Is this Nano?

Nanotechnology is a "*system of innovative methods to control and manipulate matter at near-atomic scale to produce new materials, structures, and devices*".

Nanomaterials (NMs)

Materials in the range of 100 nm are considered to be nanoparticles. They exhibit a wide range of properties, including optical, electrical, catalytic, magnetic, and biological activity.

Regulatory Toxicology and Pharmacology 65 (2013) 119–125

Contents lists available at SciVerse ScienceDirect

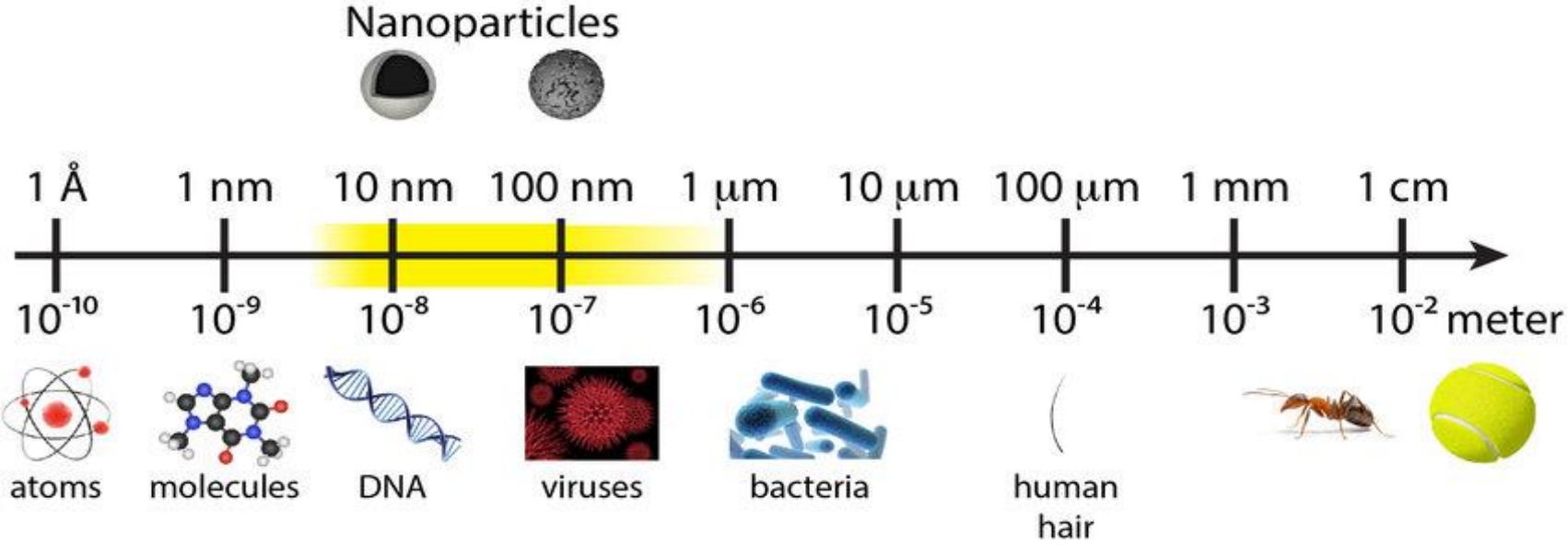
Regulatory Toxicology and Pharmacology

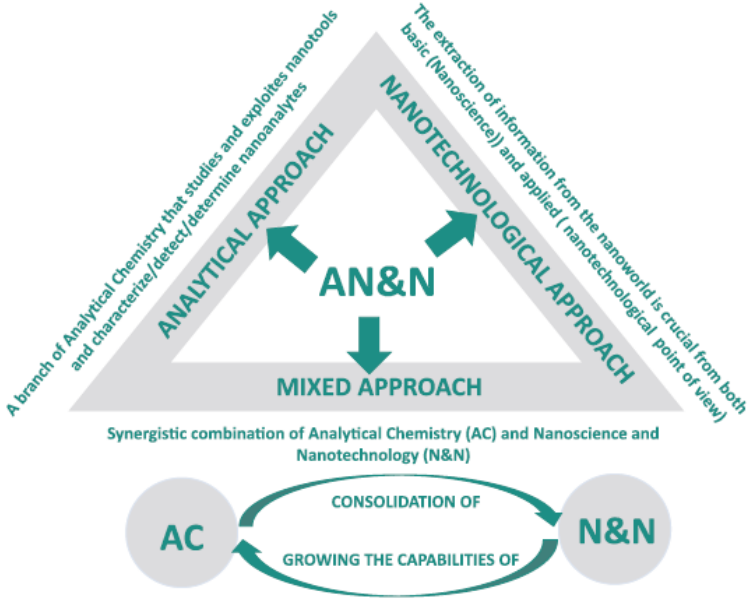
journal homepage: www.elsevier.com/locate/yrtph

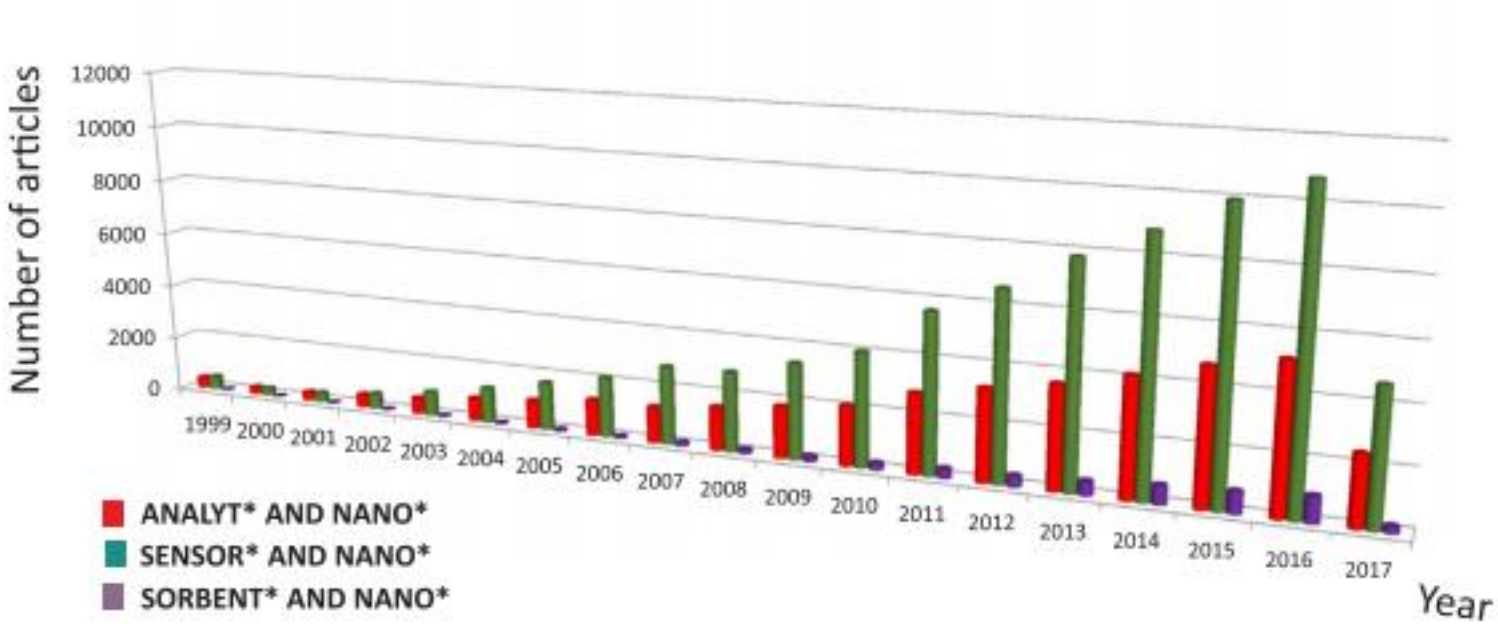
Considerations on the EU definition of a nanomaterial: Science to support policy making

Eric A.J. Bleeker*, Wim H. de Jong, Robert E. Geertsma, Monique Groenewold, Evelyn H.W. Heugens, Marjorie Koers-Jacquemijns, Dik van de Meent, Jan R. Popma, Anton G. Rietveld, Susan W.P. Wijnhoven, Flemming R. Cassee, Agnes G. Oomen

Is this Nano?





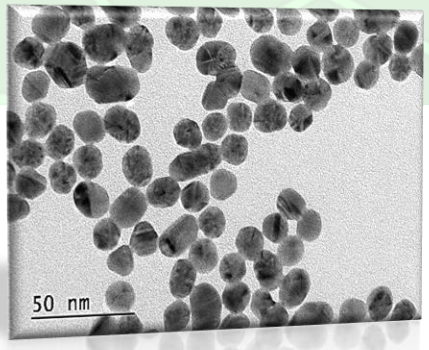


European Commission, Commission Recommendation of 18 October 2011 on the definition of nanomaterial, Official Journal of the European Union. 2011/696/EU: 38-40, 2011

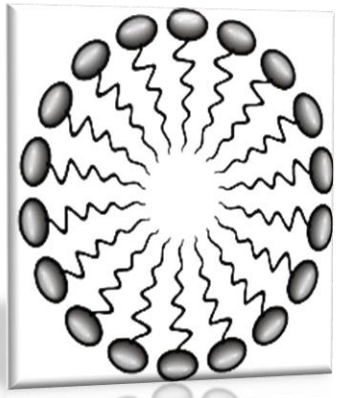
Nanomaterials

Nanomaterials (NMs)

