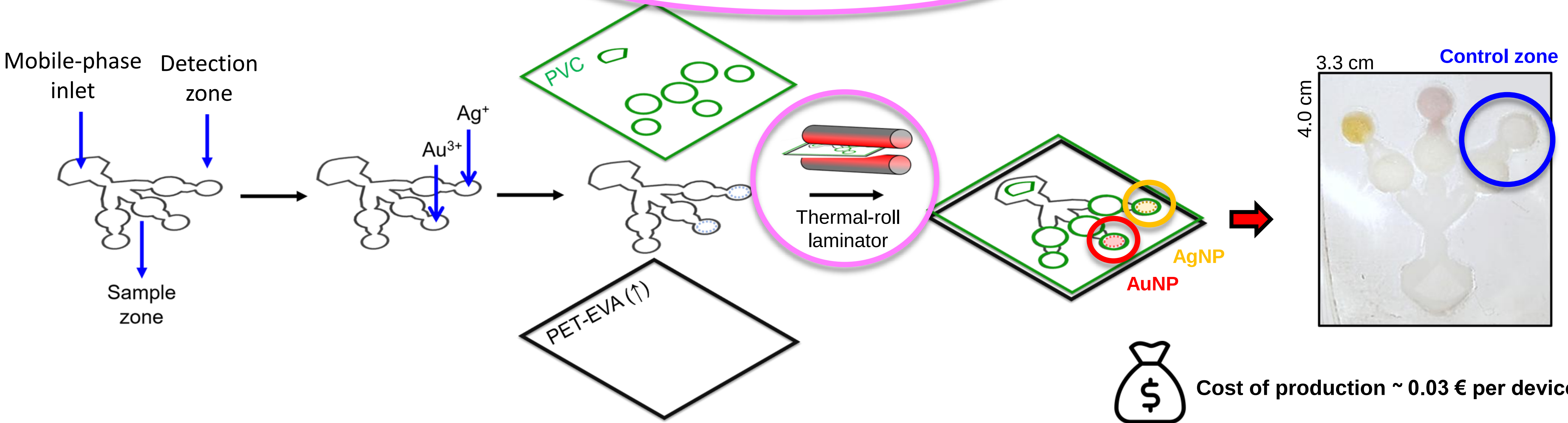
# MNPs as colorimetric probe: Device conceptualization and realization