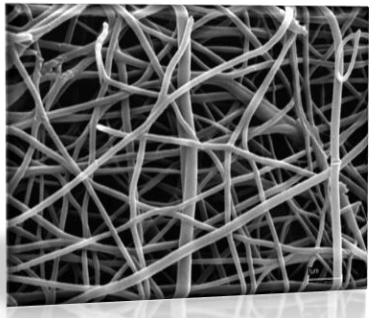
Nano-objects
Nano-particles



Micelle

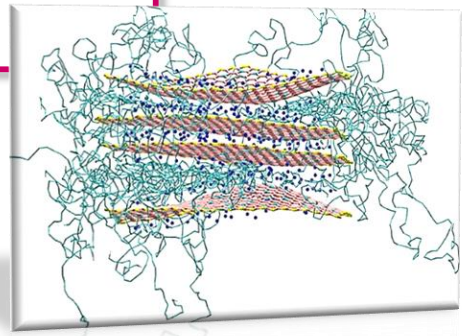


Nanofiber

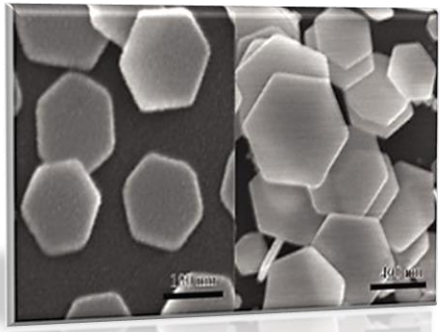


Nanoformulations

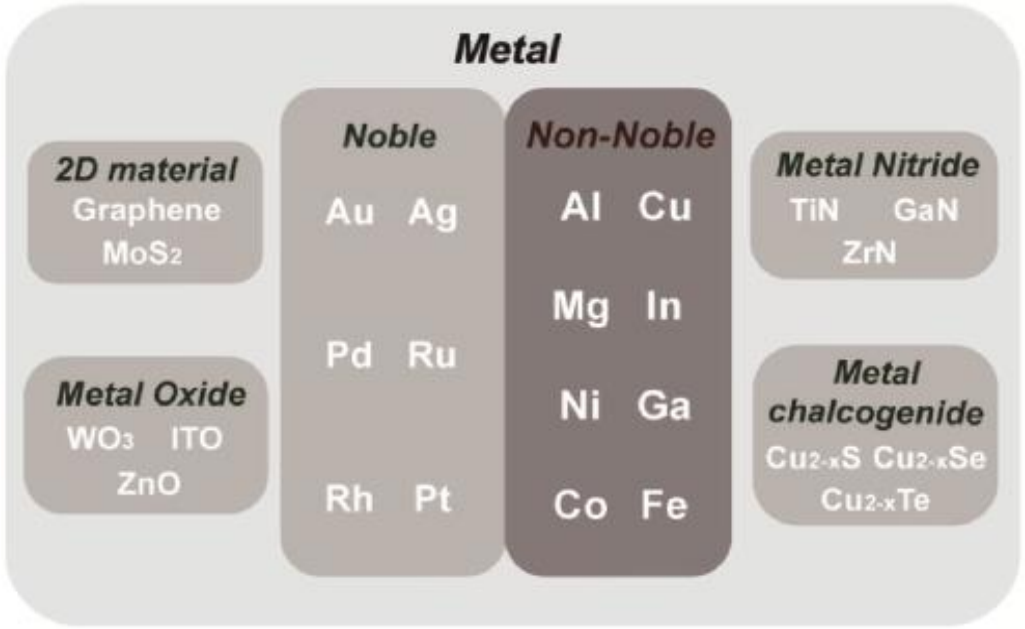
Nanocomposite

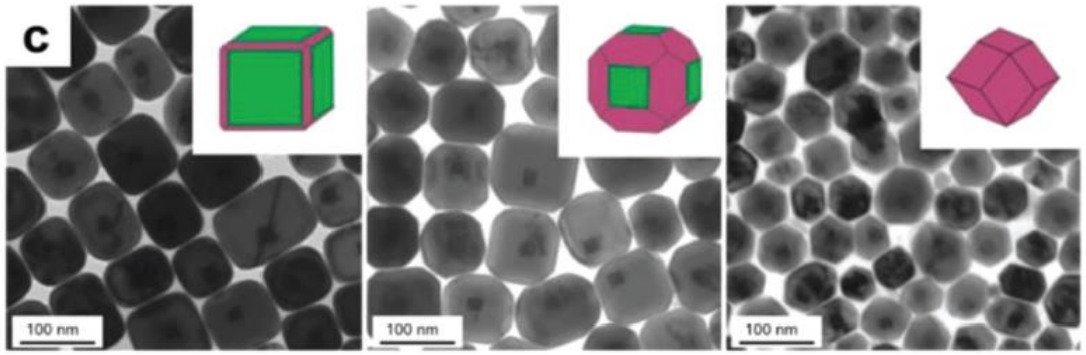


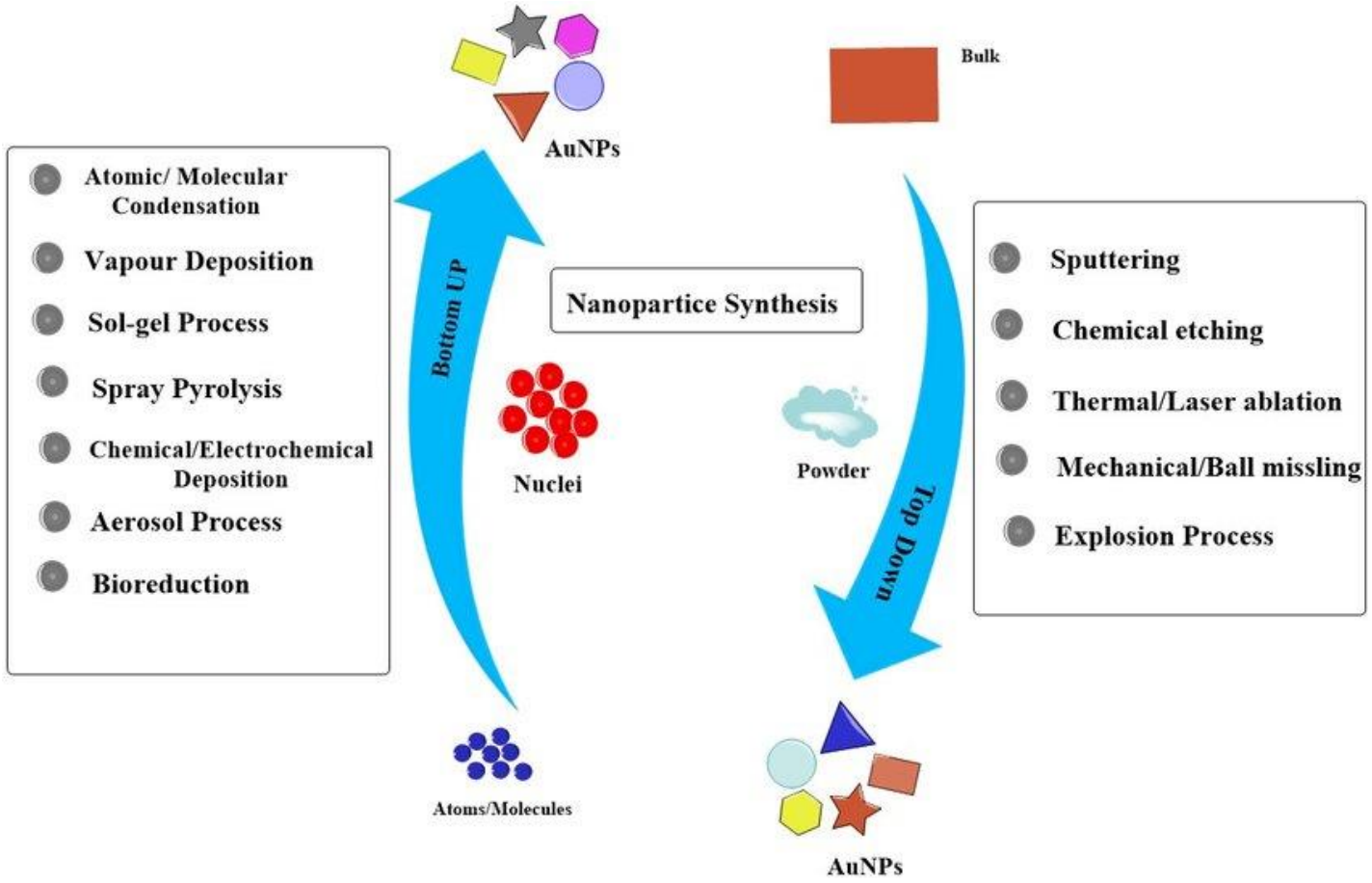
Nanoplate



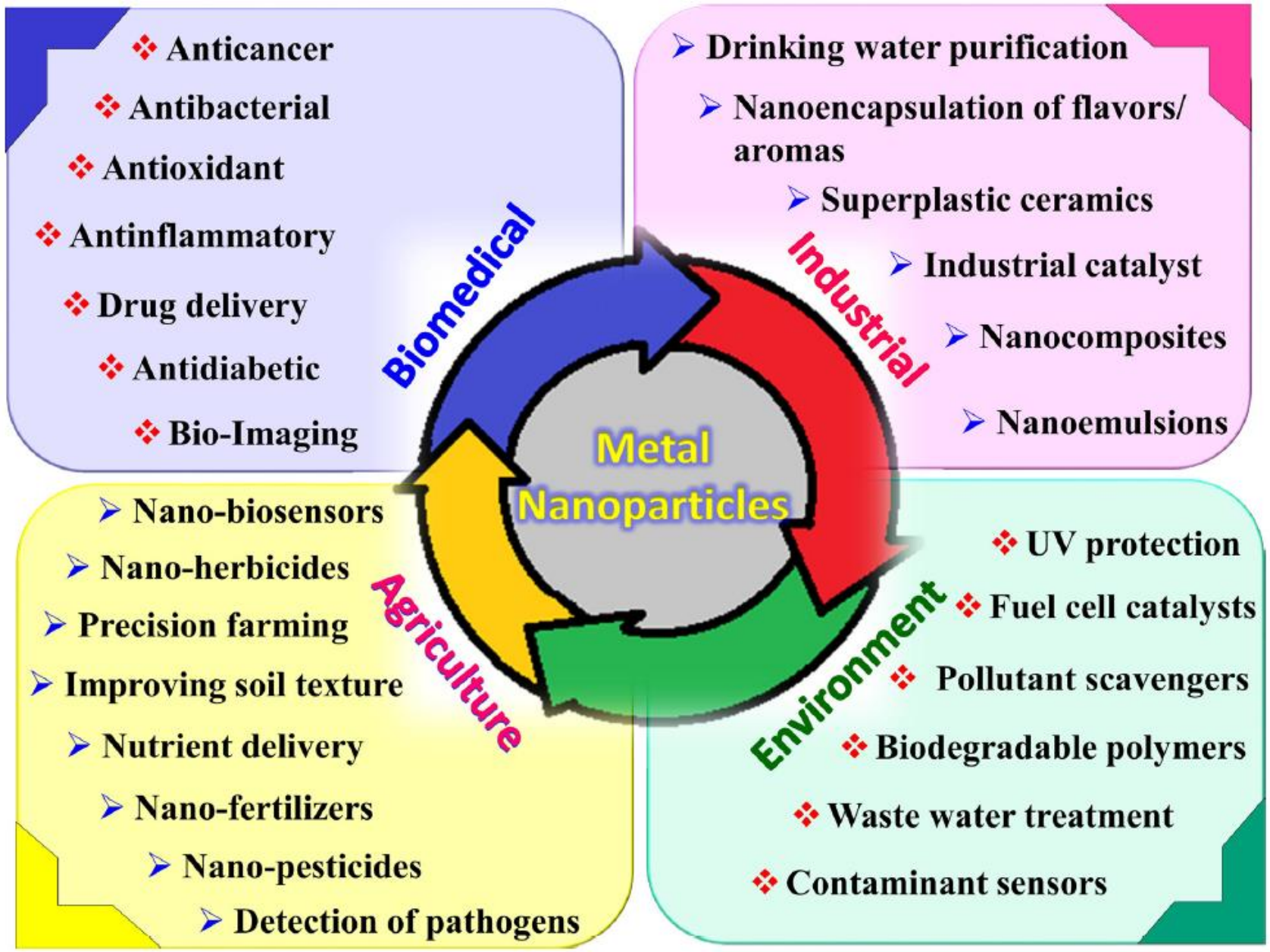
Metal based Nanoparticles







Metal Nanoparticles application fields



Nanoparticles in food technology, an overview

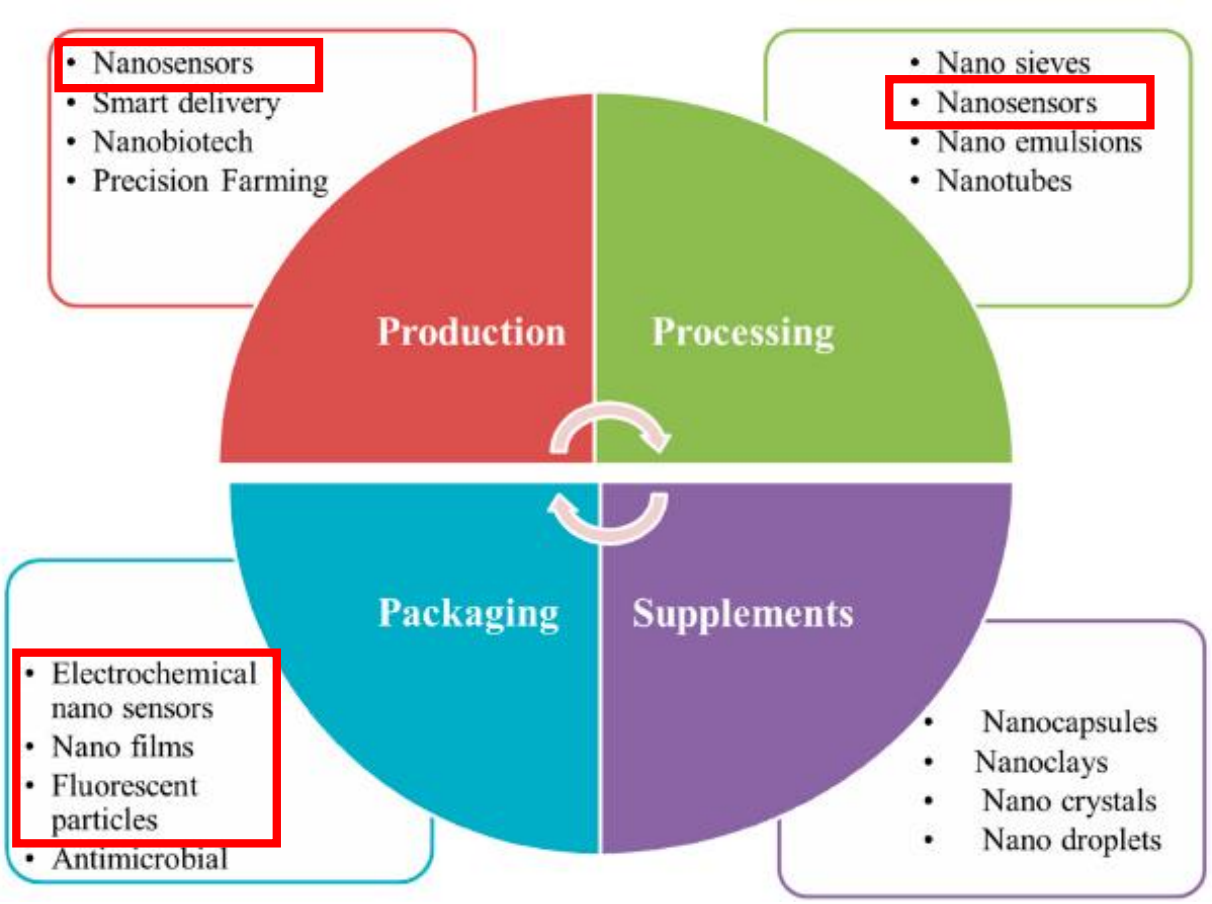
foods

MDPI

Review

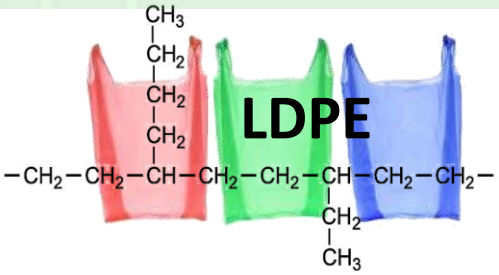
An Overview of the Applications of Nanomaterials and Nanodevices in the Food Industry

Mehwish Shafiq [1], Sumaira Anjum [1,*], Christophe Hano [2], Iram Anjum [1] and Bilal Haider Abbasi [3]



Nanomaterials	Type of Nanomaterials	Applications in Food Industry
Nanoparticles	Ag, ZnO, Mg, SiO_2	Food packaging, oxidation of contaminant, anti-bacterial
Nanosieves	Specific nanoparticles	Removal of pathogens or contaminants
Nanocapsules	Bioactive compounds	Increased efficacy and water solubility, local and controlled release
Nano-emulsions	Tweens or spans; gum arabica or modified starch, soy, caseinate	Food encapsulation, food processing, antimicrobial and storage, stability, colorant
Nanospheres	Starch nanosphere	Food encapsulation, synthetic adhesives
Nanosensors	Aptasensors	Detection of micro-organisms, food deterioration control
Nanocochleates	Coiled Nanoparticles	Enhanced nutritional value of food, antioxidant, food protection and stability
Nanocomposite	Fe-Cr/Al_2O_3 Ni/Al_2O_3	Enhanced shelf life of food, food protection and food packaging
Nanomicelles	Aquanova, novasol	Liquid carrier, enhanced solubility

Nanoparticles application in food technology

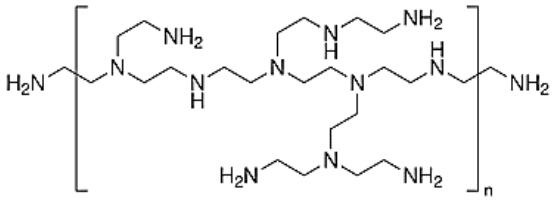


Commercial low-density polyethylene (LDPE) films coated using a layer-by-layer (LbL) technique by alternating the deposition of polyethyleneimine (PEI), poly(acrylic acid) polymer (PAA) solutions and antimicrobial silver nanoparticles (Ag).

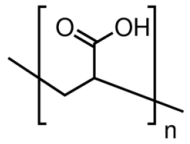
2 different LbL condition

Modified pH (MpH)

PEI pH 9
PAA pH 6,5



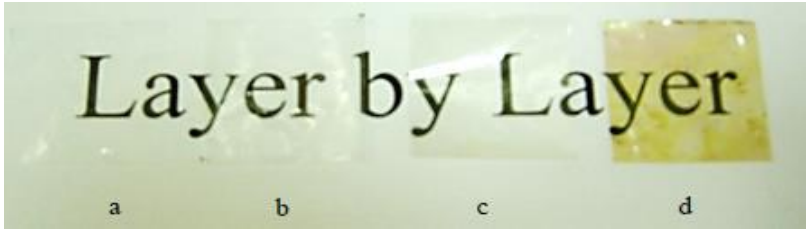
PEI



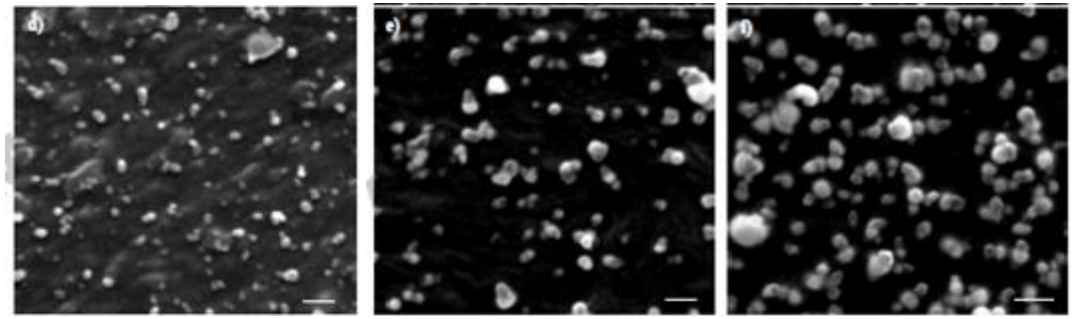
PAA

Non-Modified pH (NMpH)

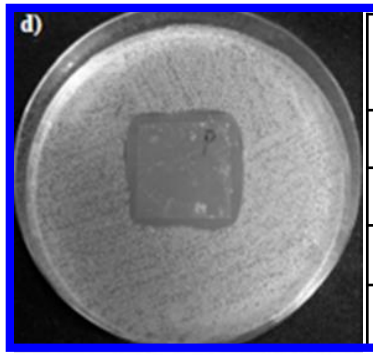
PEI pH 10,5
PAA pH 4



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.

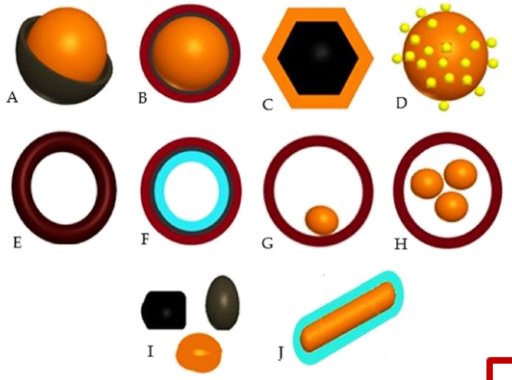


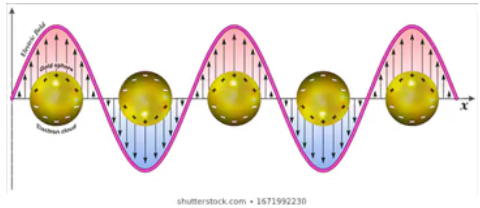
(d) LbL coated (3 coating) immersed in 0,5% $AgNO_3$, (e) LbL coated (3 coatings) immersed in 2% $AgNO_3$; and (f) LbL coated (3 coatings) immersed in 5% $AgNO_3$. Scale bar = 500nm



	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

Advantages of metal nanoparticles for analyitical purposes





Nano

High conductivity

Easy preparation (tunable)

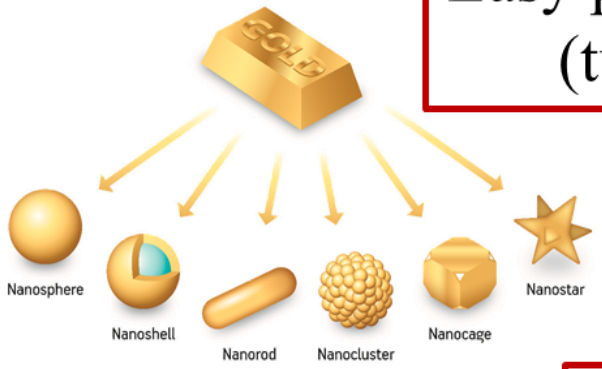
MNPs

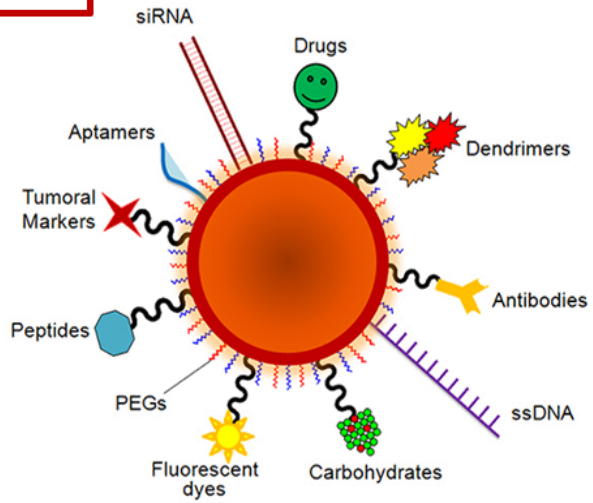
Robust / stable

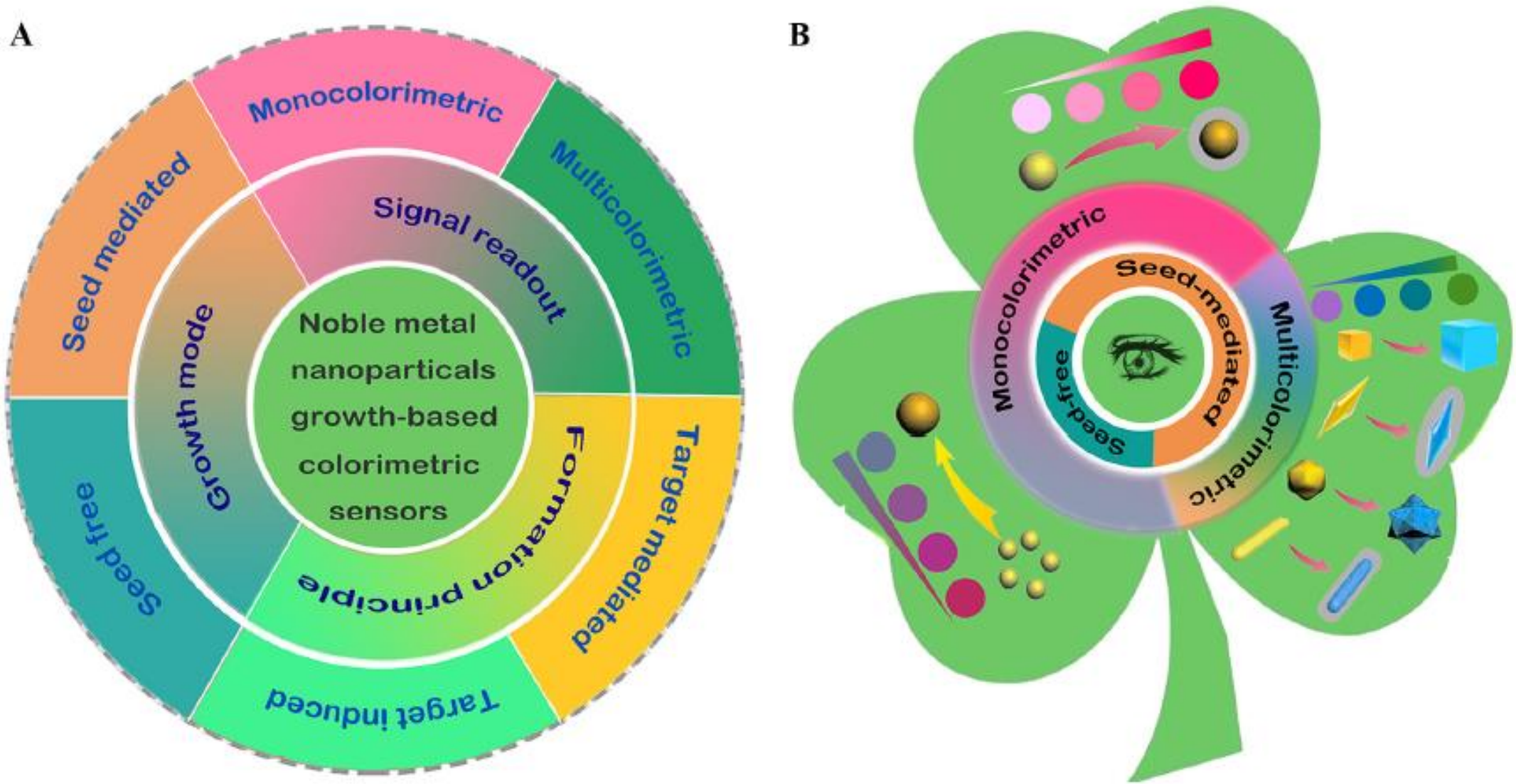
(Inhert)

Good biocompatibility

Surface (Bio)functionalization

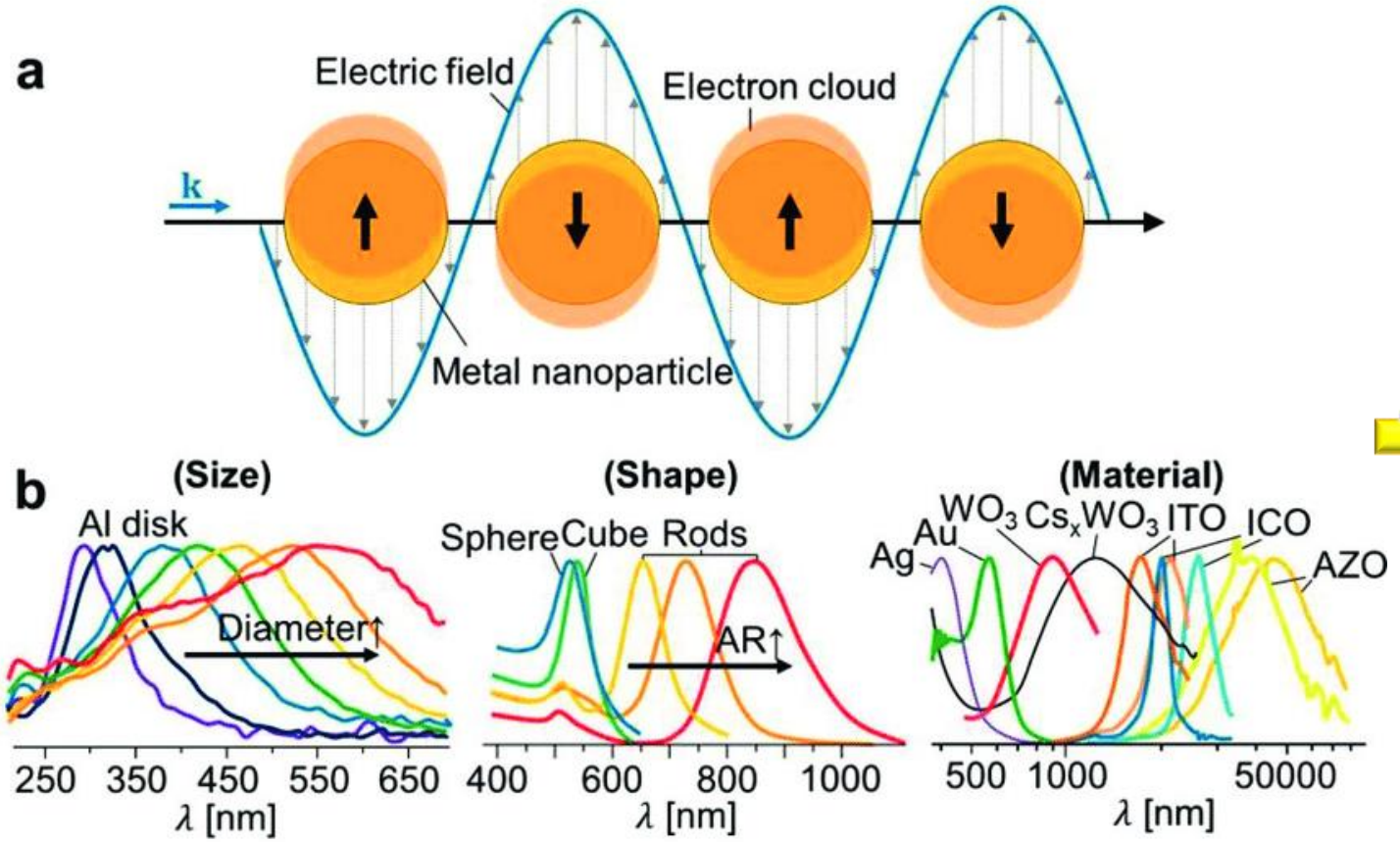


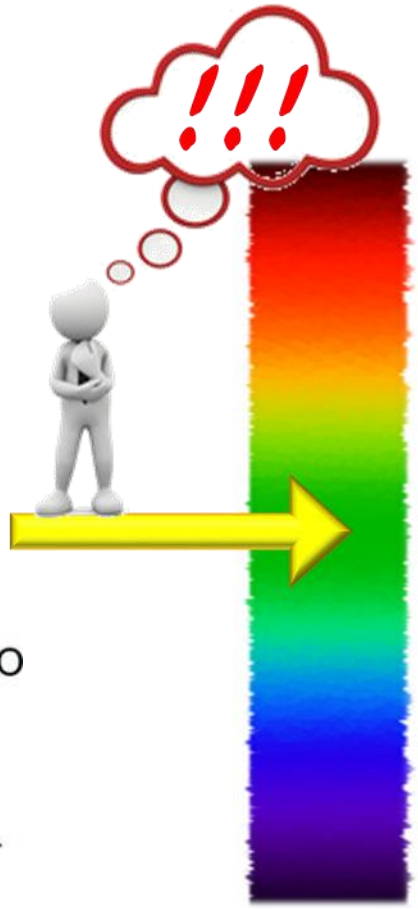



A
Monocolorimetric
Multicolorimetric
Seed mediated
Seed free
Target mediated
Target induced
Signal readout
Growth mode
Formation principle
Noble metal nanoparticals growth-based colorimetric sensors
B
Monocolorimetric
Seed-mediated
Multicolorimetric
Seed-free

Localized Surface Plasmon Resonance (LSPR)

Principle



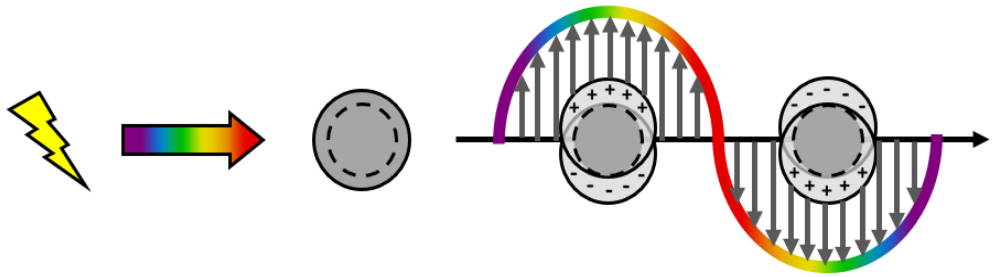


GÉRARD, Davy; GRAY, Stephen K. Aluminium plasmonics. *Journal of Physics D: Applied Physics*, 2014, 48.18: 184001.

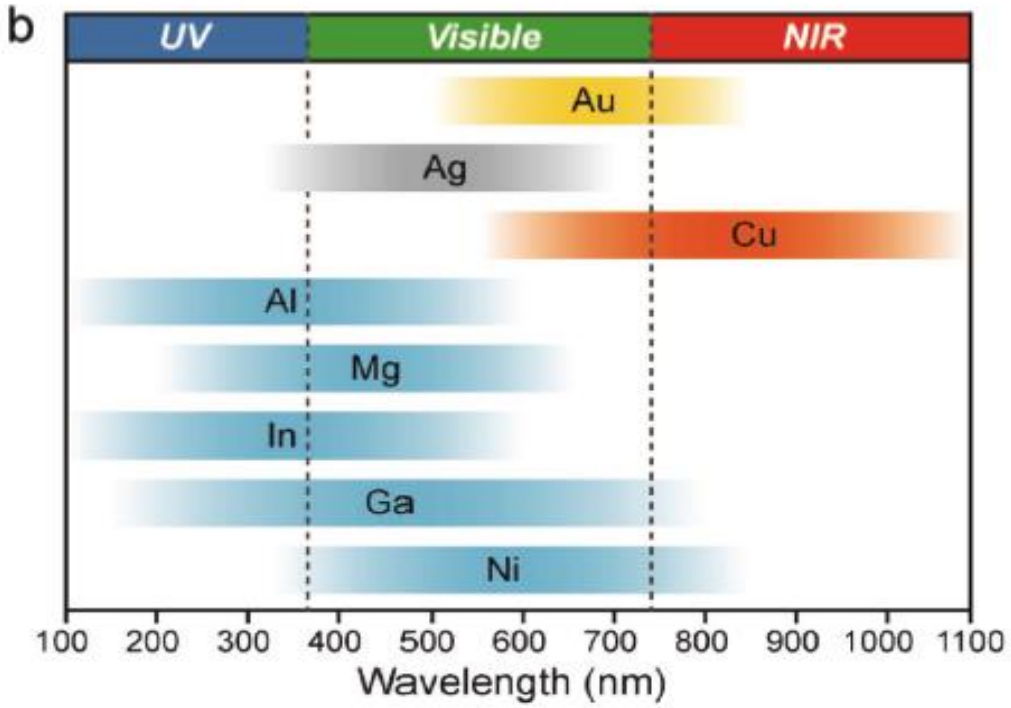
CHEN, Huanjun, et al. Shape-and size-dependent refractive index sensitivity of gold nanoparticles. *Langmuir*, 2008, 24.10: 5233-5237.

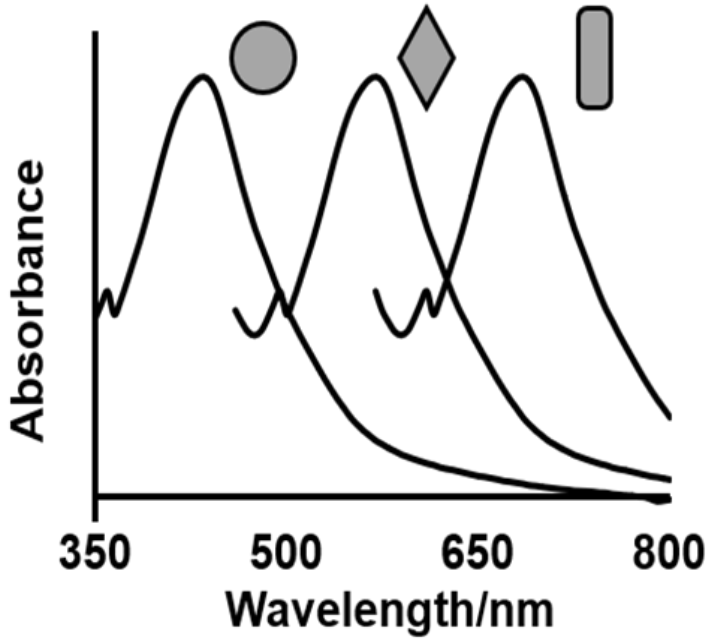
LOUNIS, Sebastien D., et al. Defect chemistry and plasmon physics of colloidal metal oxide nanocrystals. *The journal of physical chemistry letters*, 2014, 5.9: 1564-1574.