UNITE

## 1) Device components fabrication




## 2) Device assembling and sensing elements (AgNP and AuNP) formation



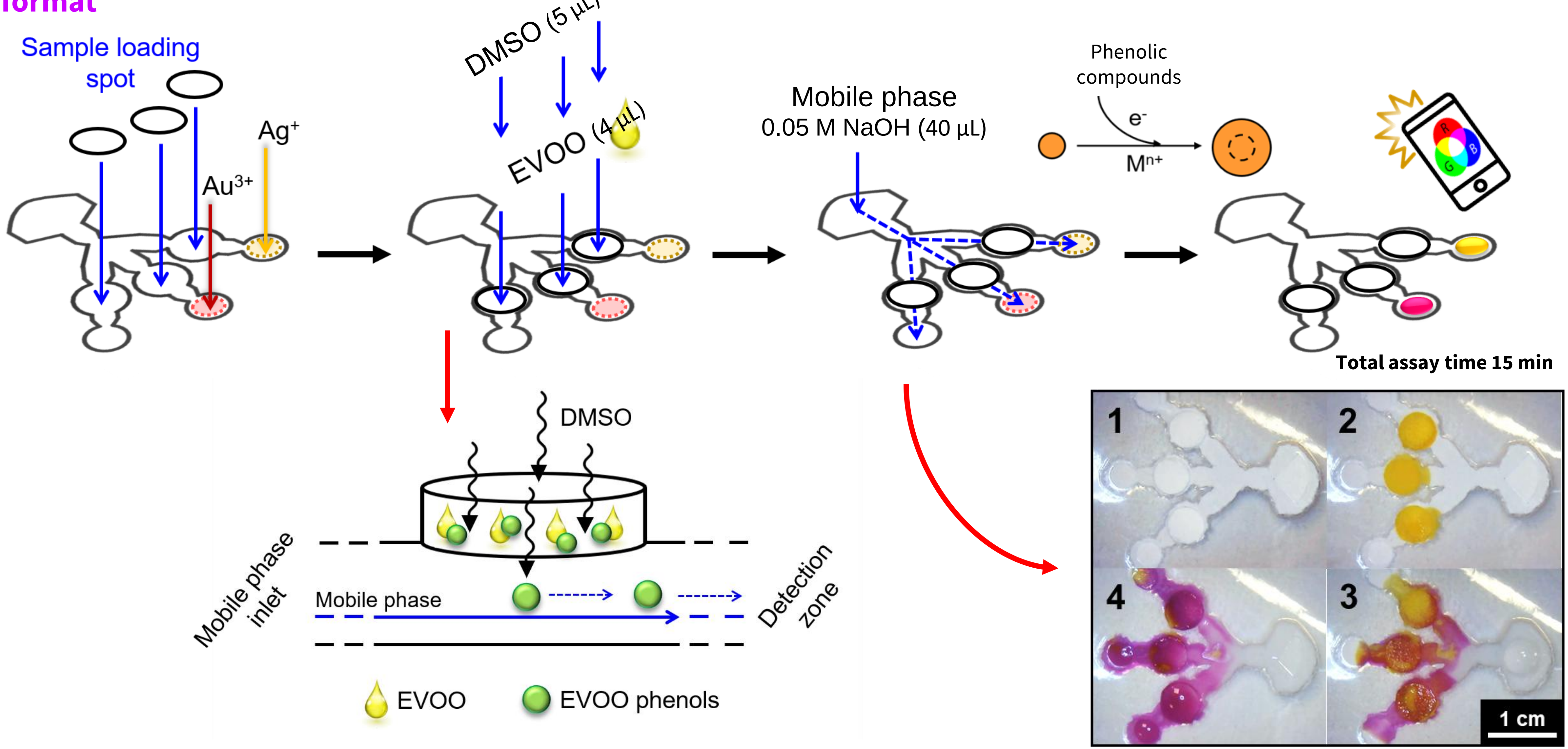

Cost of production ~ 0.03 € per device

# MNPs as colorimetric probe: Extraction-free phenolic compounds determination

## Extraction-free olive oil phenolic compounds evaluation through a MNPs seed growth strategy

### Assay format

### Assay simulation with a colorimetric dye

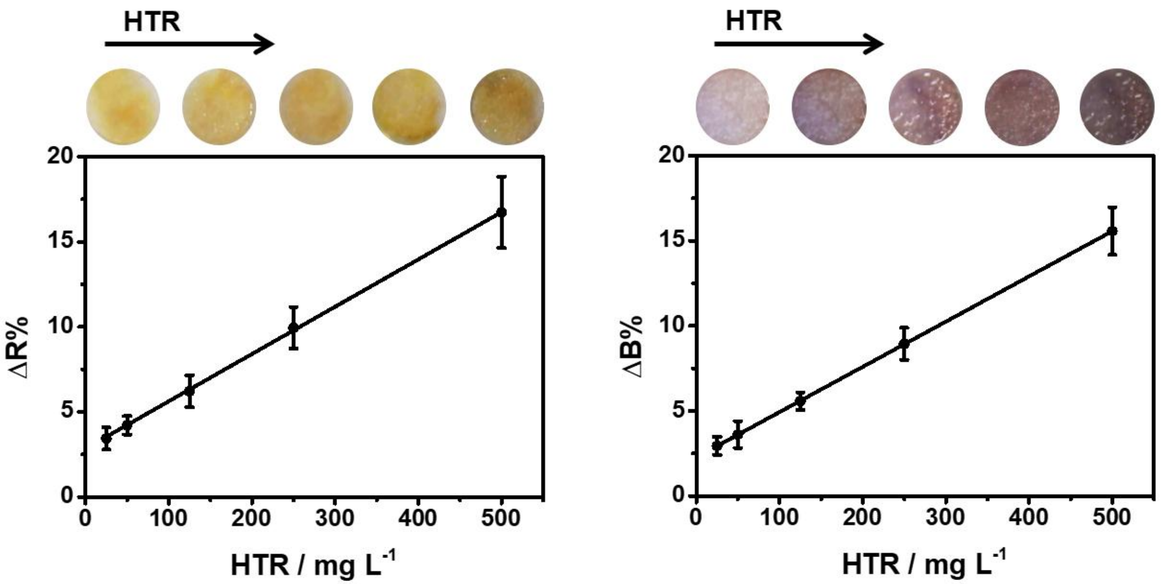



Total assay time 15 min

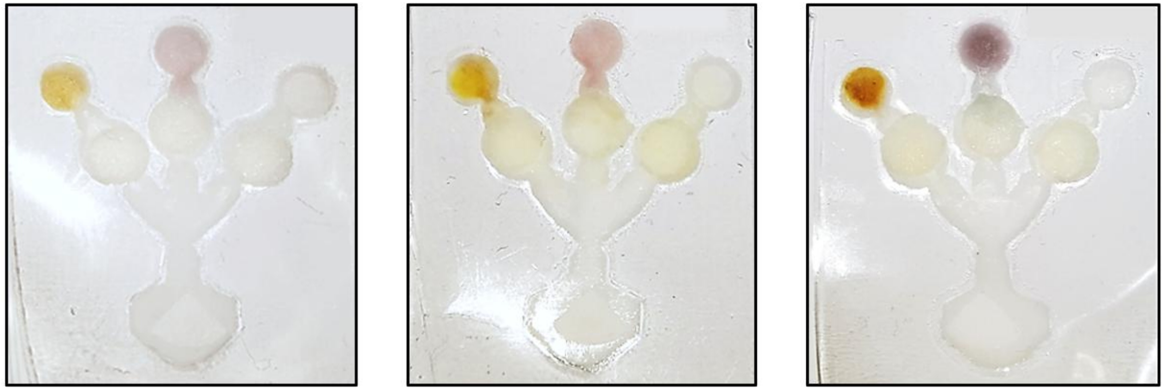
# Paper-based colorimetric sensor

## Extraction-free olive oil phenolic compounds evaluation trough a seed growth strategy

### Dose-response curve

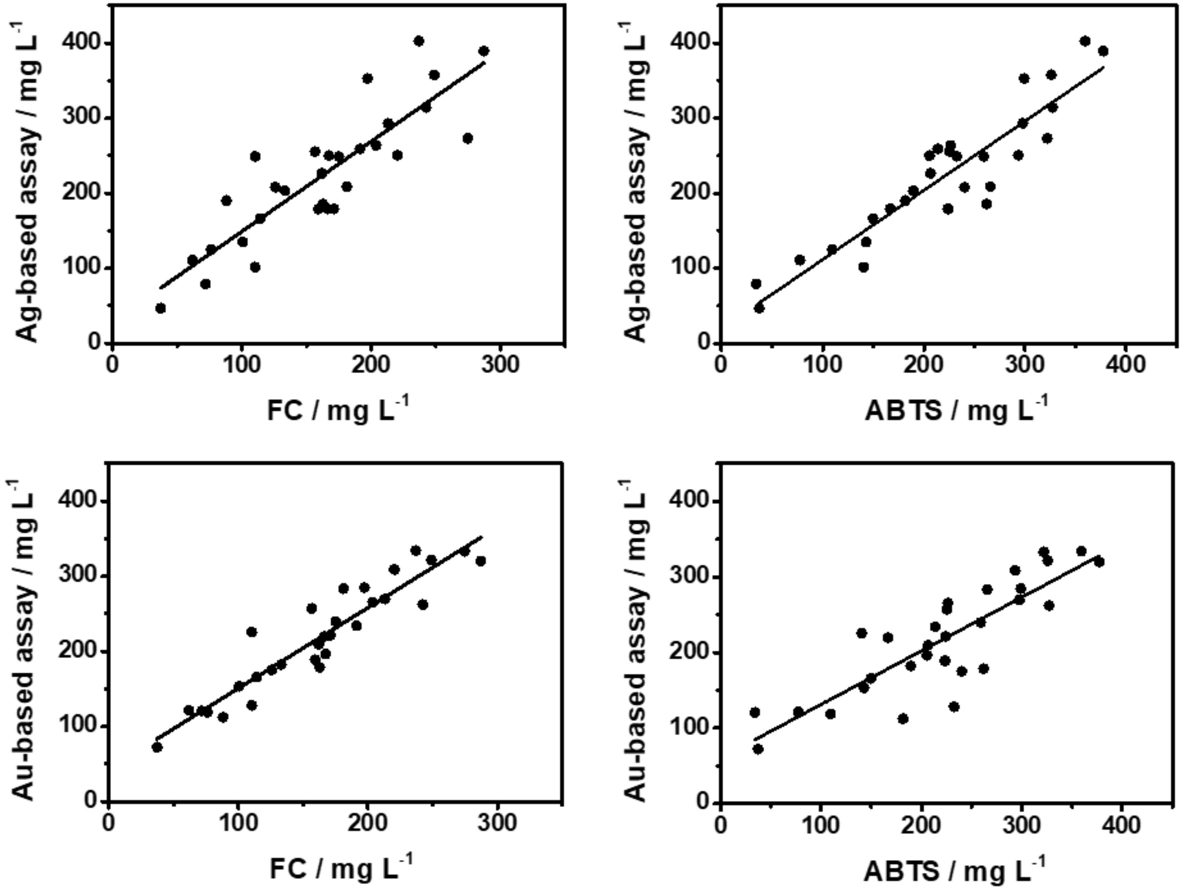



### EVOO samples' phenolyc compounds content



Low Mean High

### Sample analysis, analytical performances

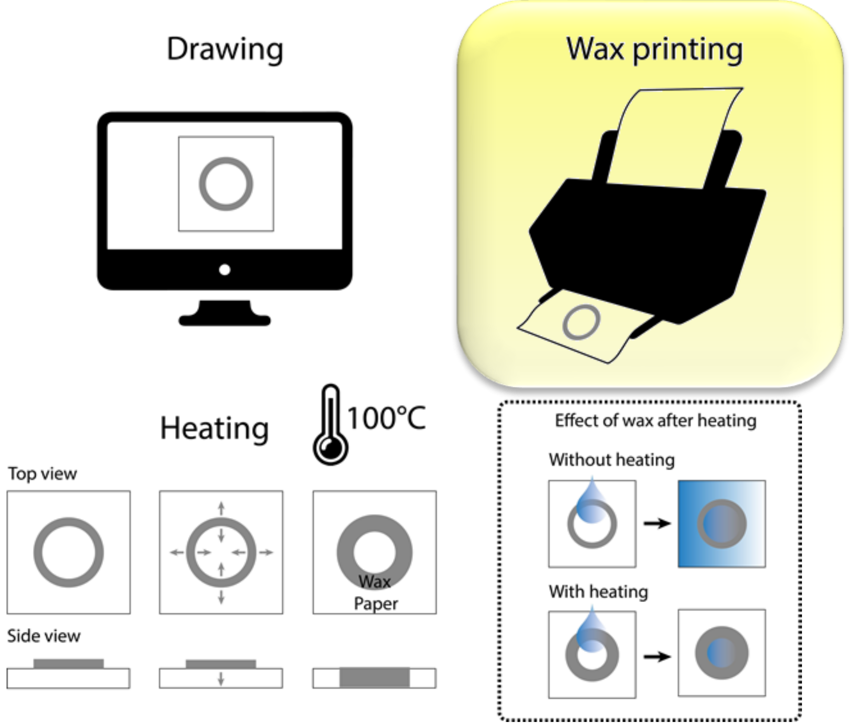


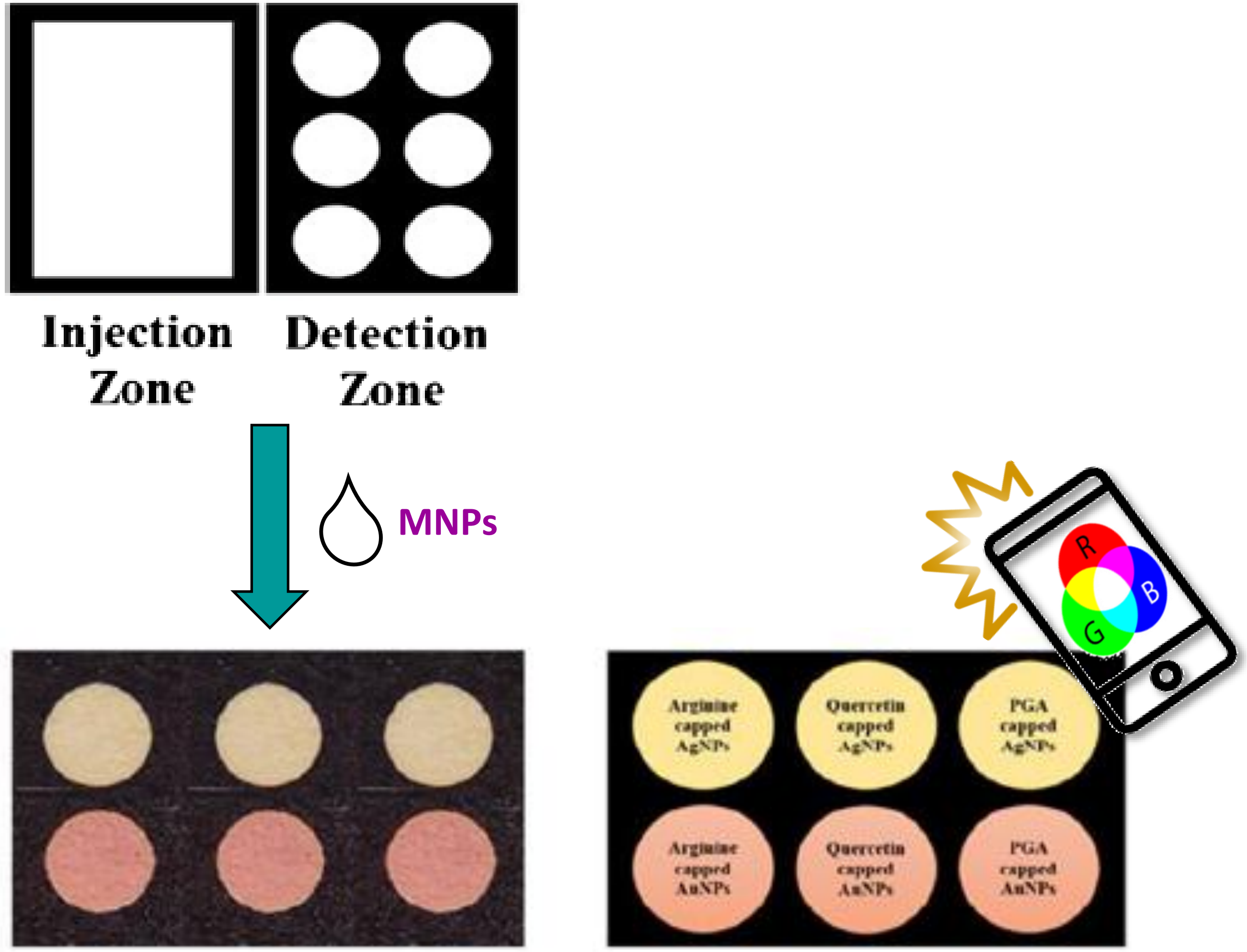

No interterferences by compounds commonly present in EVOO

# Paper-based colorimetric sensor



## Pesticides determination trough MNPs aggregation integrated in a paper-based device




Microchimica Acta (2020) 187:621
https://doi.org/10.1007/s00604-020-04596-x

ORIGINAL PAPER

A paper-based colorimetric sensor array for discrimination and simultaneous determination of organophosphate and carbamate pesticides in tap water, apple juice, and rice

Mohammad Mahdi Bordbar[1] · Tien Anh Nguyen[2] · Fabiana Arduini[3] · Hasan Bagheri[1]

# Paper-based colorimetric sensor

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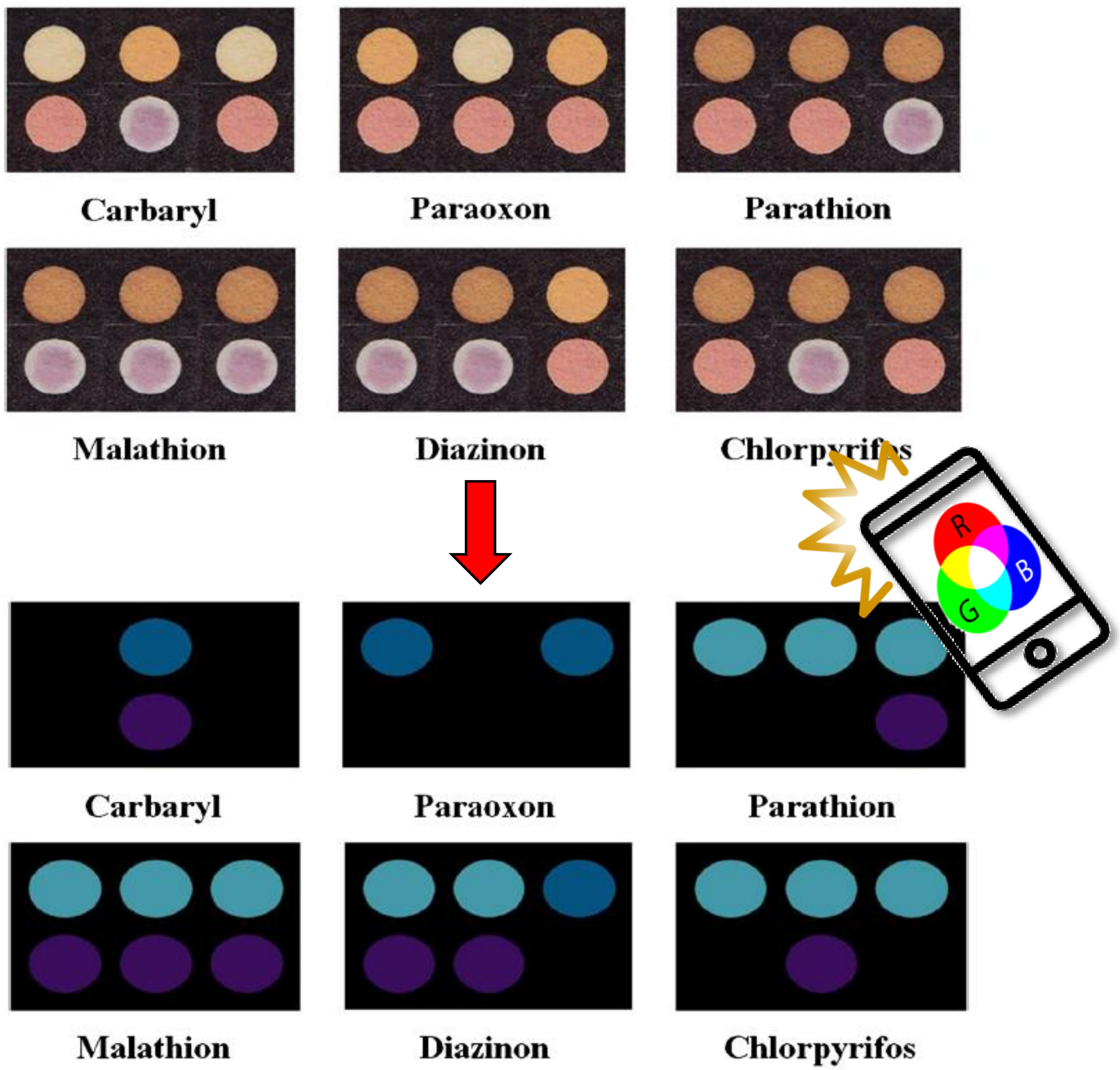
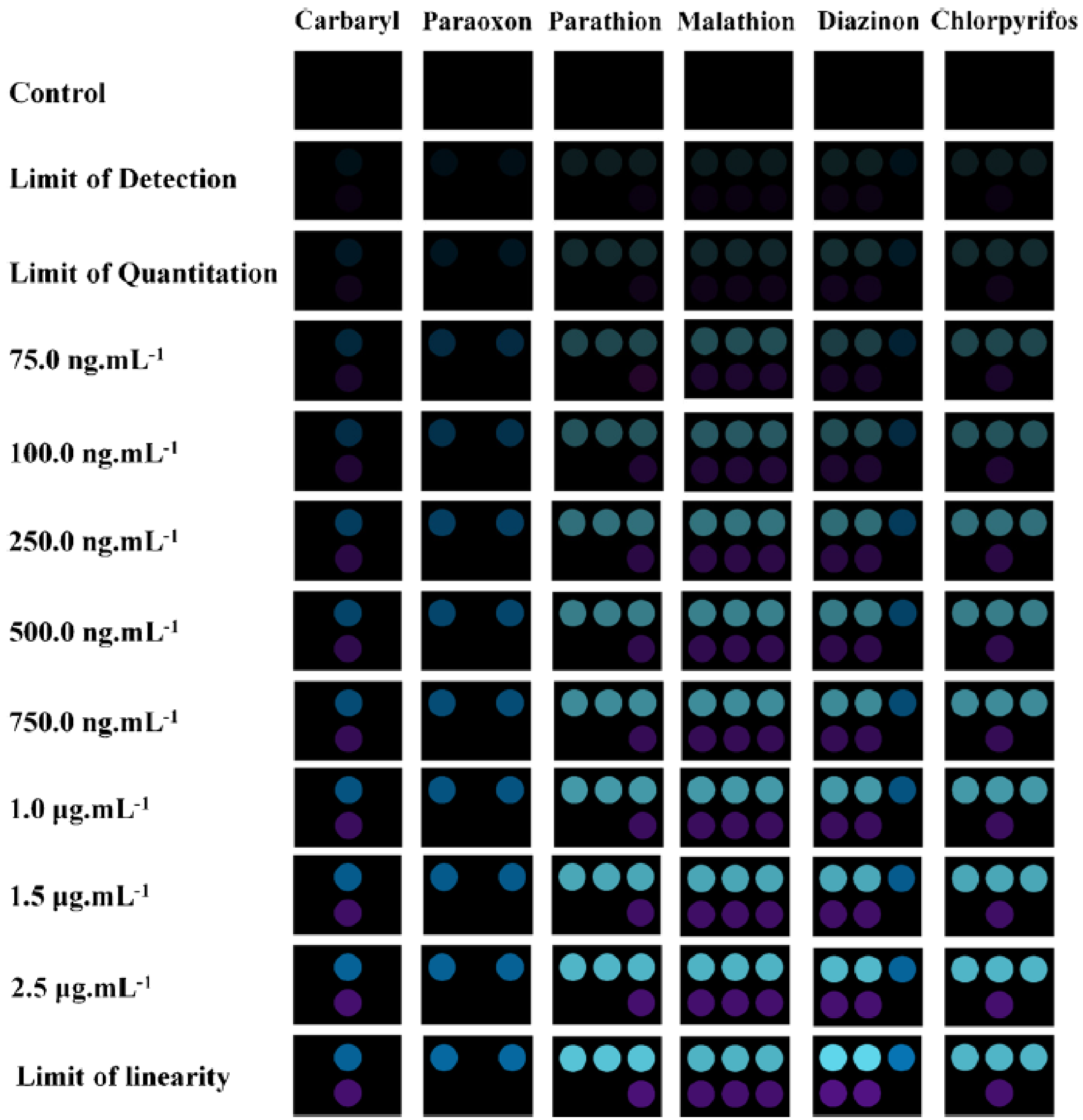
## Pesticides determination trough MNPs aggregation integrated in a paper-based device

### Analytes screening

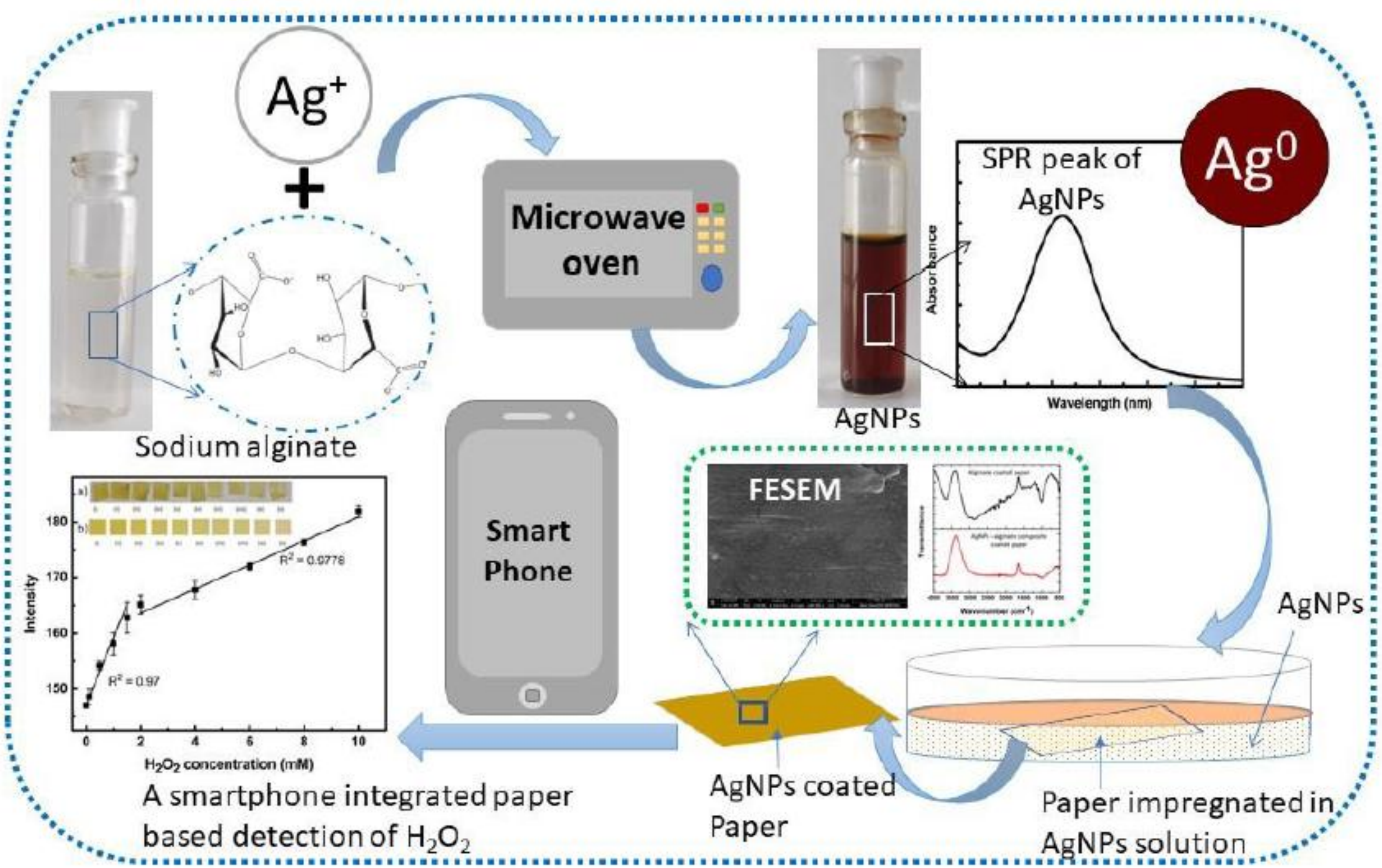



### Dose-response curve and analytical parameters



# Paper-based colorimetric sensor

## $H_2O_2$ determination trough MNPs etching integrated in a paper-based substrate





Articles

**Development of a surface-modified paper-based colorimetric sensor using synthesized Ag NPs-alginate composite**

Lokesh Sharma, Shubhankar Gouraj, Pranit Raut & Chandrakant Tagad

# Paper-based colorimetric sensor

UNIVERSITÀ DEGLI STUDI DI TERAMO
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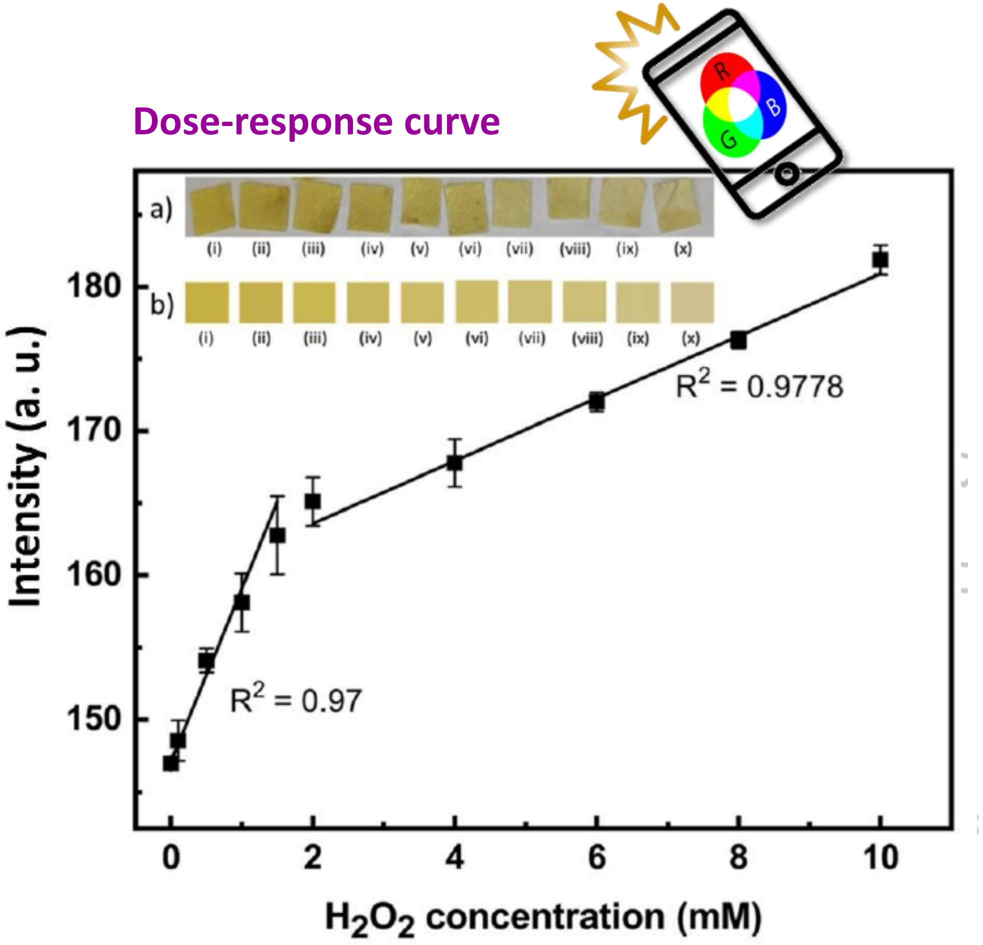
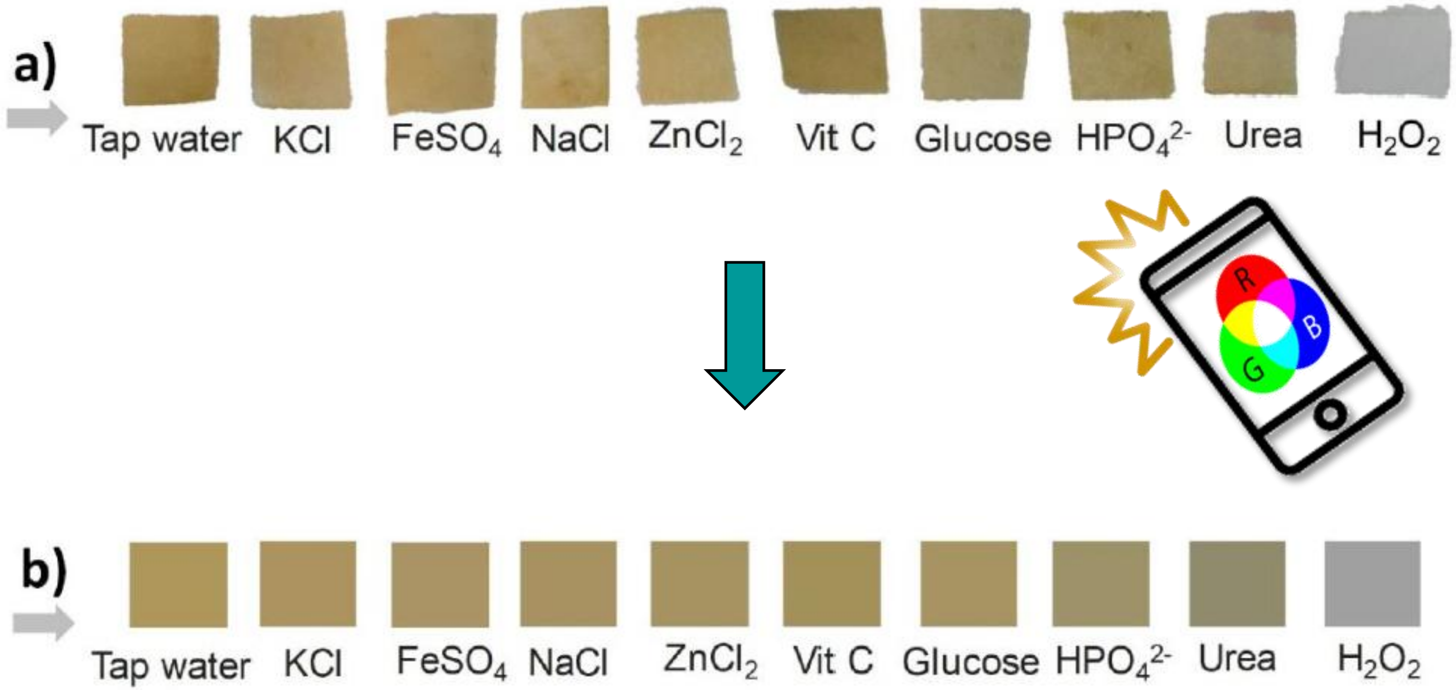
## $H_2O_2$ determination trough MNPs etching integrated in a paper-based substrate