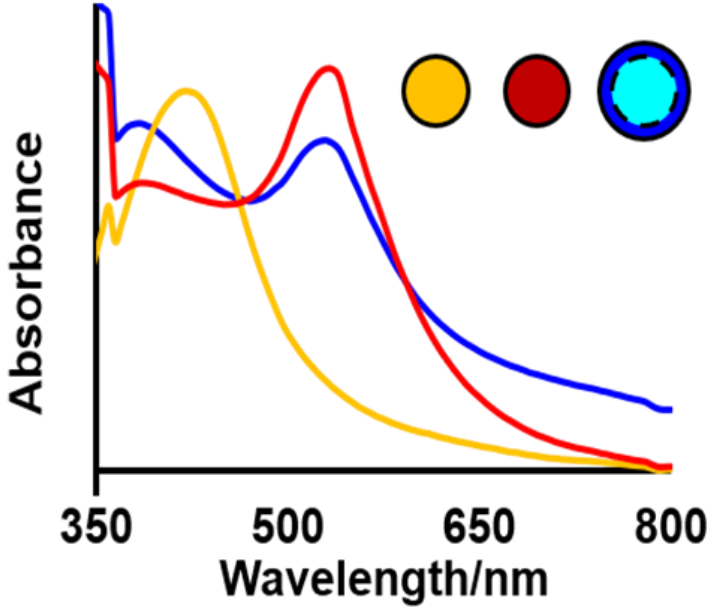
Metal nanoparticles optiocal key feature



Localized Surface Plasmon Resonance

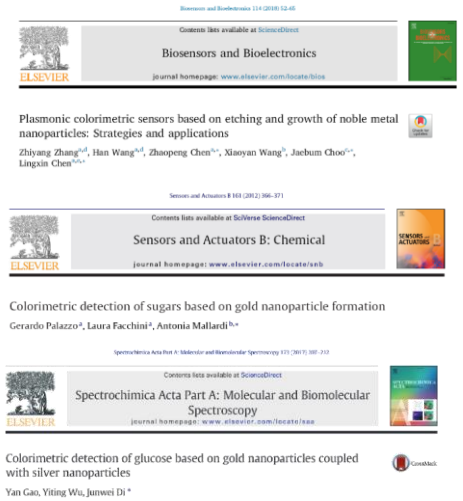


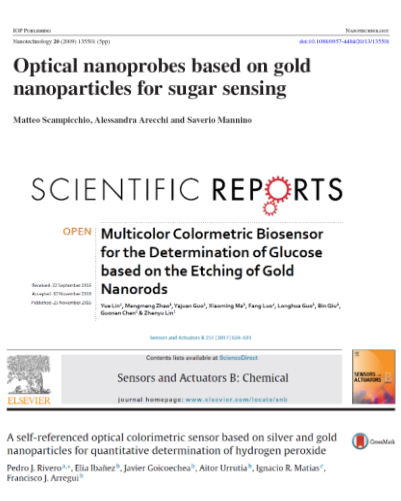


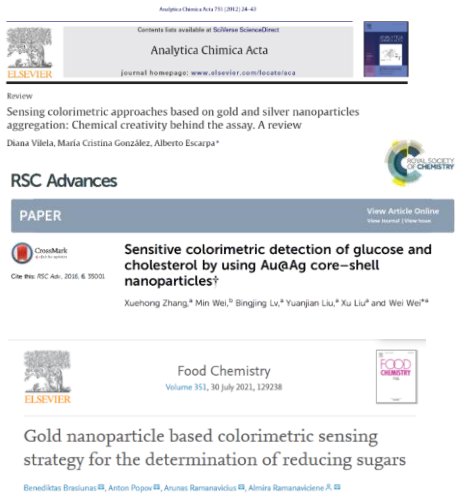


Plasmonic-active nanostructured materials for sensing and biosensing

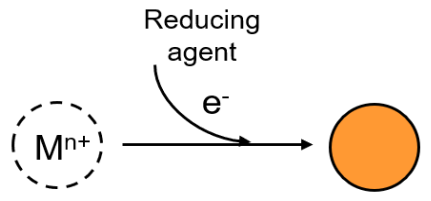
Colloidal metal nanoparticles based assays

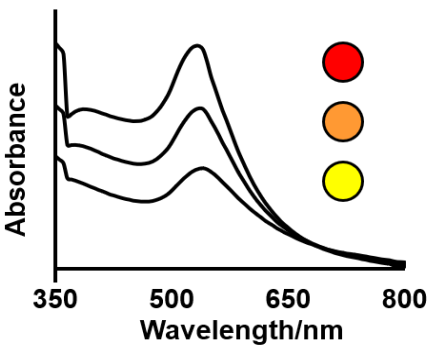


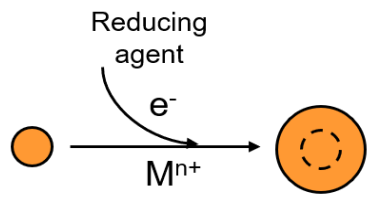


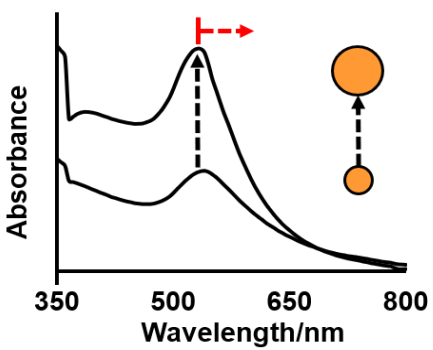


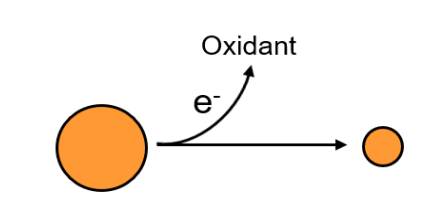
Localized Surface Plasmon Resonance

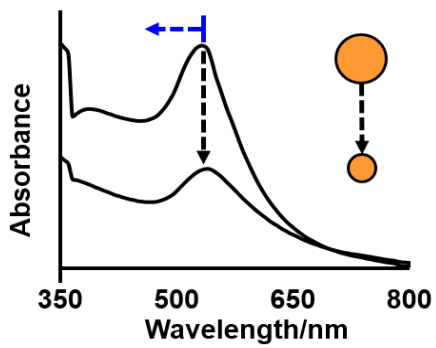


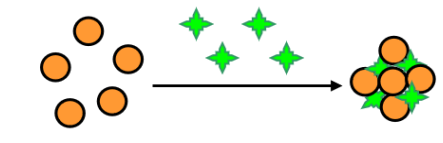


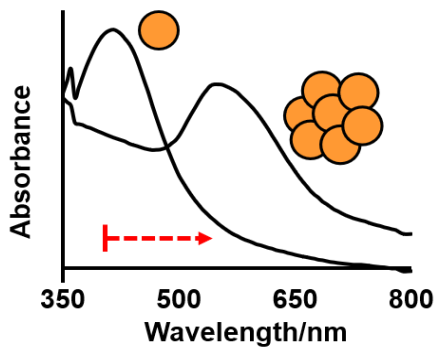




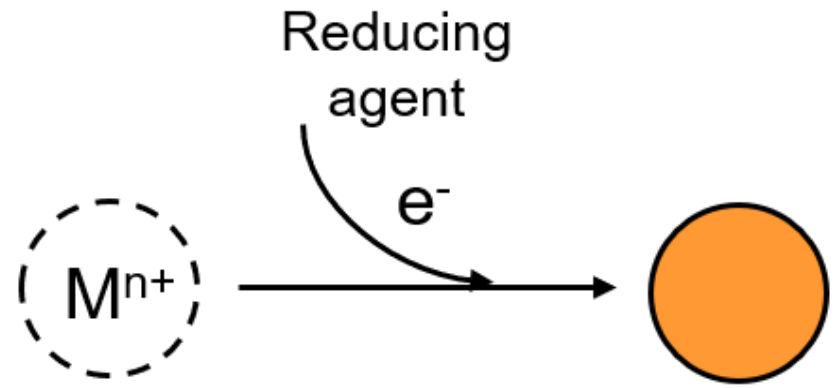


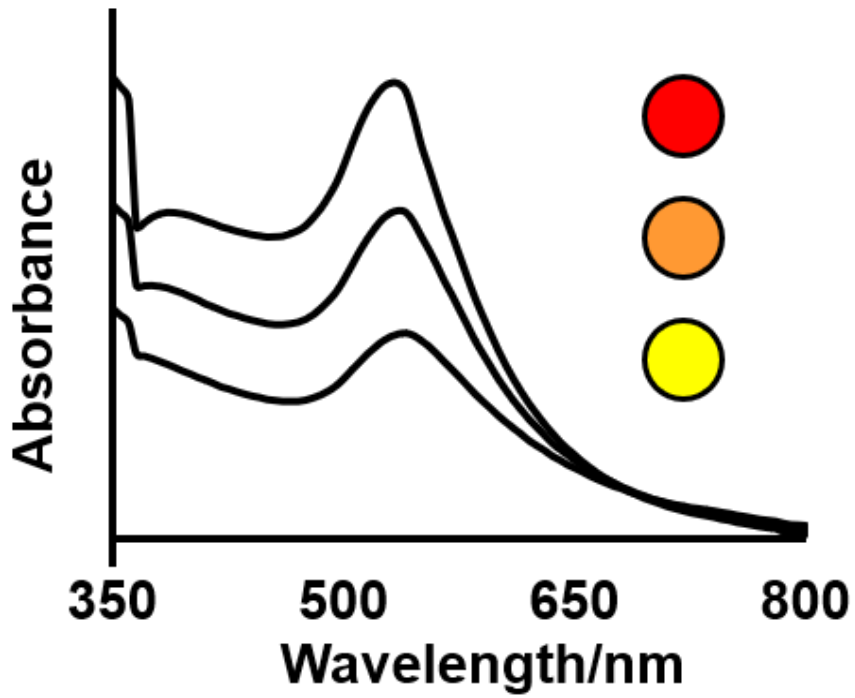






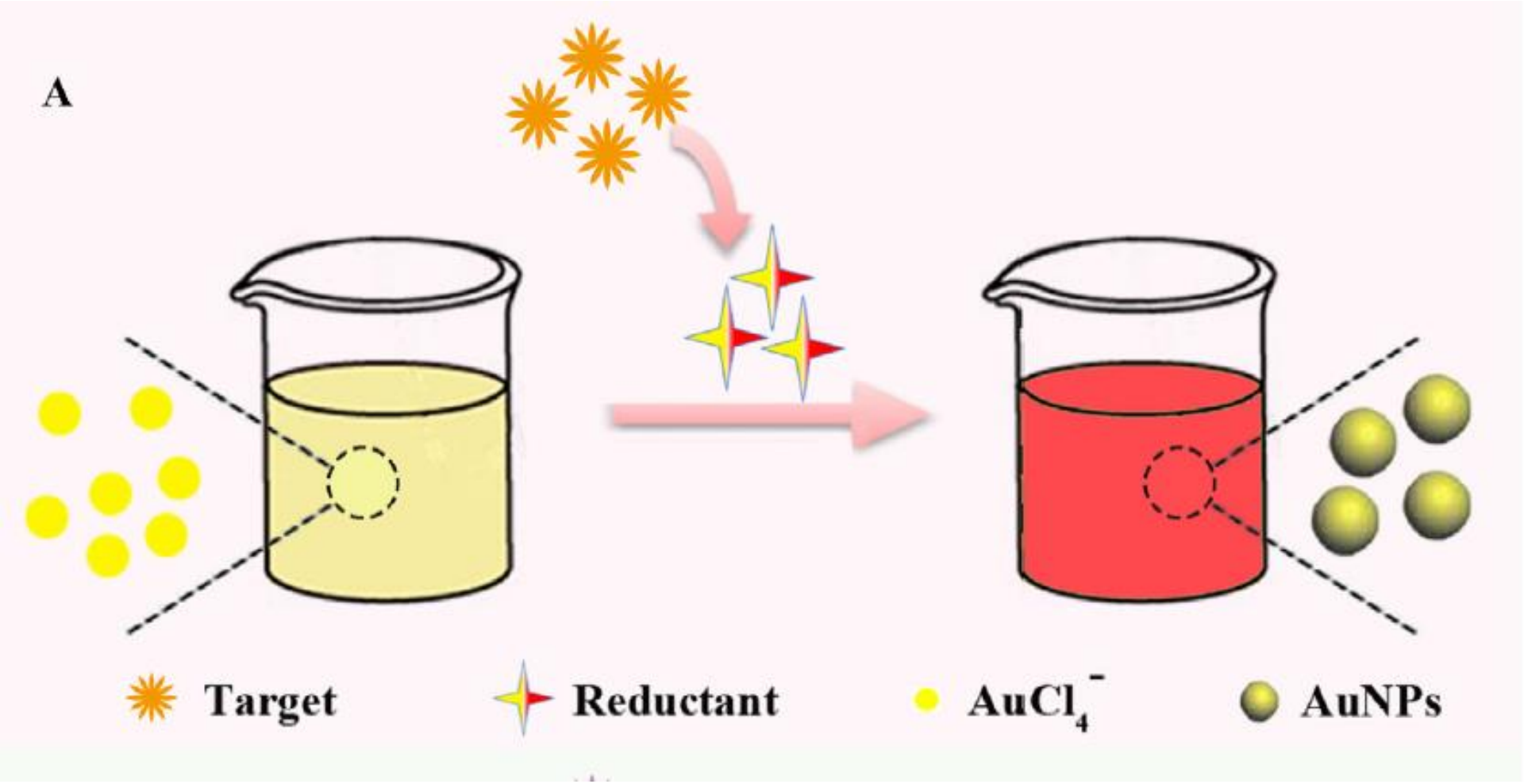
Metal nanoparticles formation





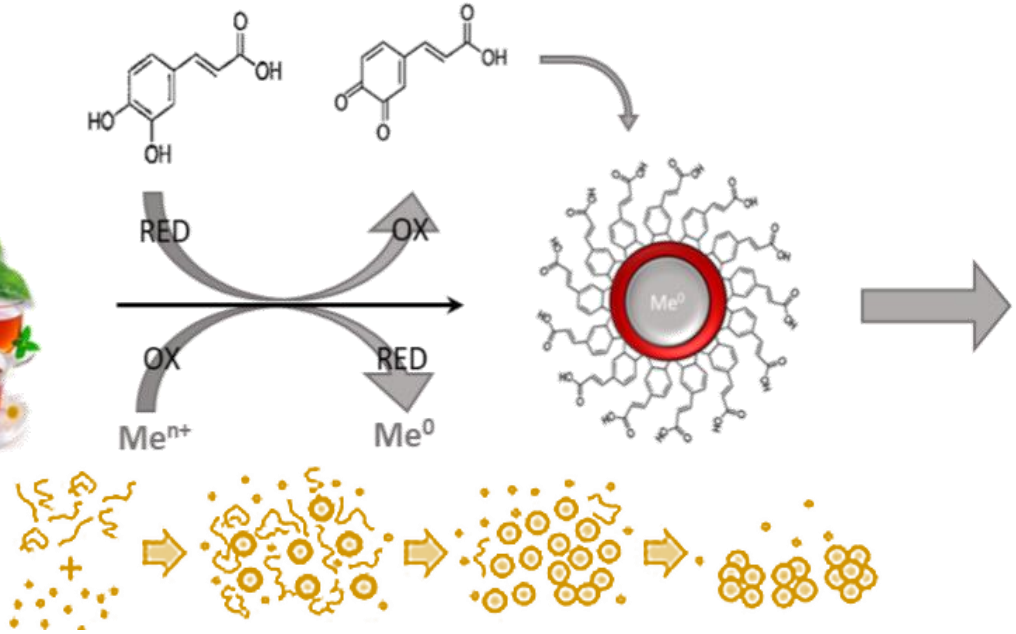
Metal nanoparticles formation.

Main strategy

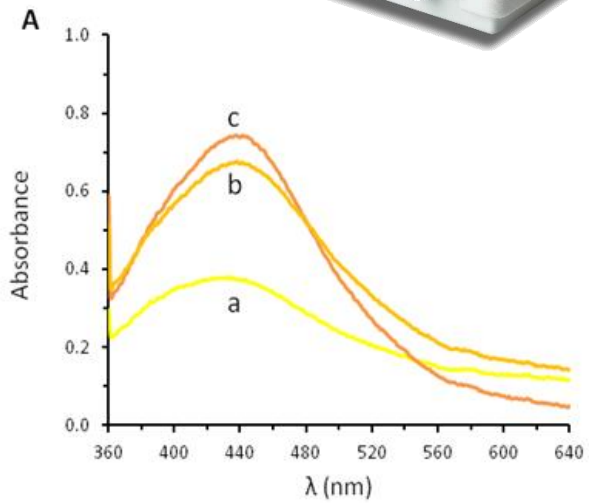


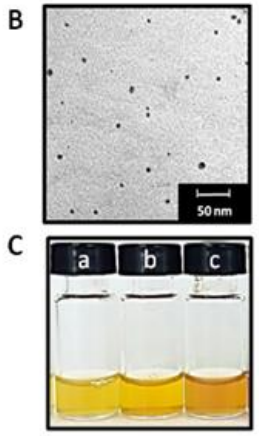
Metal nanoparticles formation

Reducing compounds evaluation trough Au and AgNPs formation



LSPR





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 *

… 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.

Table 11.1: Food antioxidants.