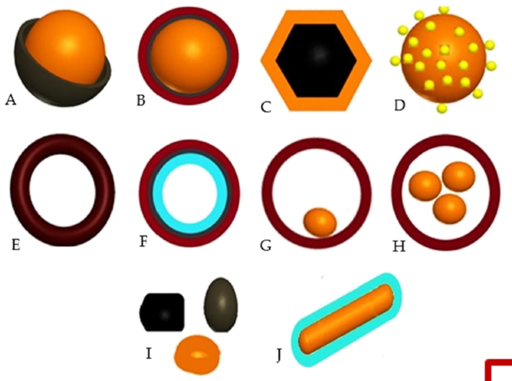
**Dose-response curve**

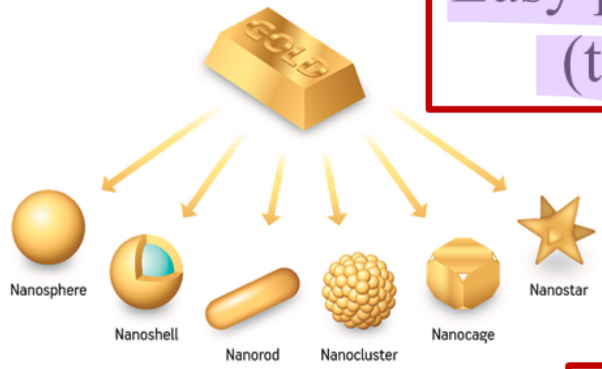


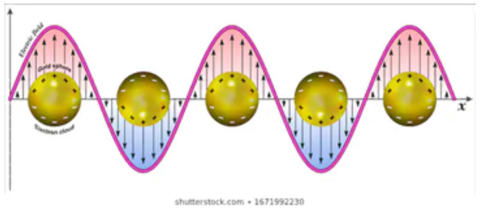

**Interferents evaluation**



# Advantages of metal nanoparticles for analyitical purposes



**MNPs**

Nano

High conductivity

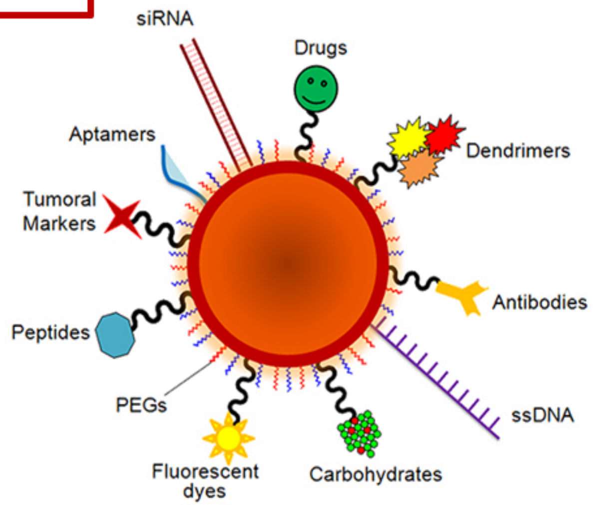
Robust / stable

*(Inhert)*

Surface (Bio)functionalization

Good biocompatibility

Easy preparation (tunable)



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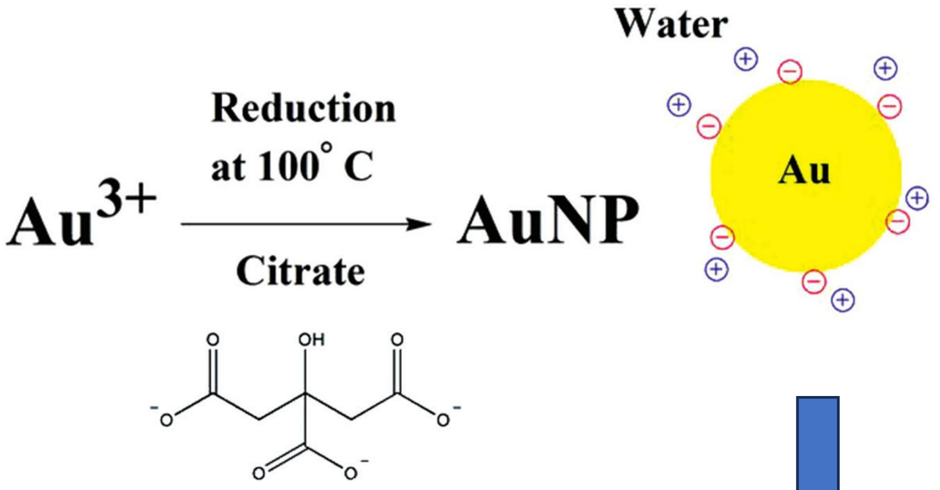


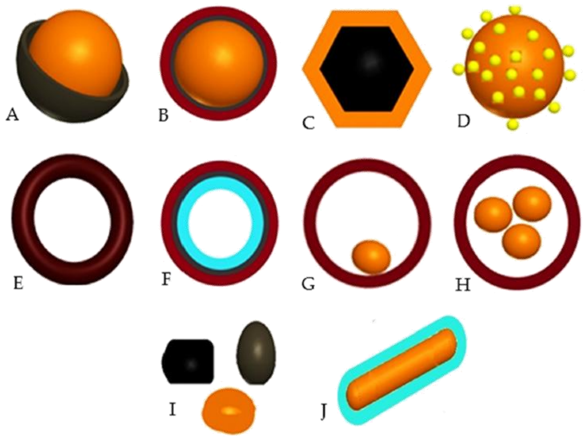


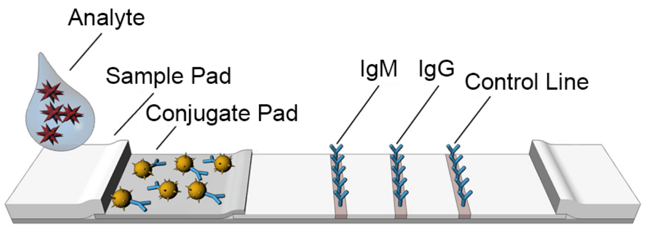


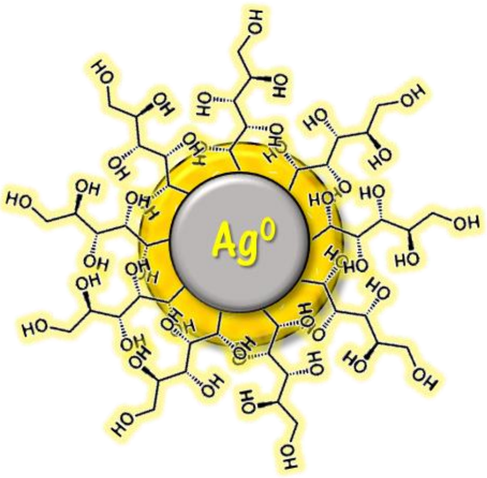


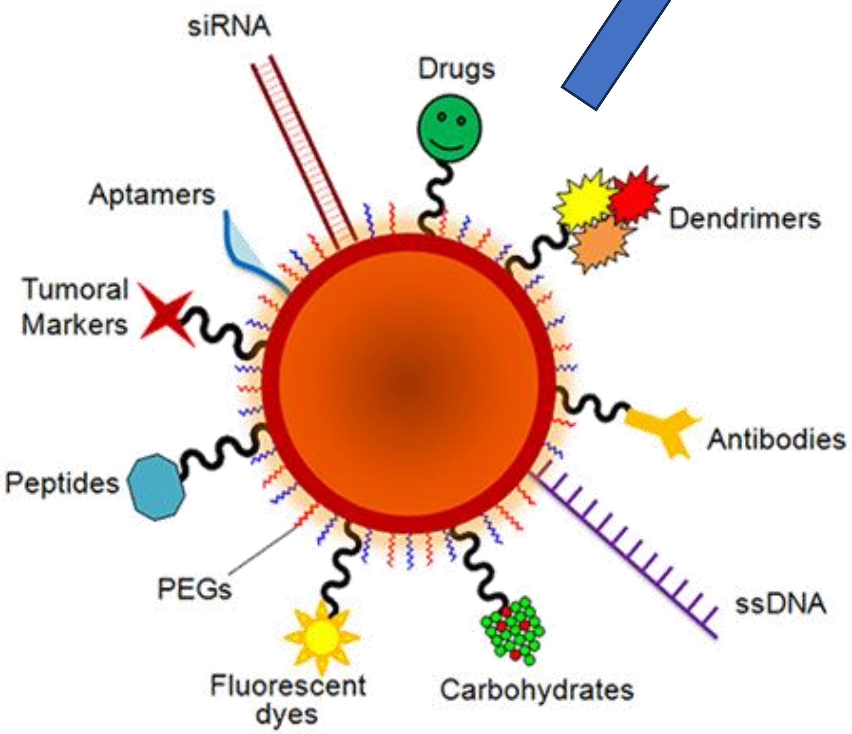

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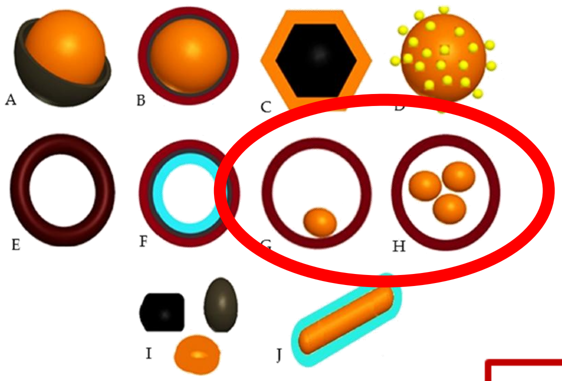


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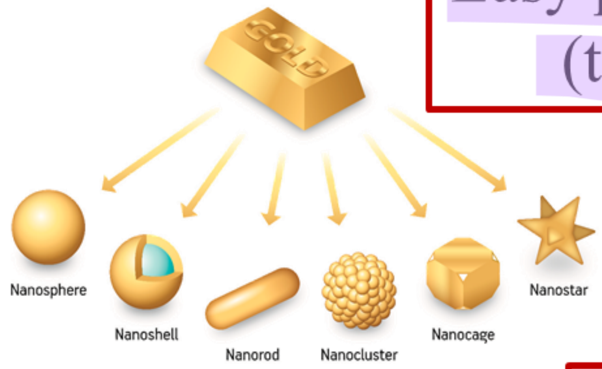


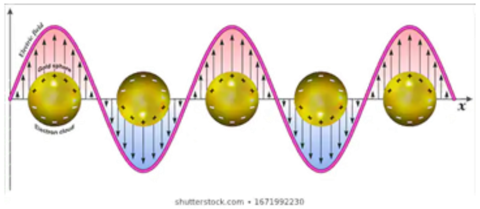

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- Nano
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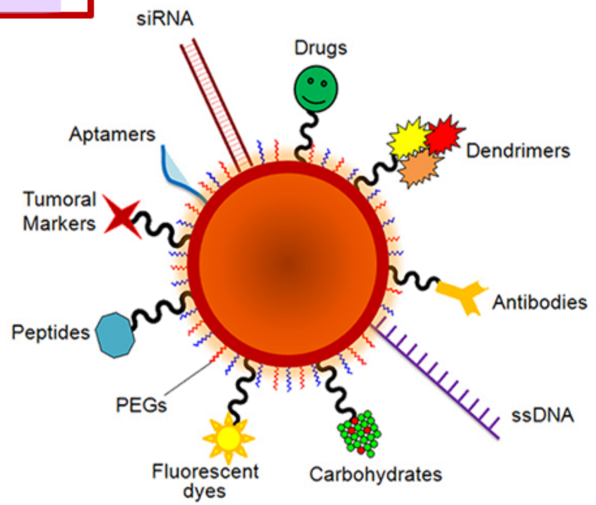
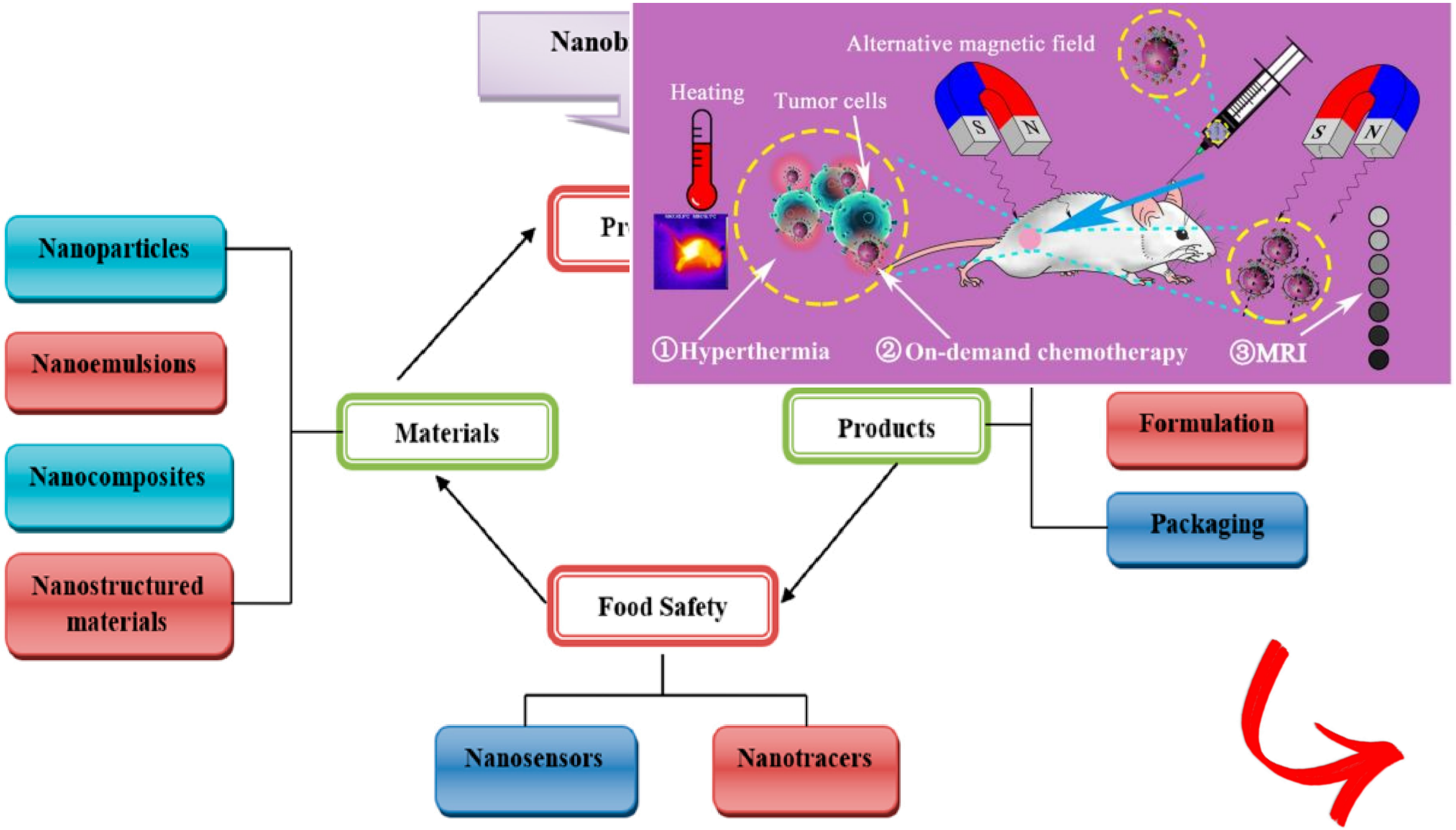
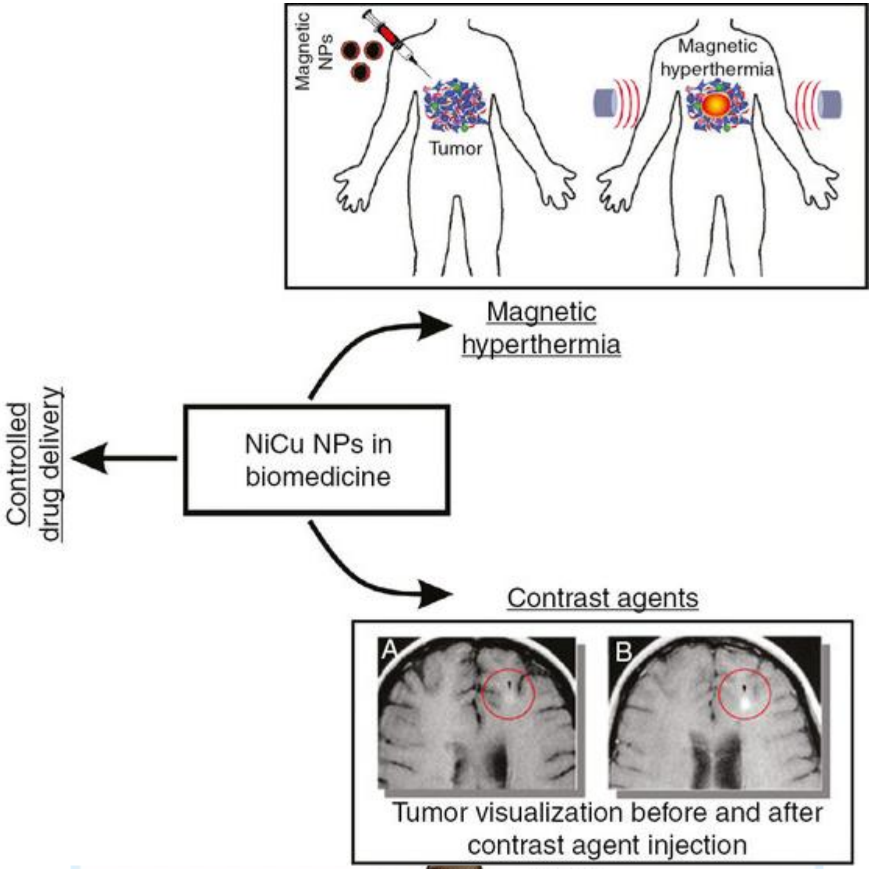
- Good biocompatibility
- Easy preparation (tunable)