Antioxidant	Subclasses	Formula	Examples	Sources
Phenolic acids	Hydroxybenzoic acids	C_6–C_1	Gallic acid, *p*-hydroxybenzoic acid, protocatechuic acid, vanillic acid, syringic acid	Blackberry, raspberry, tea
	Hydroxycinnamic acids	C_6–C_3	Caffeic acid, ferulic acid, *p*-coumaric acid, sinapic acid	Blueberry, coffee
Flavonoids	Flavonols	C_6–C_3–C_6	Quercetin, kaempferol	Onions, leeks, broccoli
	Flavones		Apigenin, luteolin	Parsley, celery
	Flavanones		Naringenin, hesperetin, eriodictyol	Orange, grapefruit, lemon
	Flavanols		Catechin, epicatechin	Tea, chocolate
	Isoflavones		Genistein, daidzein, glycitein	Soy
	Anthocyanidins		Cyanidin, malvidin, delphinidin	Berries
Carotenoids	Xanthophylls	$C_{40}H_{56}O_n$	β-Cryptoxanthin, lutein, zeaxanthin, neoxanthin, violaxanthin, α-cryptoxanthin	Peppers, green leafy vegetables
	Carotenes	$C_{40}H_{56}$	α-Carotene, β-carotene, lycopene	Pumpkin, carrot, tomato
Vitamins	Vitamin C	$C_6H_8O_6$		Citrus fruits, kiwi, strawberry
	Vitamin E	$C_{29}H_{50}O_2$	Tocopherols, tocotrienols	Nuts, seeds, fish oil, whole grains

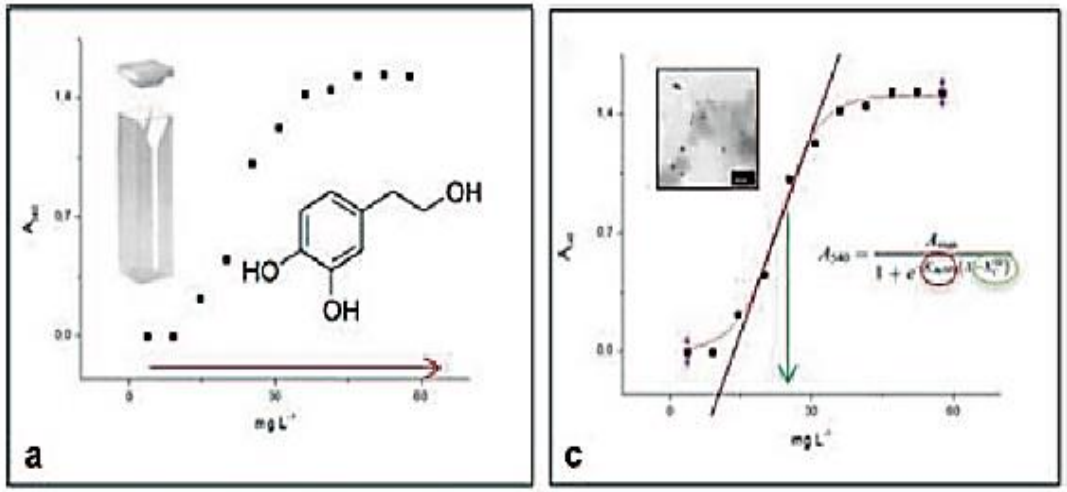
Polyphenols sensing

AuNPs

AoC
Idrophilic
Matrix Sample

- AoC evaluation
- The pH (8) avoid sugar interference
- High correlation with classical methods for antioxidant determination
- Sensitivity to intrinsic antioxidant power (o-diphenols most reactive)

Total assay time: 25 min



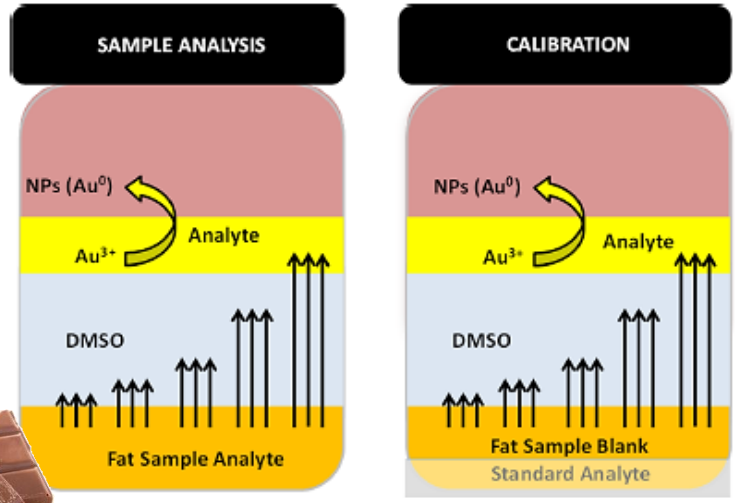
DELLA PELLE, Flavio, et al. Development of an Optical Sensing Strategy Based on Gold Nanoparticles Formation Driven by Polyphenols. Application to Food Samples. In: *Sensors*. Springer, Cham, 2015. p. 39-46.

AuNPs
Fat

AoC
Fat
Matrix Sample

- Total polyphenols determination (40C°)
- Extraction free: directly applicable in fat sample matrix
- Low amount of sample is required (30 µL)
- Rapid and robust
- Sensitive

Total assay time: 10 min

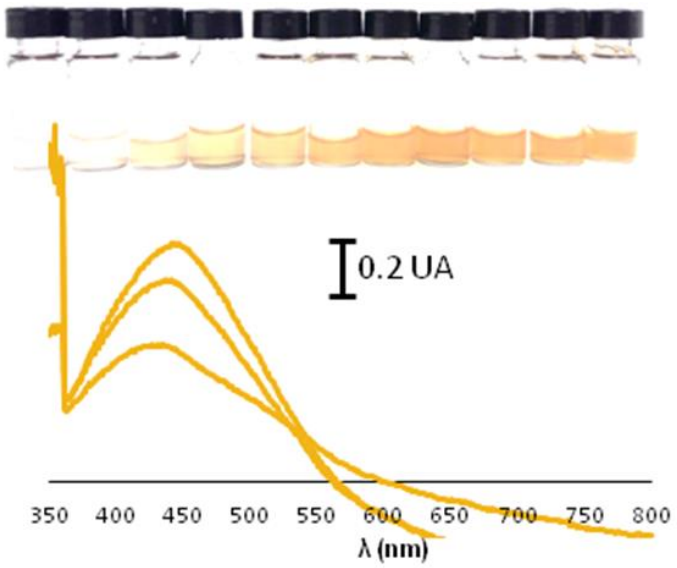


DELLA PELLE, Flavio, et al. Gold nanoparticles-based extraction-free colorimetric assay in organic media: an optical index for determination of total polyphenols in fat-rich samples. *Analytical chemistry*, 2015, 87.13: 6905-6911.

Metal nanoparticles formation

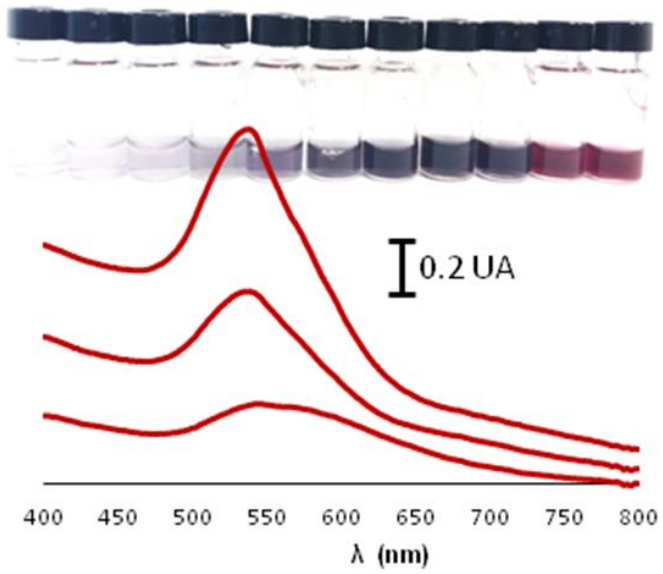
Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation

AgNPs

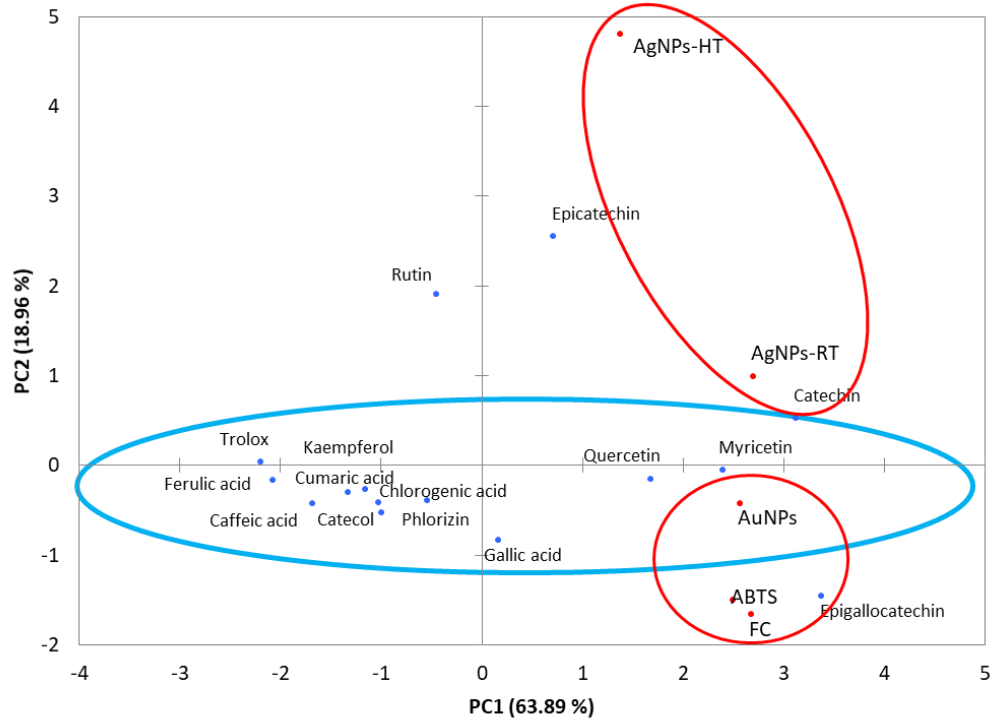


Epicatechin concentration:
2, 4 and 6 µM

AuNPs



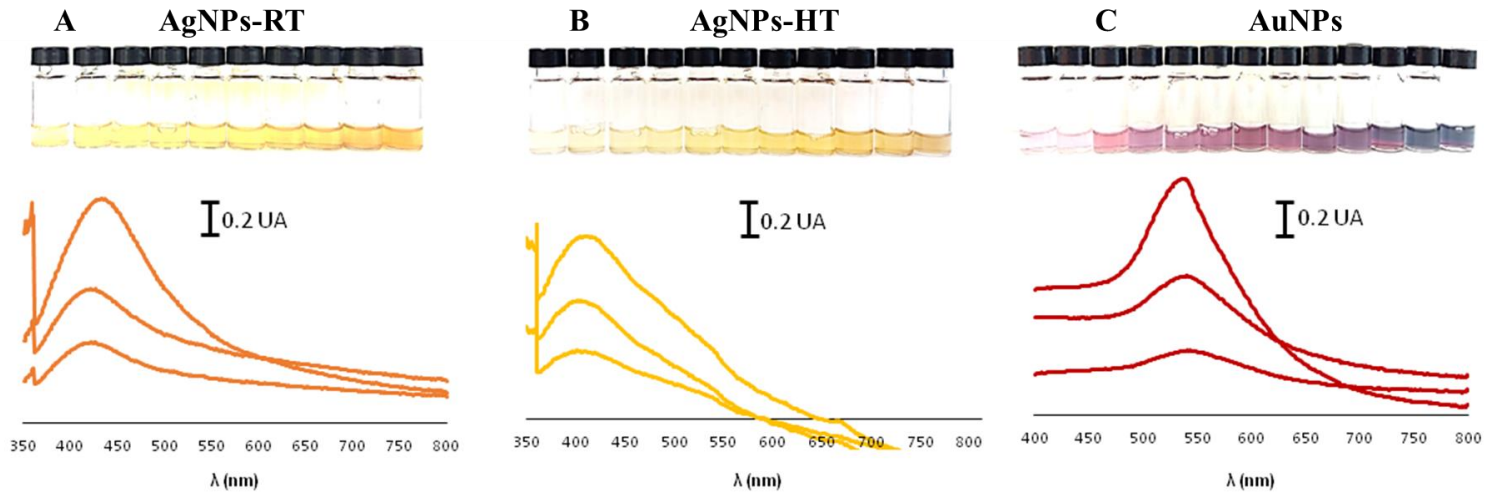
Epicatechin concentration:
70, 90, 110 µM



R	ABTS		FC		AgNPs-HT		AgNPs-RT		AuNPs	
ABTS	1	(p = 0)	0.876	(p = 0.002)	0.891	(p = 0.001)	0.956	(p = 0.000)	0.977	(p = 0.000)
FC	0.876	(p = 0.002)	1	(p = 0)	0.733	(p = 0.025)	0.913	(p = 0.001)	0.801	(p = 0.009)
AgNPs-HT	0.891	(p = 0.001)	0.733	(p = 0.025)	1	(p = 0)	0.770	(p = 0.015)	0.826	(p = 0.006)
AgNPs-RT	0.956	(p = < 0.0001)	0.913	(p = 0.001)	0.770	(p = 0.015)	1	(p = 0)	0.950	(p = < 0.0001)
AuNPs	0.977	(p = < 0.0001)	0.801	(P = 0.009)	0.826	(p = 0.006)	0.950	(p = < 0.0001)	1	(p = 0)

Metal nanoparticles formation

Phenolic content and antioxidant capacity evaluation in teas and infuses



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

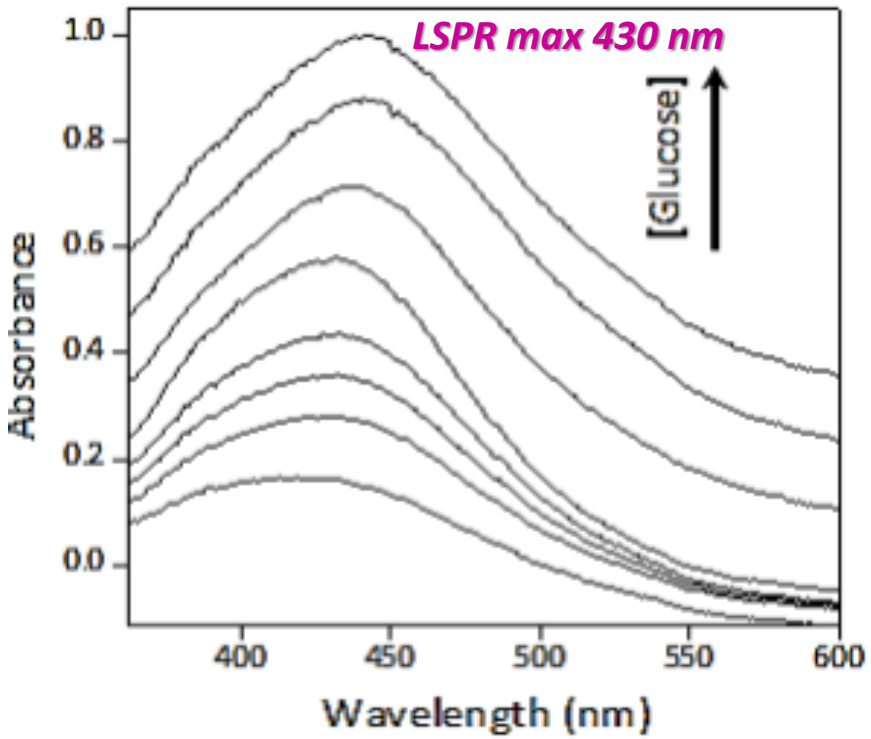
RB: Rosa di bosco Infused
LT: Lemon Tea
IN: Finocchio infused
DIG: Digestiva infused

MNPs spectra obtained with AgNPs-*RT* (A), AgNPs-*HT* (B) and AuNPs (C) assays using increasing volume of the sample 'RE' ('relax')

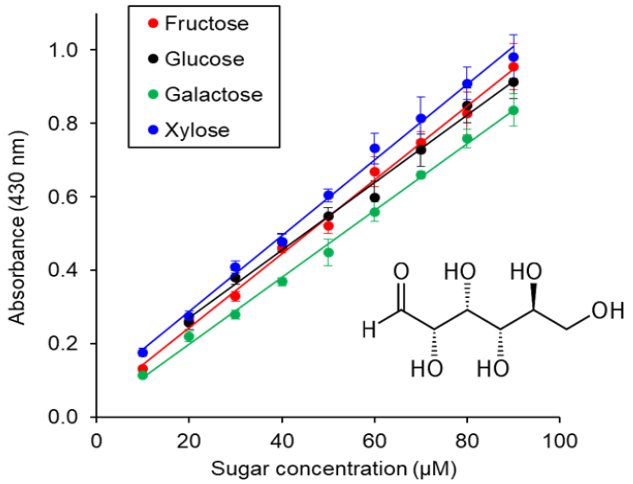
Sample / Method	DIG (g Kg^{-1})	RSD (%)	IN (g Kg^{-1})	RSD (%)	LT (g Kg^{-1})	RSD (%)	RB (g Kg^{-1})	RSD (%)	RE (g Kg^{-1})	RSD (%)	SD (g Kg^{-1})	RSD (%)	TC (g Kg^{-1})	RSD (%)	TG (g Kg^{-1})	RSD (%)	VT (g Kg^{-1})	RSD (%)
AgNPs-RT	8.66	4	1.20	9	9.91	5	5.31	3	9.12	8	9.62	7	49.50	8	143.01	3	52.19	4
AgNPs-HT	11.10	9	12.52	9	14.73	5			7.78	10	6.98	14	13.33	6	24.42	7	7.82	12
AuNPs	18.63	5	1.52	7	15.64	2	15.86	5	15.58	7	14.03	5	20.56	6	132.35	3	27.95	4
ABTS	3.03	12	1.12	14	11.26	7	0.70	14	2.13	9	2.21	12	11.55	8	54.57	5	8.92	7
FC	5.98	4	2.51	11	14.54	3	3.70	10	5.51	4	5.42	5	21.10	7	30.54	8	16.79	6

Metal nanoparticles formation

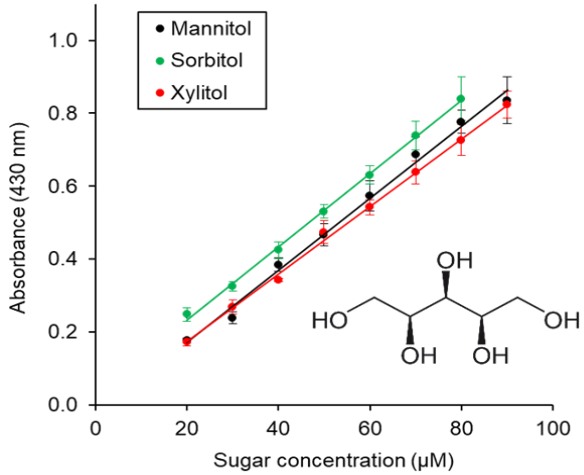
Sugars content evaluation trough AgNPs formation



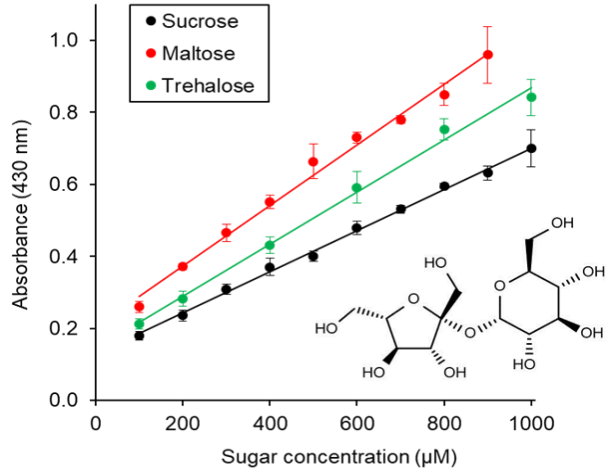
Monosaccharides



Polyols



Diosaccharides



Metal nanoparticles formation

Determination of total sugars in real samples: AgNPs method vs. ion chromatography

Sample analysis

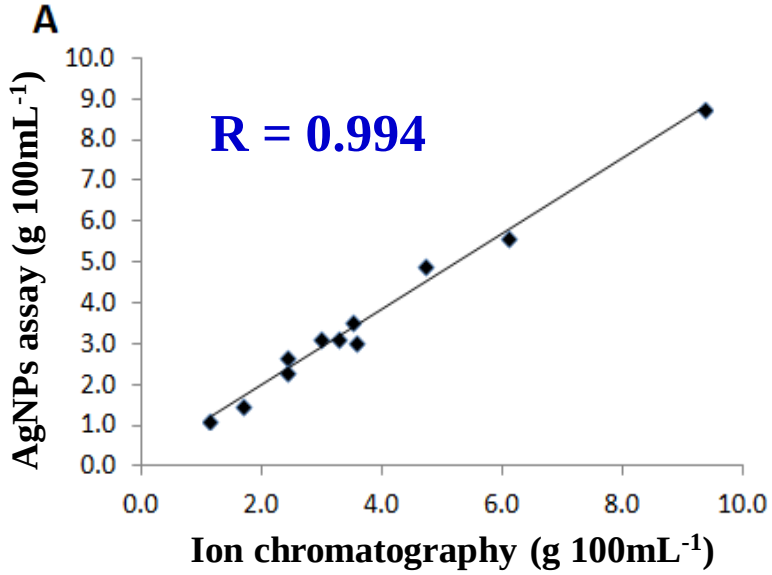
Samples challenged

- Soft drinks n° 6
- Apple extracts n° 6

Sample	AgNPs assay (g 100 mL^{-1}, Glu. Eq.)	RSD (%, n = 5)	Ion chromatography (g 100 mL^{-1}, Glu + Fru)	RSD (%, n = 3)	AgNPs assay relative 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

* mean value n= 3

Rel. error between -14.9 and + 9.9 %



Recovery between 86 % and 118 %

Metal nanoparticles formation

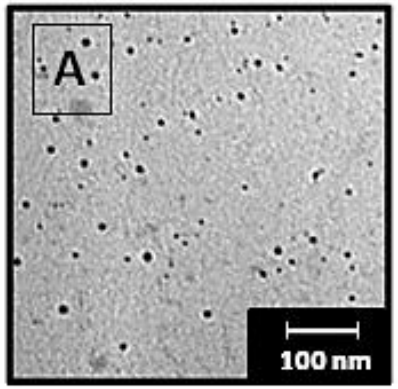
AgNPs Morphological study

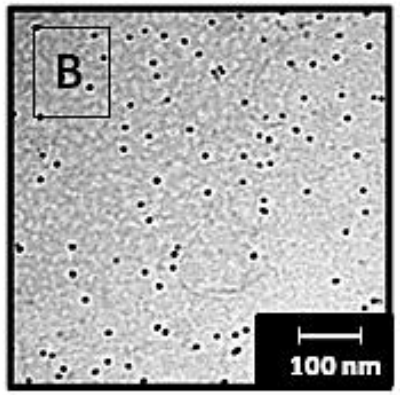
Glucose

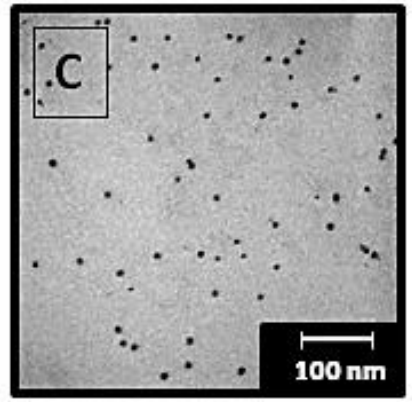
Sucrose

Xylitol

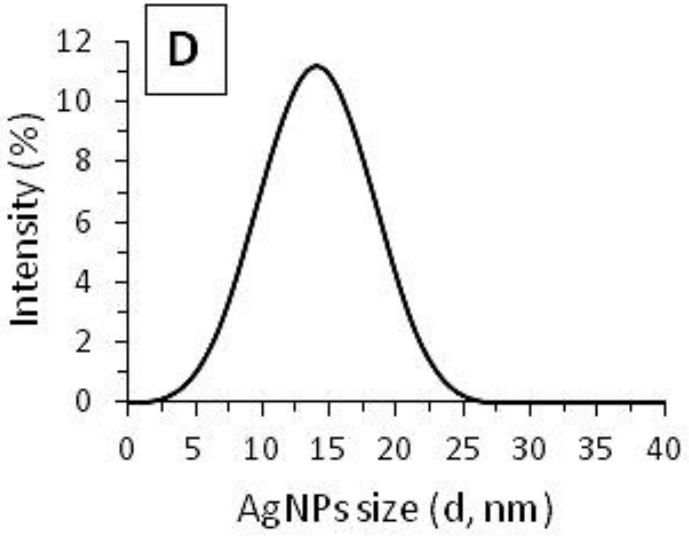
TEM

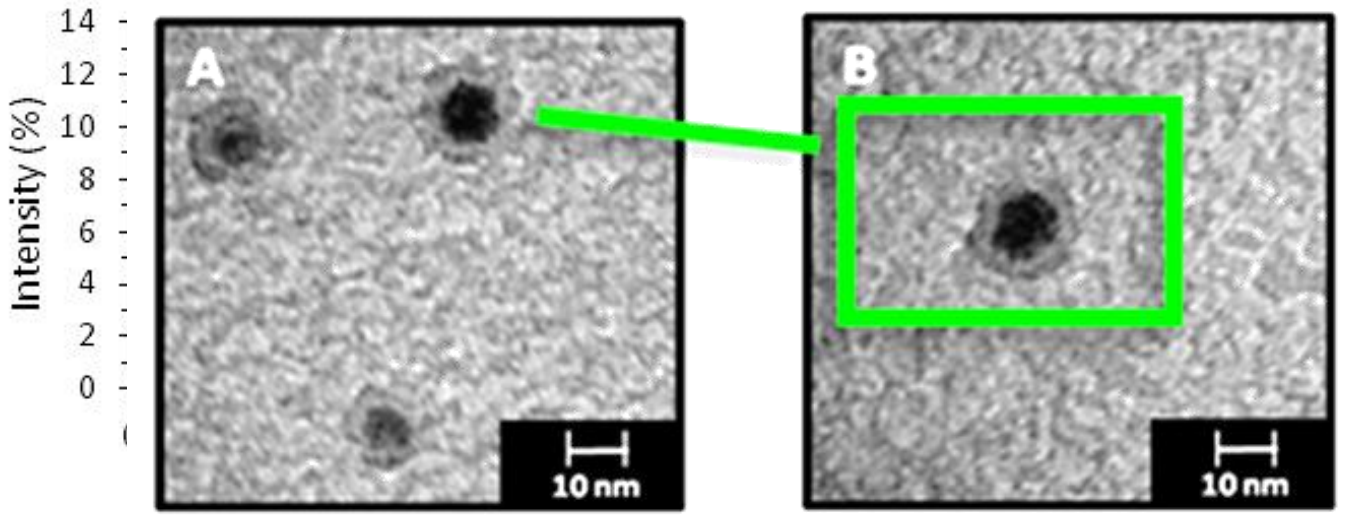


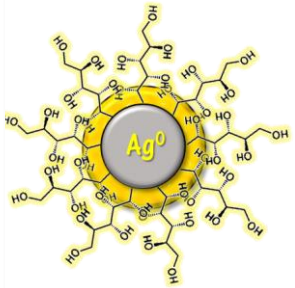




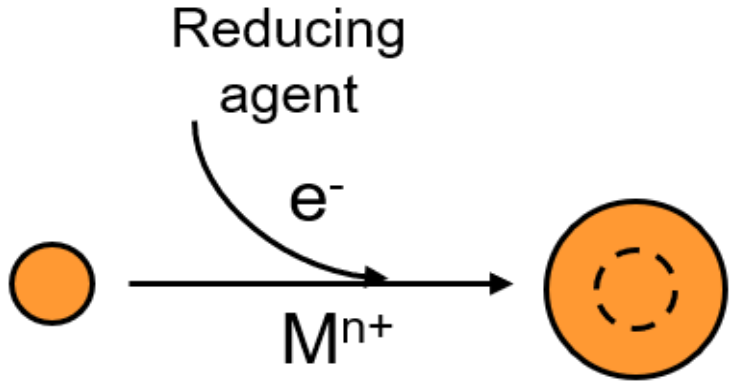
DLS

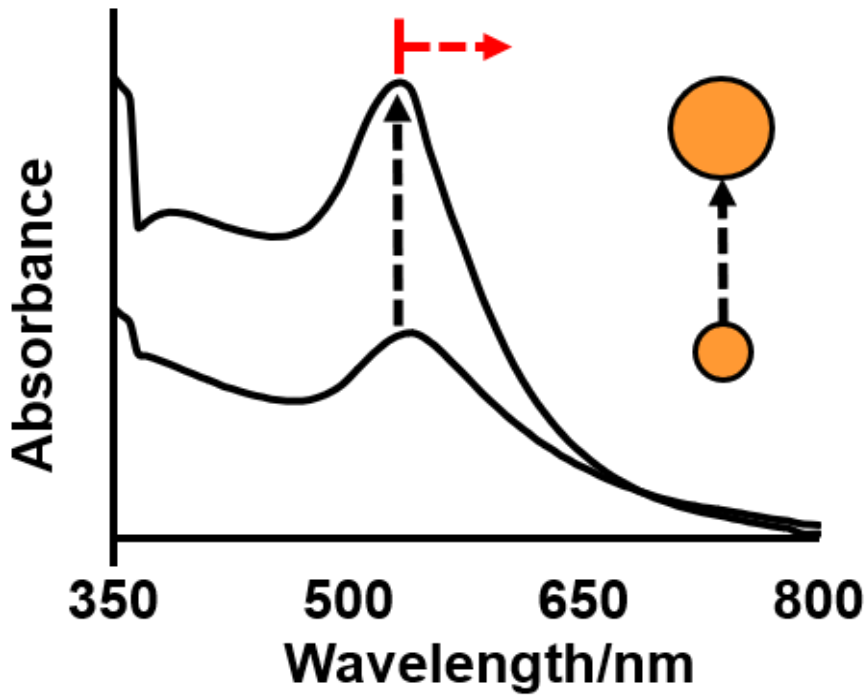






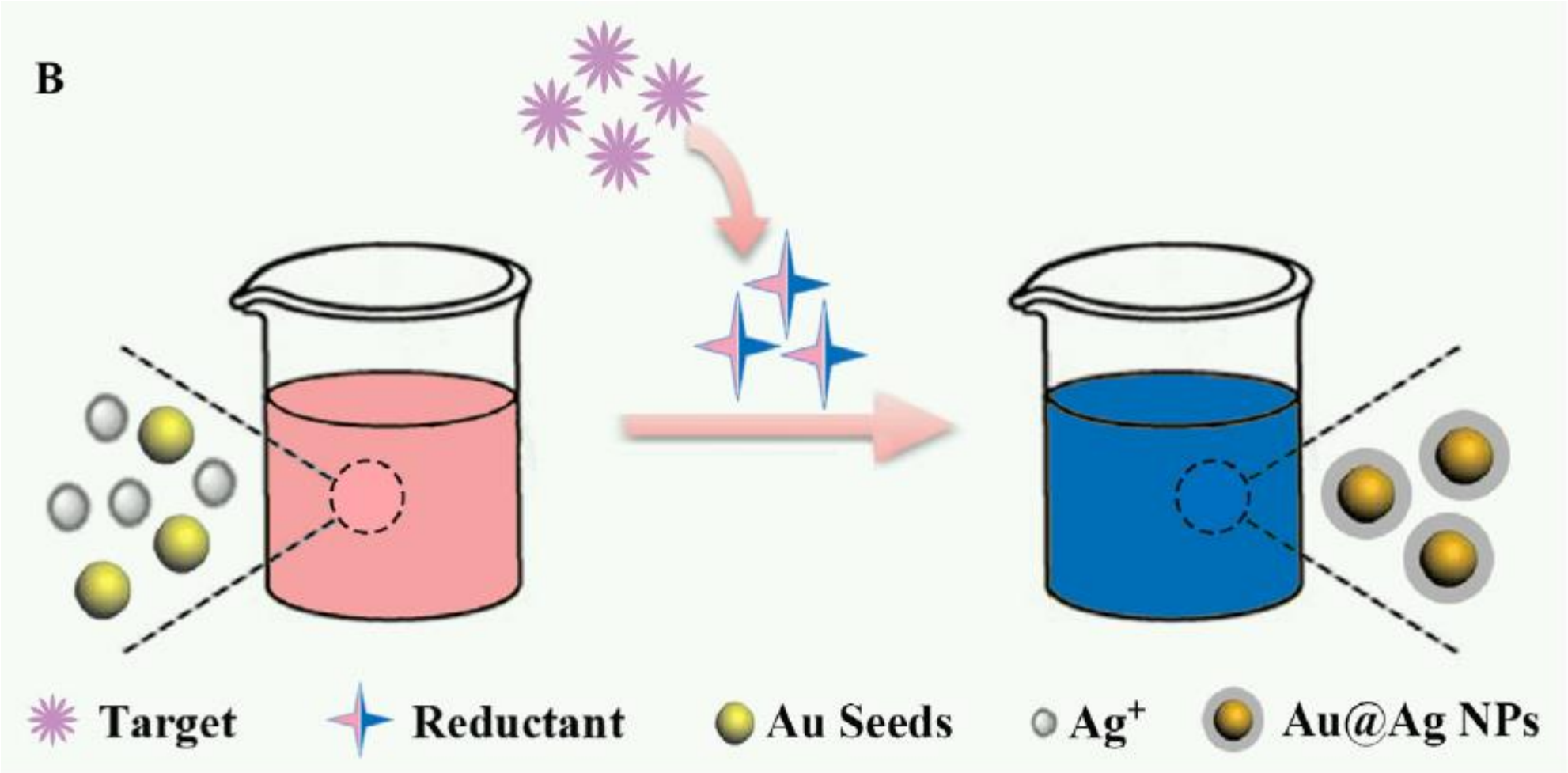
Metal nanoparticle-based seed-growth strategies