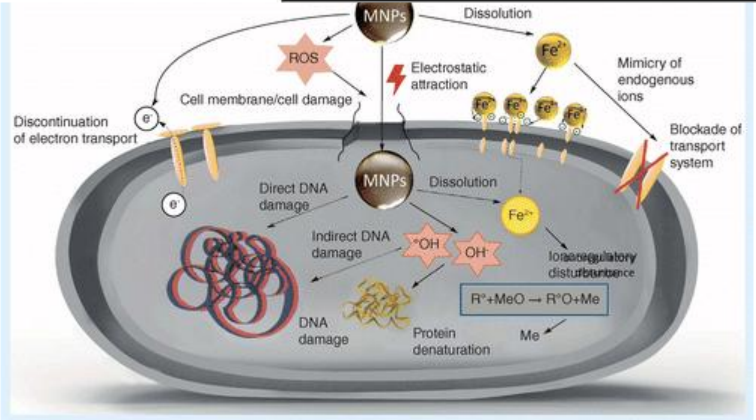


# Nanotechnology





# Biological features

Biomedical application

(Bio)sensing strategies

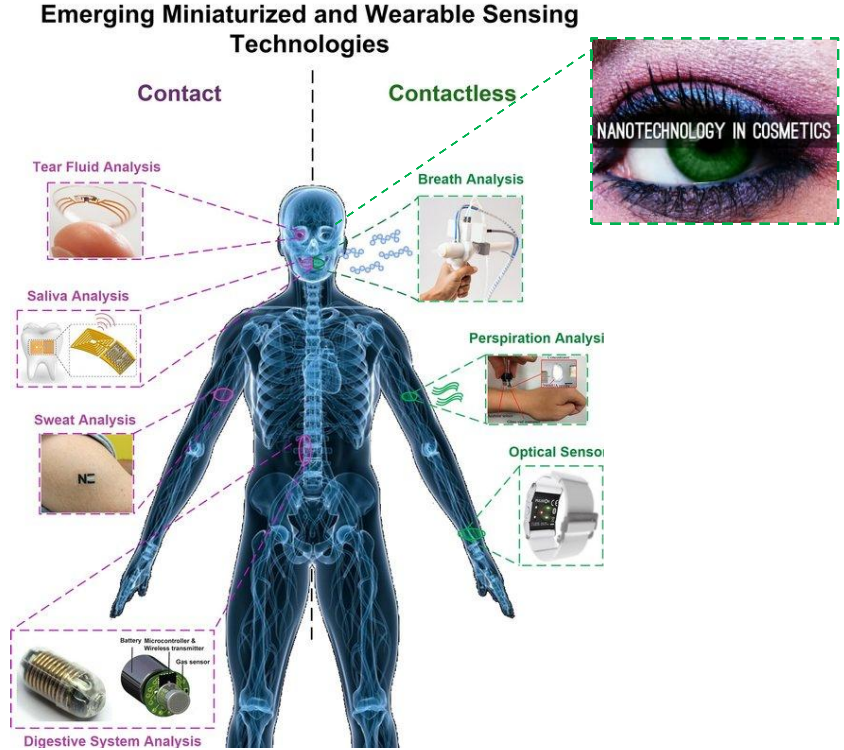
Therapeutic application

Environmental exposure

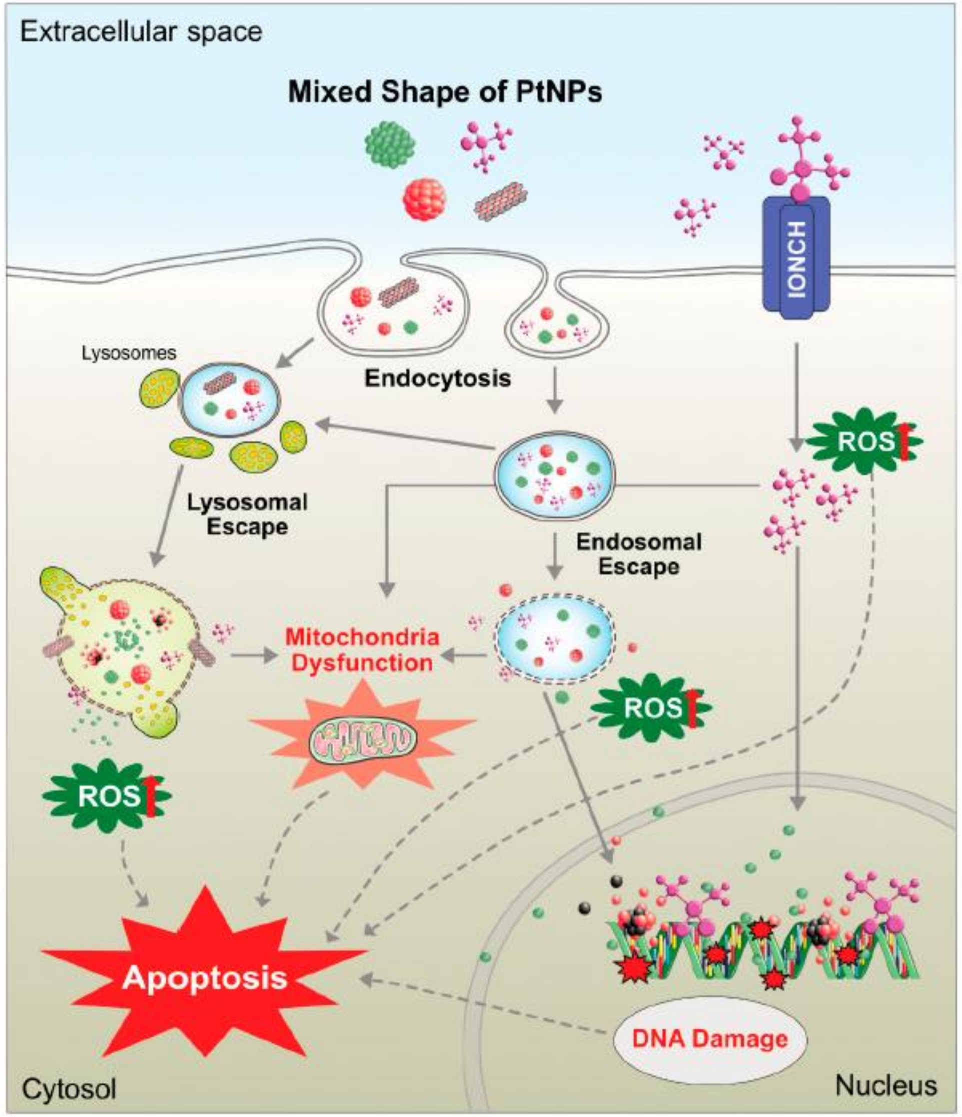
Toxicity

NANOtoxicity

Interactions of **NMs** with biological systems/living organisms




# Biological features



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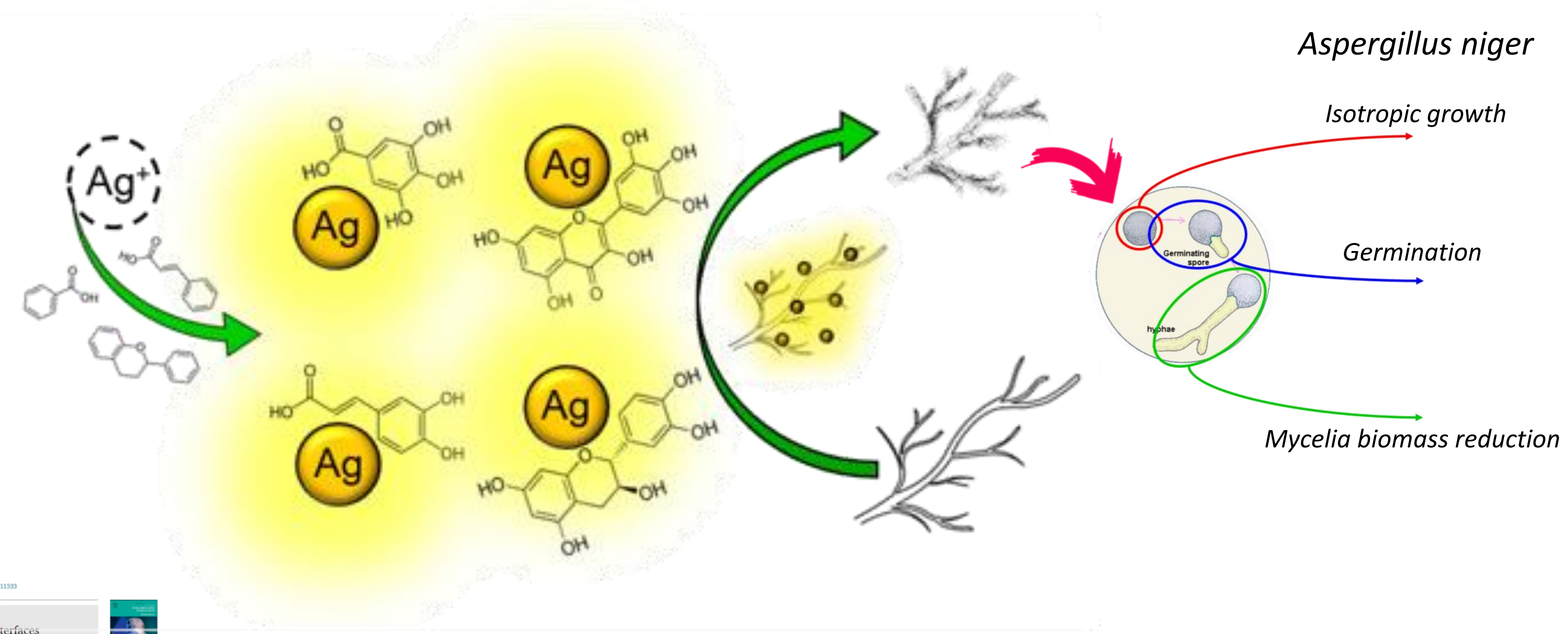
# Biological features

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Colloids and Surfaces B: Biointerfaces

journal homepage: www.elsevier.com/locate/colsurfb

Effect of phenolic compounds-capped AgNPs on growth inhibition of *Aspergillus niger*

Annalisa Scroccarello[a,1], Bernardo Molina-Hernández Junior[a,1], Flavio Della Pelle[a,*], Johnny Ciancetta[a], Giovanni Ferraro[b], Emiliano Fratini[b], Luca Valbonetti[a], Clemencia Chaves Copez[a,*], Dario Compagnone[a]

# Metal nanoparticles formation



## Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation

sensors
MDPI
Review

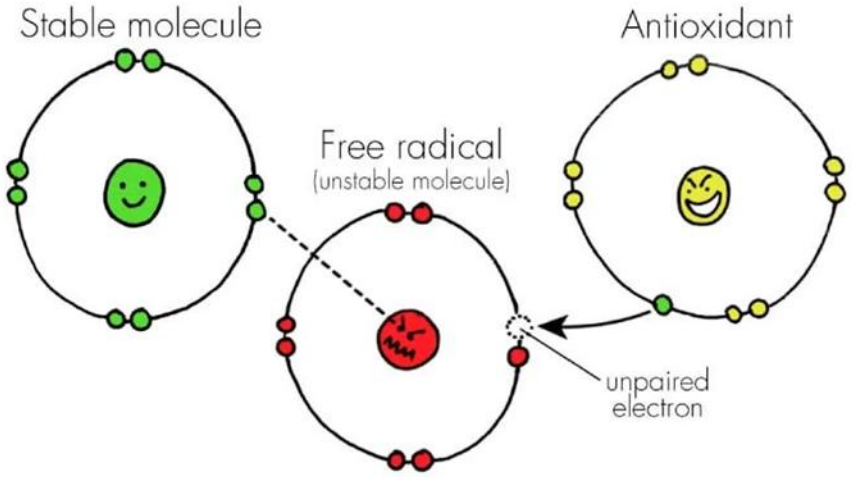
**Nanomaterial-Based Sensing and Biosensing of Phenolic Compounds and Related Antioxidant Capacity in Food**

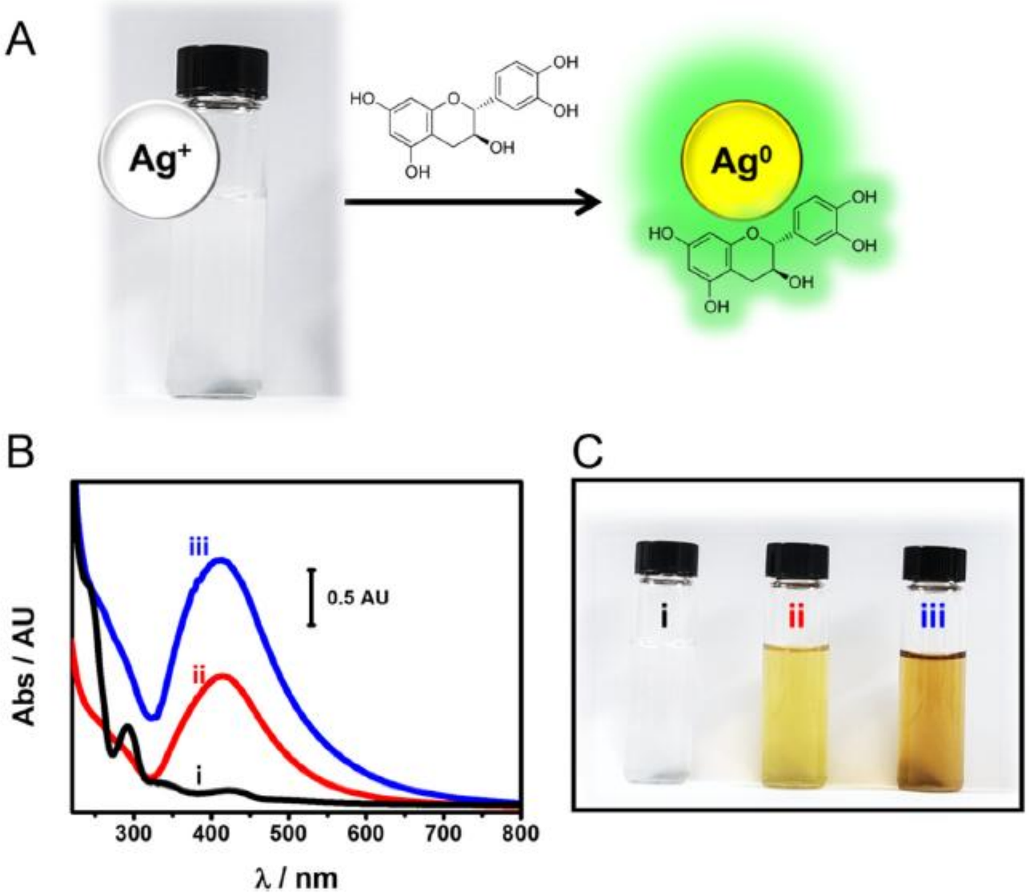
Flavio Della Pelle and Dario Compagnone *