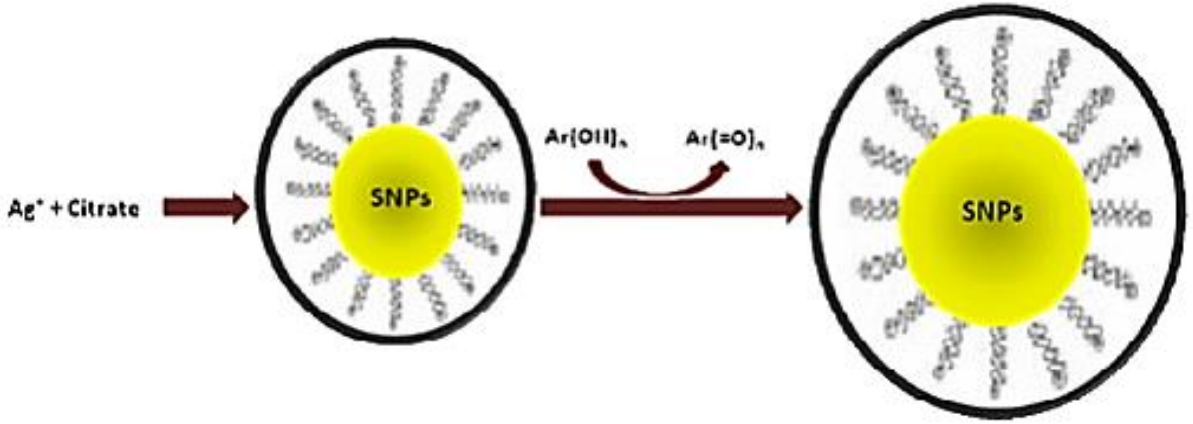
Metal nanoparticles growth

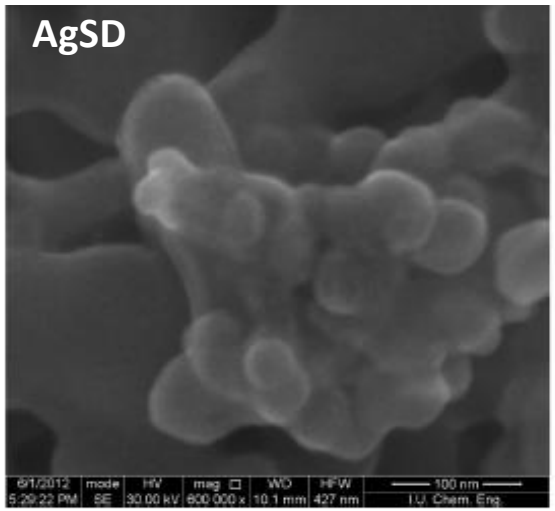
Main strategy

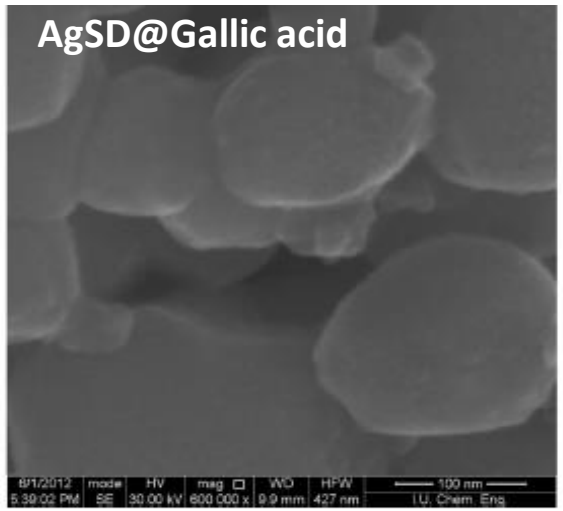


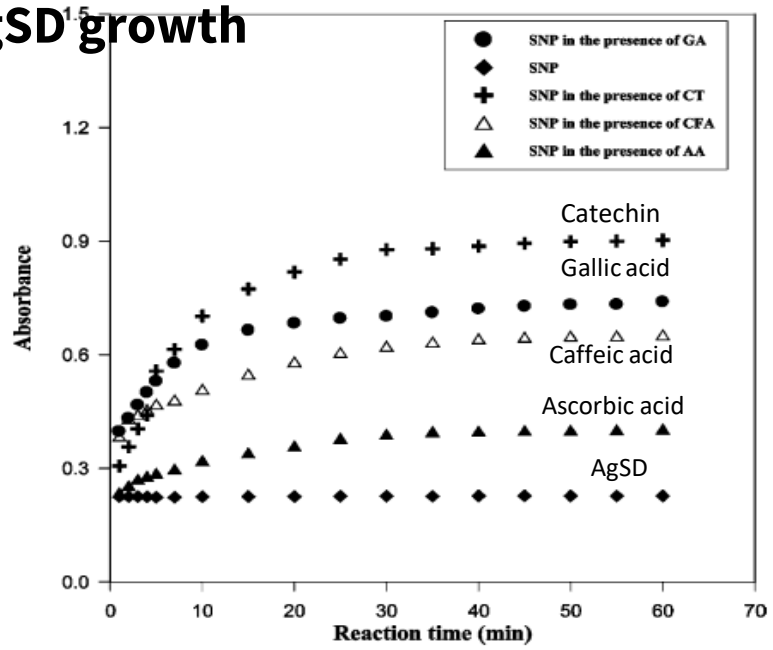
Metal nanoparticles growth

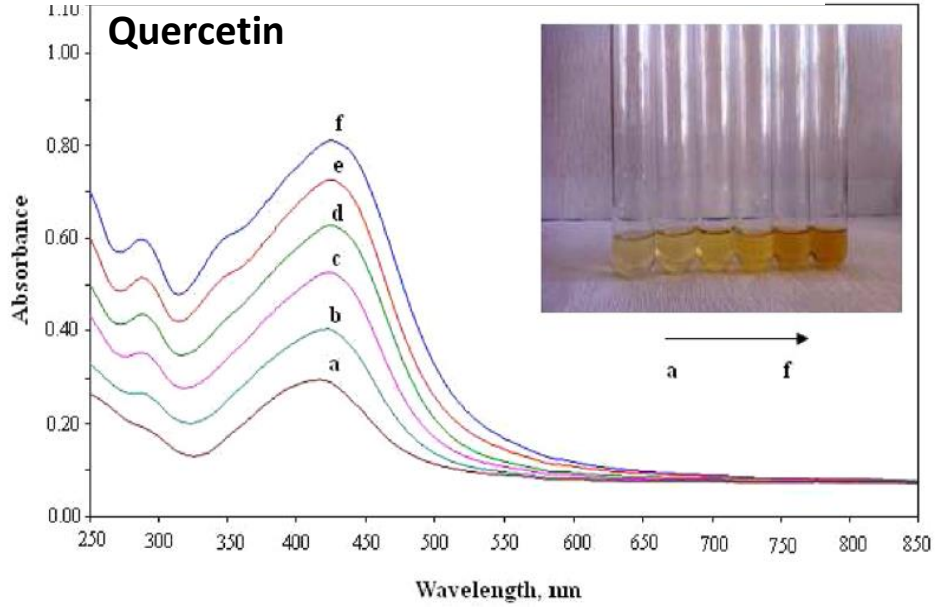
Phenolic content and antioxidant capacity evaluation trough AgSD growth











analytical chemistry
Article
pubs.acs.org/ac

Development of a Silver Nanoparticle-Based Method for the Antioxidant Capacity Measurement of Polyphenols

Mustafa Özyürek, Nilay Güngör, Sefa Baki, Kubilay Güçlü, and Reşat Apak*

Metal nanoparticles growth

Phenolic content and antioxidant capacity evaluation via AgSD growth
Standards evaluation ad sample analysis

Table 1. Linear Equations, Correlation Coefficients (r), TEAC Coefficients,[a] and Linear Ranges for Antioxidants, with Respect to the Proposed SNPAC Method

antioxidants	linear equation and correlation coefficients	linear range (μM)	$TEAC_{SNPAC}$	$TEAC_{CUPRAC}$[b]
	Simple Phenolic Acids			
gallic acid	$A = 2.27 \times 10^{-4}c + 0.01$ ($r = 0.9991$)	1.67–52.30	2.91	2.62
	Hydroxycinnamic Acids			
rosmarinic acid	$A = 3.90 \times 10^{-4}c + 0.01$ ($r = 0.9977$)	1.02–30.51	5.02	5.30
caffeic acid	$A = 1.93 \times 10^{-4}c + 0.02$ ($r = 0.9990$)	1.55–61.14	2.47	2.80
chlorogenic acid	$A = 2.37 \times 10^{-4}c + 0.02$ ($r = 0.9981$)	1.26–49.79	3.04	2.47
	Flavonols			
quercetin	$A = 2.99 \times 10^{-4}c + 0.01$ ($r = 0.9995$)	1.33–39.80	3.83	4.38
fisetin	$A = 2.82 \times 10^{-4}c - 0.019$ ($r = 0.9978$)	2.44–43.20	3.62	3.90
	Flavan-3-ols			
ECG	$A = 4.16 \times 10^{-4}c + 0.02$ ($r = 0.9993$)	0.72–28.36	5.33	5.30
EGCG	$A = 3.31 \times 10^{-4}c + 0.02$ ($r = 0.9994$)	0.91–35.65	4.24	4.88
EC	$A = 2.70 \times 10^{-4}c + 0.03$ ($r = 0.9988$)	0.74–43.33	3.46	2.77
catechin	$A = 2.82 \times 10^{-4}c + 0.04$ ($r = 0.9941$)	0.35–41.13	3.61	3.09
EGC	$A = 2.84 \times 10^{-4}c - 0.01$ ($r = 0.9994$)	2.11–42.60	3.64	3.34
	Flavons			
luteolin	$A = 2.08 \times 10^{-4}c + 0.03$ ($r = 0.9952$)	0.96–56.25	2.66	2.38
rutin	$A = 2.84 \times 10^{-4}c + 0.03$ ($r = 0.9974$)	0.70–41.20	3.64	2.56
apigenin	$A = 1.92 \times 10^{-4}c + 0.01$ ($r = 0.9973$)	2.19–62.10	2.47	0.12
	Others			
ascorbic acid	$A = 1.13 \times 10^{-4}c + 0.04$ ($r = 0.9995$)	0.88–103.00	1.44	0.96
α-tocopherol	$A = 1.04 \times 10^{-4}c + 0.04$ ($r = 0.9963$)	0.96–111.00	1.33	1.10

[a]TEAC coefficients (significantly different) (by exclusion of the values for apigenin with highest TEAC variability; $P = 0.05$, $F_{exp} = 1.487$, $F_{crit\ (table)} = 4.600$, $F_{exp} < F_{crit\ (table)}$). [b]Data taken from refs 2 and 20. $TEAC_{CUPRAC} = 1.16\ TEAC_{SNPAC} - 0.782$ ($r = 0.936$).

Recovery study

Table 2. Precision and Recovery of the Proposed SNPAC Method

added conc (μM)	mean (μM)	stand dev, SD	rel stand dev, RSD (%)	REC (%)[a]
	RT Addition to Green Tea			
5.43	5.15 ± 0.09	0.04	0.78	94.8
10.86	10.42 ± 0.17	0.07	0.67	96.0
21.72	21.16 ± 0.20	0.08	0.38	97.4
	CT Addition to Green Tea			
3.66	3.48 ± 0.22	0.09	2.61	95.1
7.32	7.52 ± 0.19	0.08	1.06	102.7
14.64	14.82 ± 0.20	0.08	0.54	101.2
	GA Addition to Green Tea			
4.65	4.67 ± 0.22	0.09	1.93	100.2
9.30	9.14 ± 0.10	0.04	0.44	98.3
18.6	18.18 ± 0.17	0.07	0.36	97.7
	CT Addition to Olive Oil			
3.66	3.38 ± 0.16	0.06	1.87	92.3
7.32	6.91 ± 0.12	0.05	0.72	94.4
14.64	14.07 ± 0.10	0.04	0.28	96.1

[a]Recovery ($N = 3$).

Methods reliability

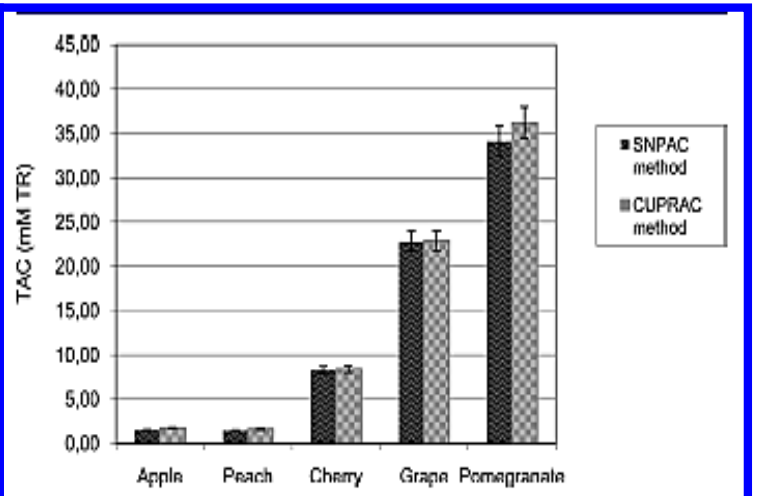
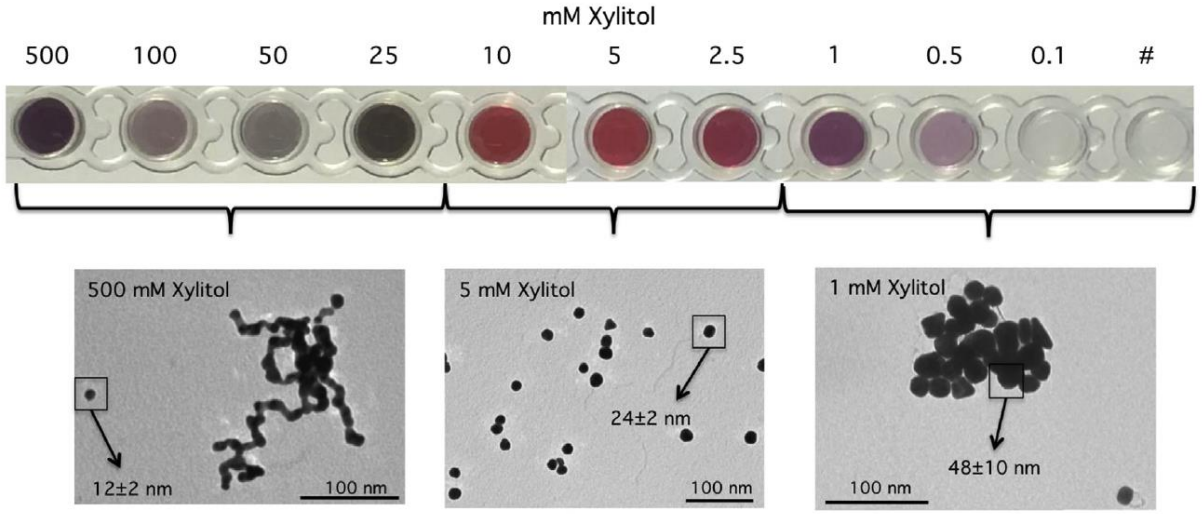


Figure 5. Comparative TAC values (mM TR equiv) of some commercial fruit juices measured by the SNPAC and CUPRAC assays. Data are presented as (mean ± SD) (error bars), $N = 3$. ($P = 0.05$, $F_{exp} = 0.775$, $F_{crit\ (table)} = 7.709$, $F_{exp} < F_{crit\ (table)}$.)