**!!!! LAB PRACTICAL !!!**

… Nanomaterial-based method for estimating the antioxidant activity relies on the polyphenol-mediated growth of MNPs (AuNPs and AgNPs), and optical monitoring of the corresponding plasmon absorption bands…

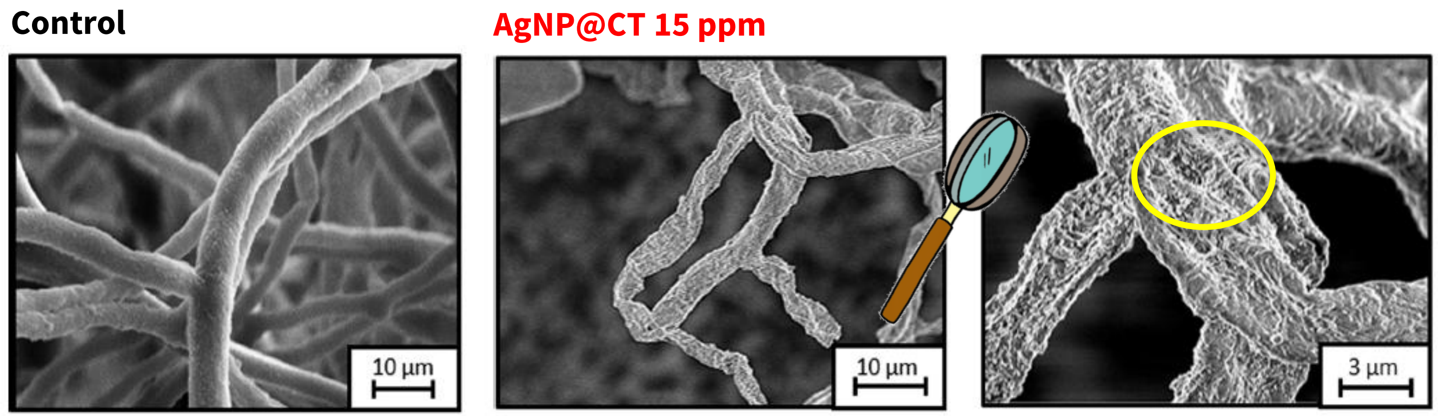
SCAMPICCHIO, Matteo, et al. Nanoparticle-based assays of antioxidant activity. *Analytical chemistry*, 2006, 78.6: 2060-2063.



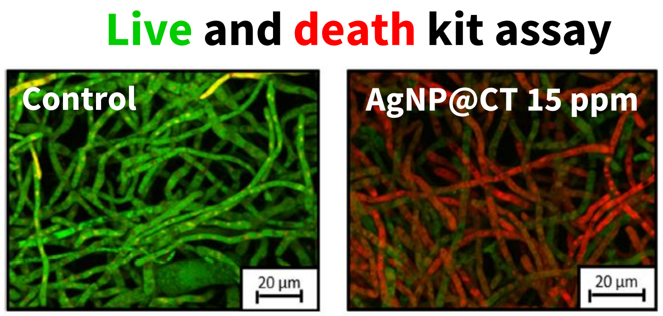
# Biological features

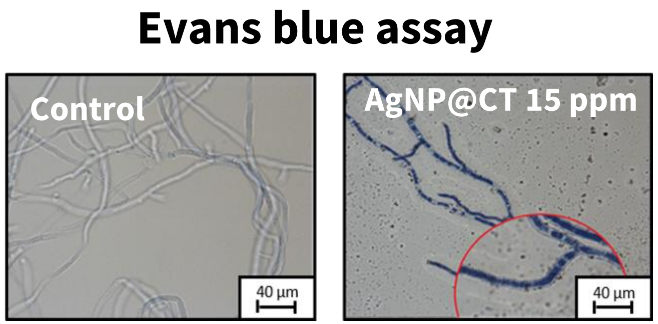
*Hyphae interaction*

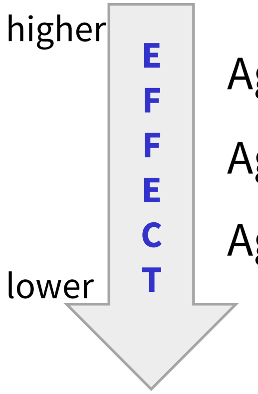



HYPOTHESIS:

- AgNPs adhesion
- Membrane damages
- Hyphae necrosis



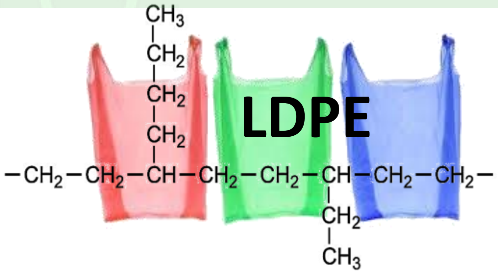

AgNPs@CT

AgNPs@CF

AgNPs@MY ~ AgNPs@GL

# Nanoparticles application in food technology



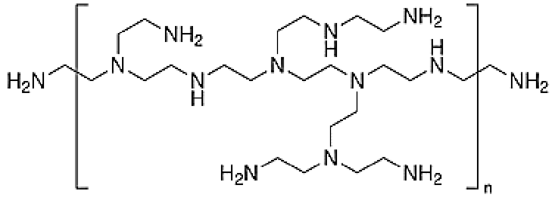



Commercial low-density polyethylene (LDPE) films coated using a layer-by-layer (LbL) technique by alternating the deposition of polyethyleneimine (PEI), poly(acrylic acid) polymer (PAA) solutions and antimicrobial silver nanoparticles (Ag).

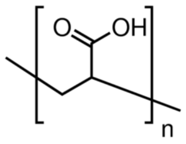
2 different LbL condition

Modified pH (MpH)

PEI pH 9
PAA pH 6.5



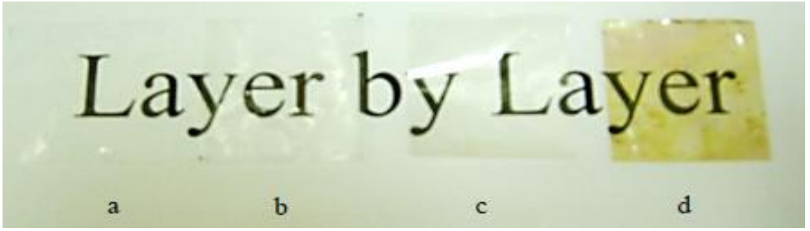
PEI



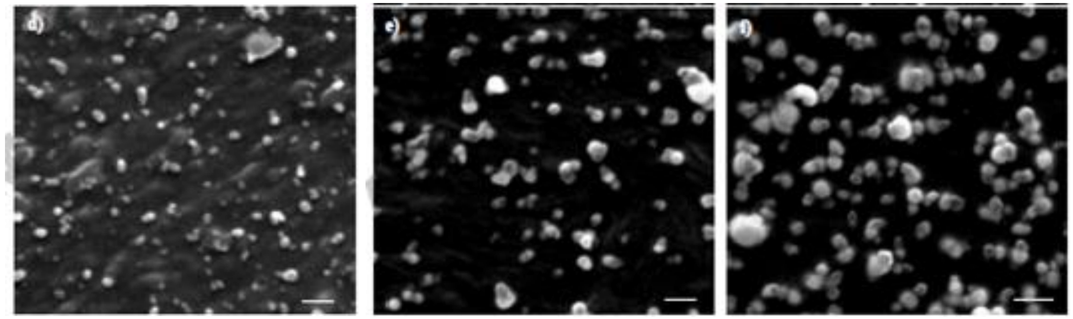
PAA

Non-Modified pH (NMpH)

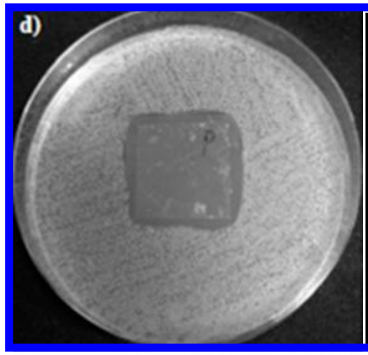
PEI pH 10.5
PAA pH 4




The colour changes of a) LDPE films and b) LDPE LbL coated (3 coatings) films without Ag and c) AgNPs presence on LDPE LbL coated (3 coatings) films immersed in 0,5% $AgNO_3$, or d) AgNPs presence on LDPE LbL coated with (3 coatings) film immersed in 5% $AgNO_3$ and UV/ozone treated for 20 min.




(d) LbL coated (3 coating) immersed in 0,5% $AgNO_3$, (e) LbL coated (3 coatings) immersed in 2% $AgNO_3$; and (f) LbL coated (3 coatings) immersed in 5% $AgNO_3$. Scale bar = 500nm



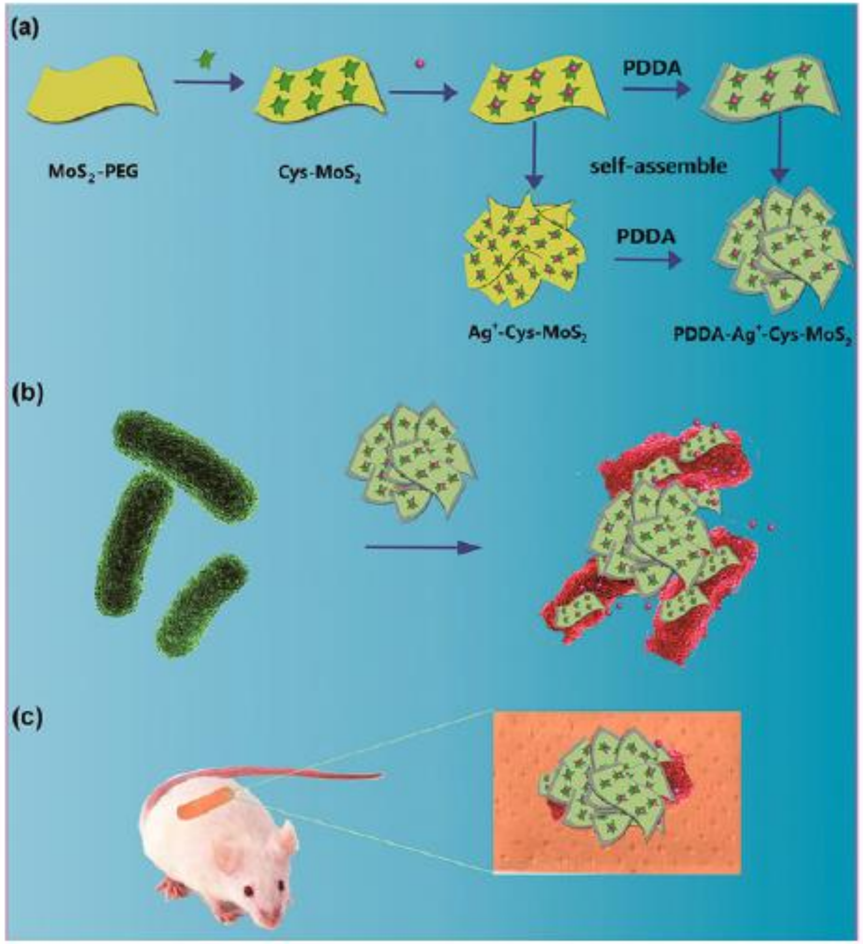

| | Inibition zone ($mm^2$) | |
|---|---|---|
| Film | *S. aureus* | *P. fluorescens* |
| LPDE films | 0.00 | 0.00 |
| LPDE + PEI/PAA (MpH) | 350.4 ± 13.30 | 694.8 ± 19.15 |
| LPDE + PEI/PAA (NMpH) | 460.0 ± 25.41 | 737.0 ± 15.08 |

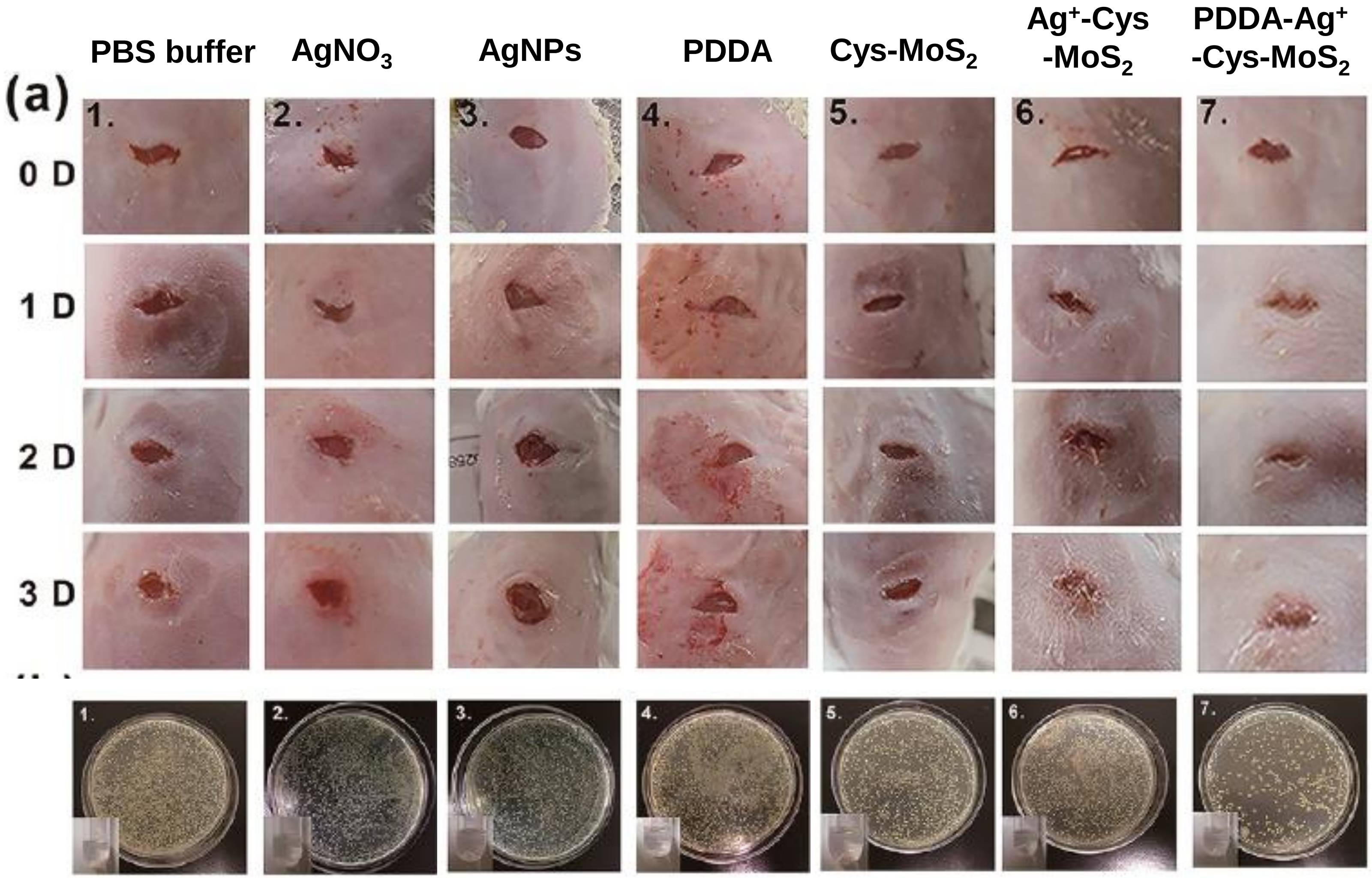
# Biological features


ACS NANO www.acsnano.org ARTICLE

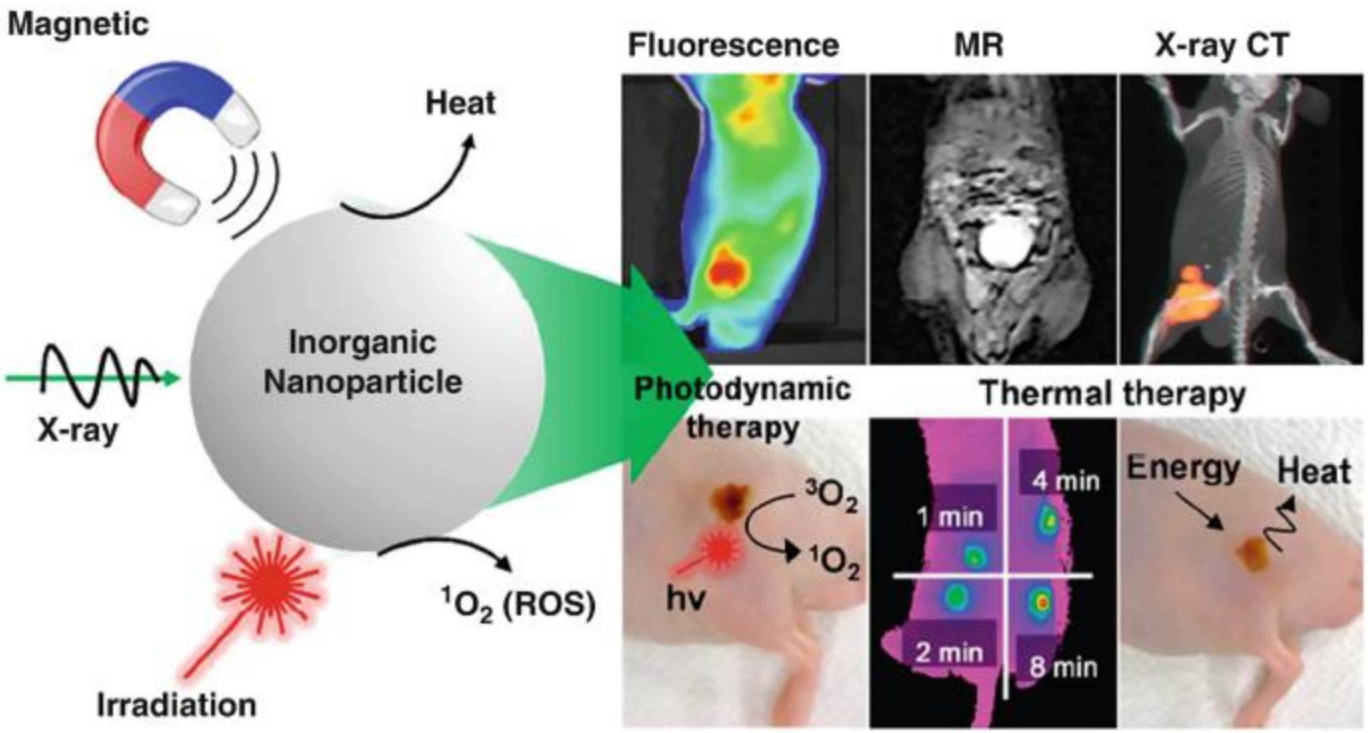
An Efficient and Benign Antimicrobial Depot Based on Silver-Infused $MoS_2$

Fangfang Cao,[†,‡] Enguo Ju,[†,§] Yan Zhang,[†,§] Zhenzhen Wang,[†,§] Chaoqun Liu,[†,§] Wei Li,[†,§] Yanyan Huang,[†,§] Kai Dong,[†,§] Jinsong Ren,[*,†] and Xiaogang Qu[*,†]

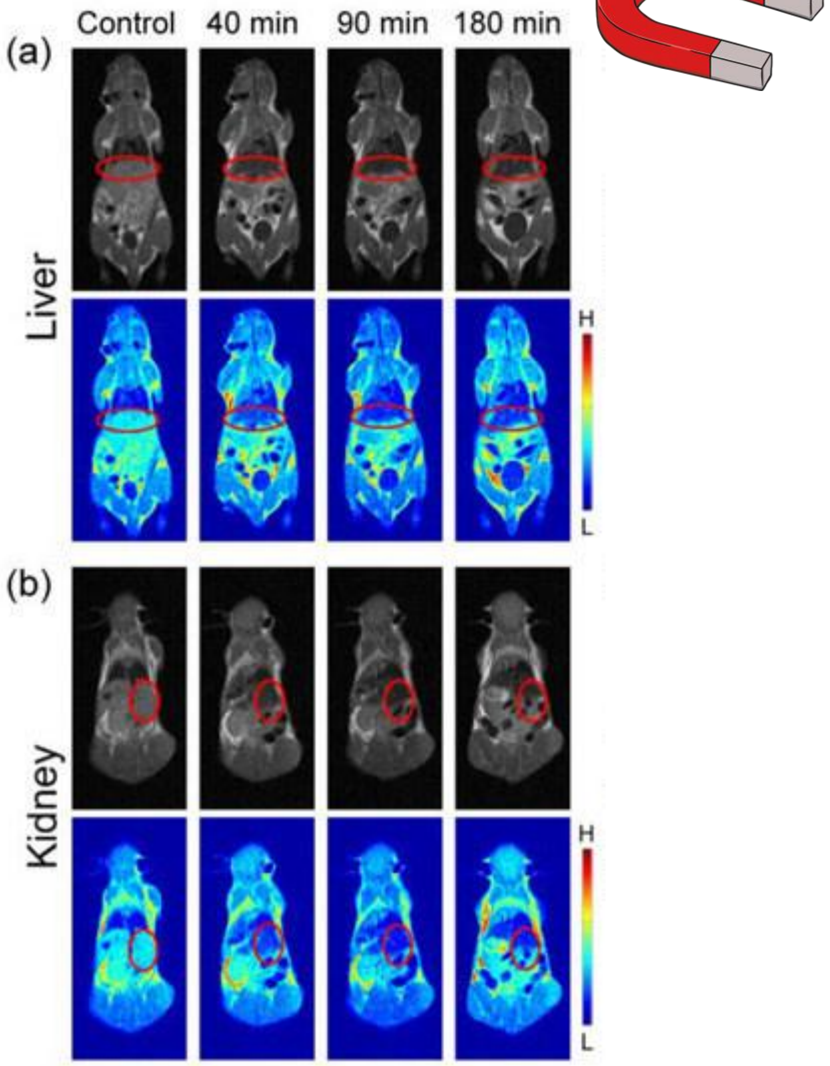


# Optical/ biological features – Imaging




$Fe_3O_4$-NPs



# Optical/ biological featu