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

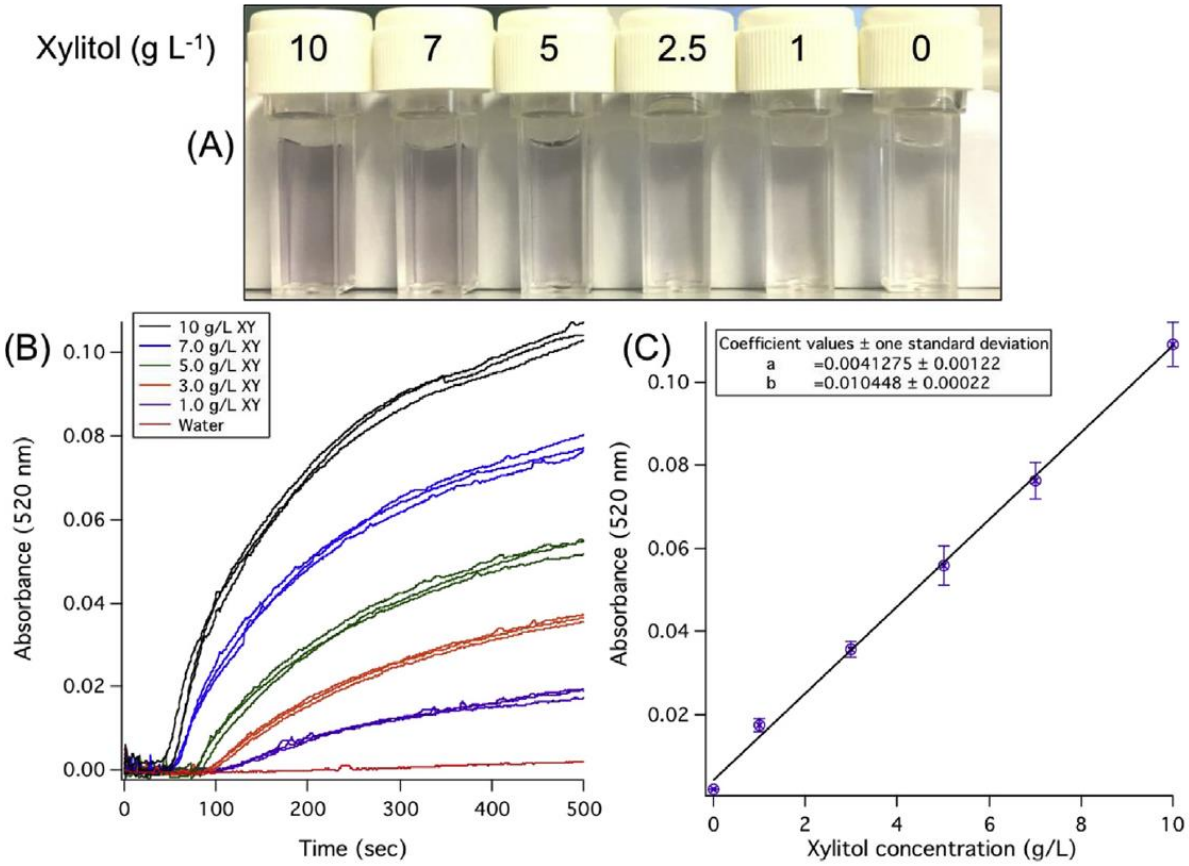
Analytica Chimica Acta

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

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

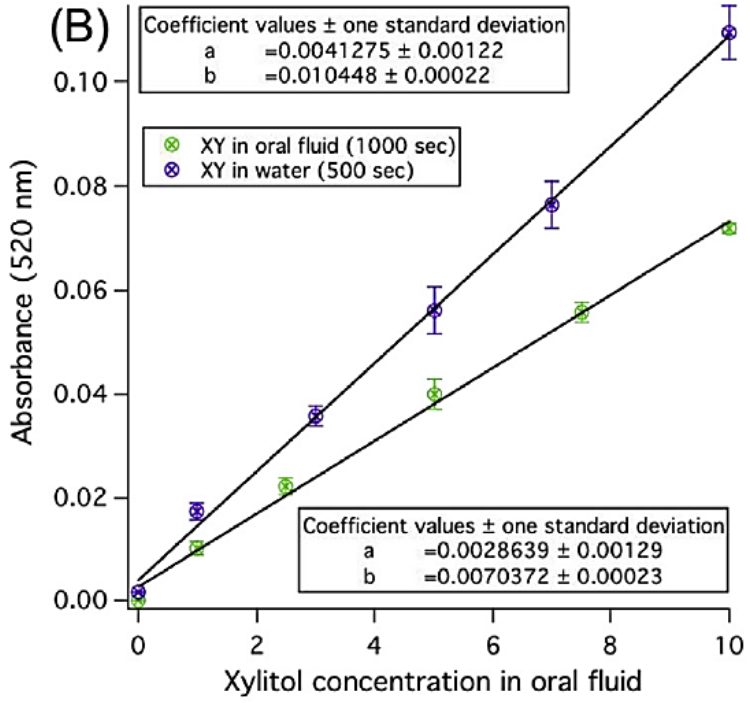


Metal nanoparticles growth

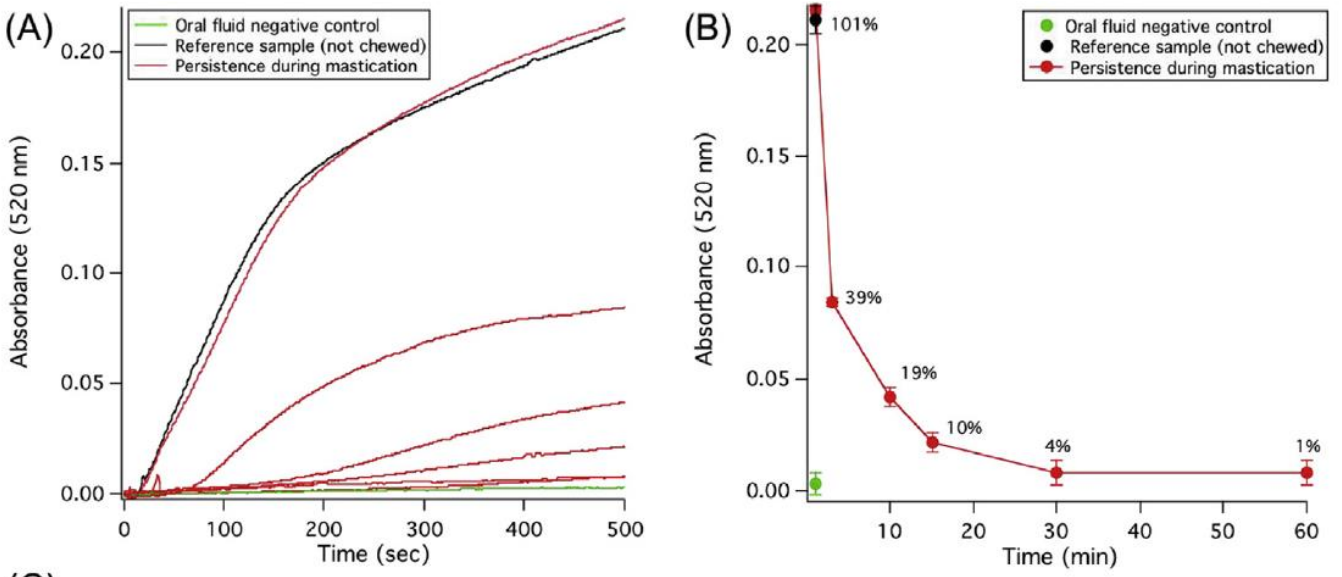
Xylitol monitoring in human saliva trough AuNPs growth

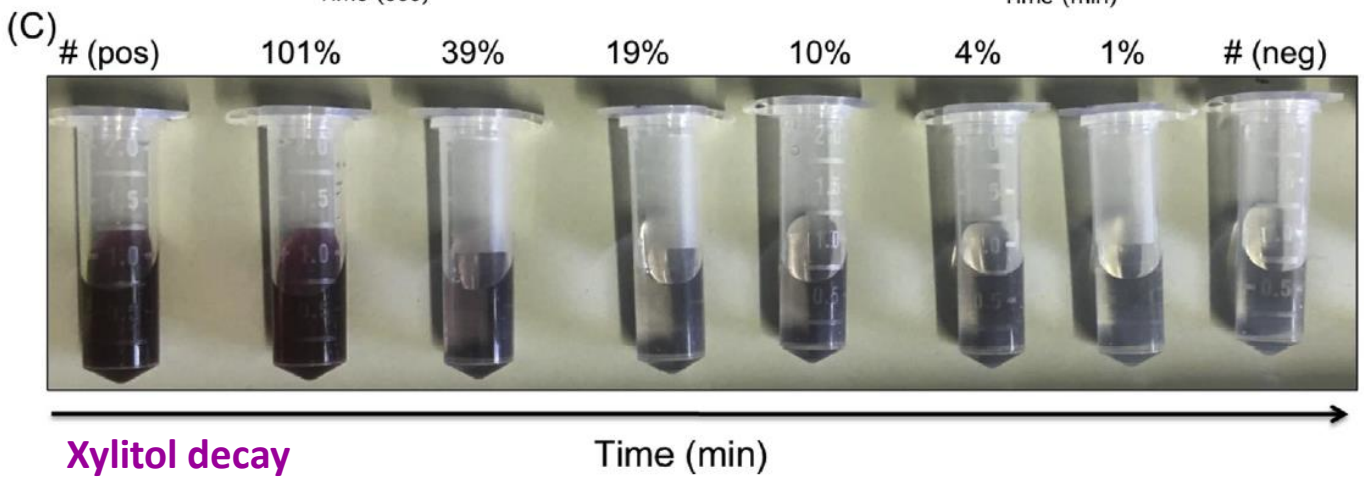
Recovery study

Methods evaluation for sample analysis

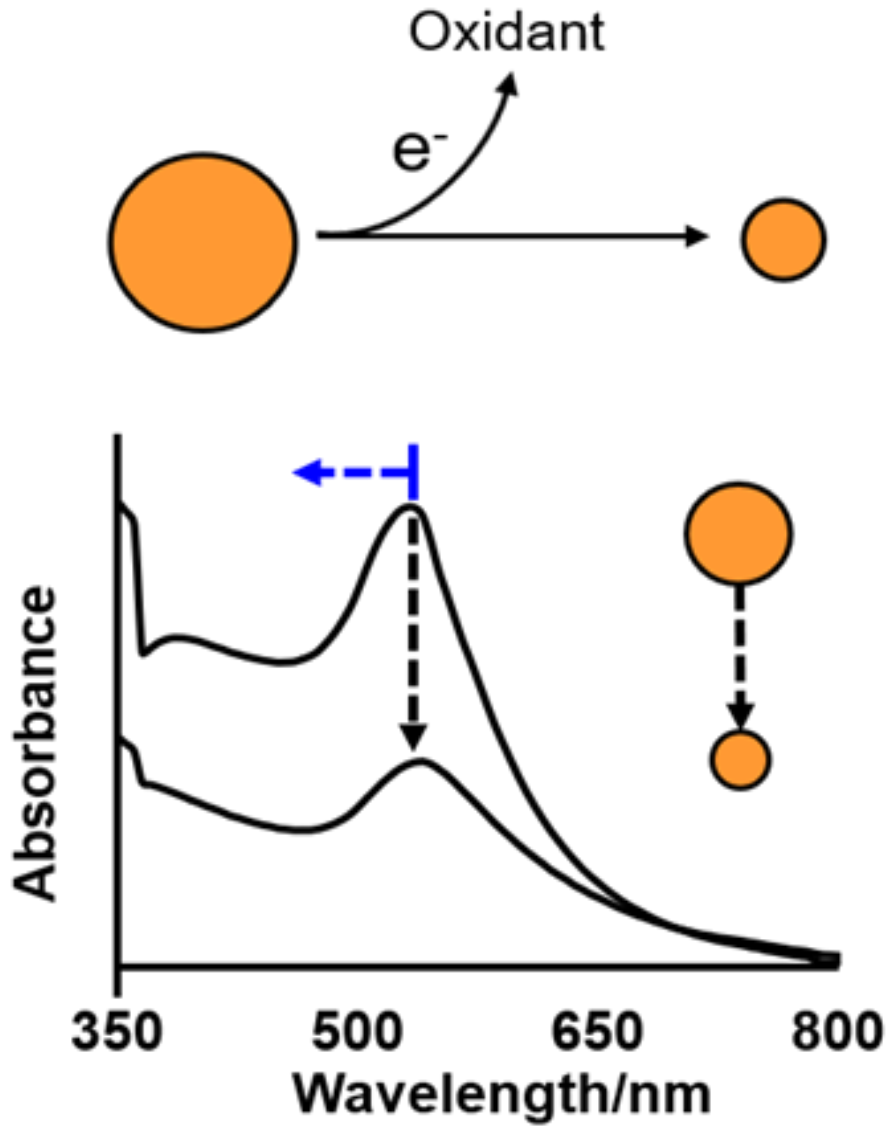


Xylitol monitoring 1 h of chewing-gum



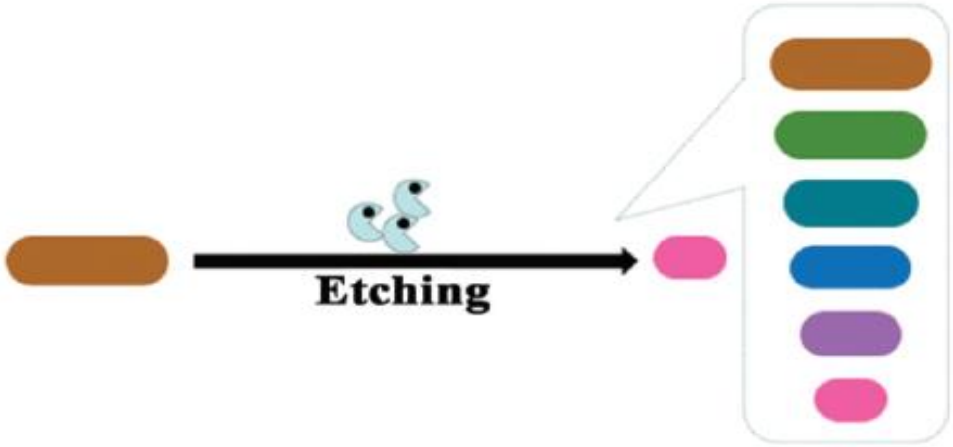


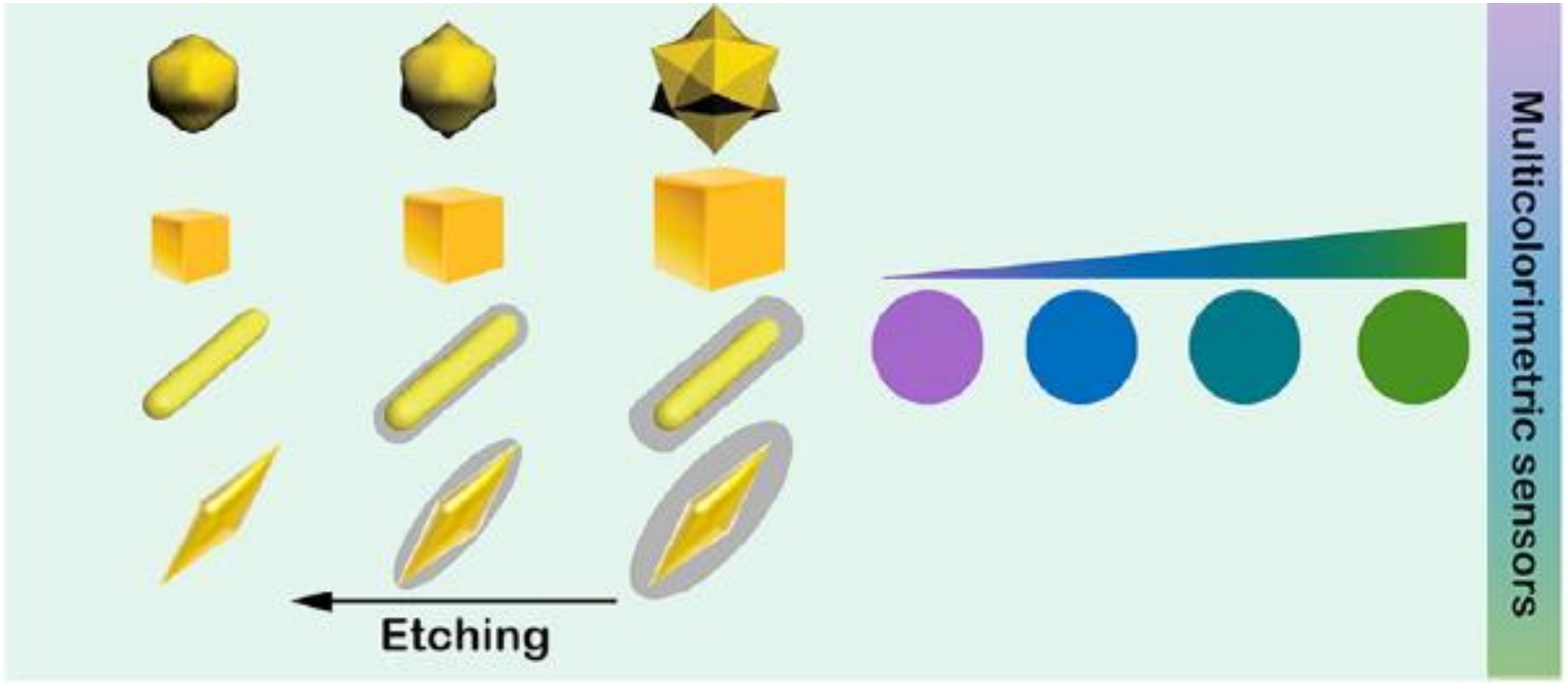
Metal nanoparticle etching



Metal nanoparticles etching

Main strategy

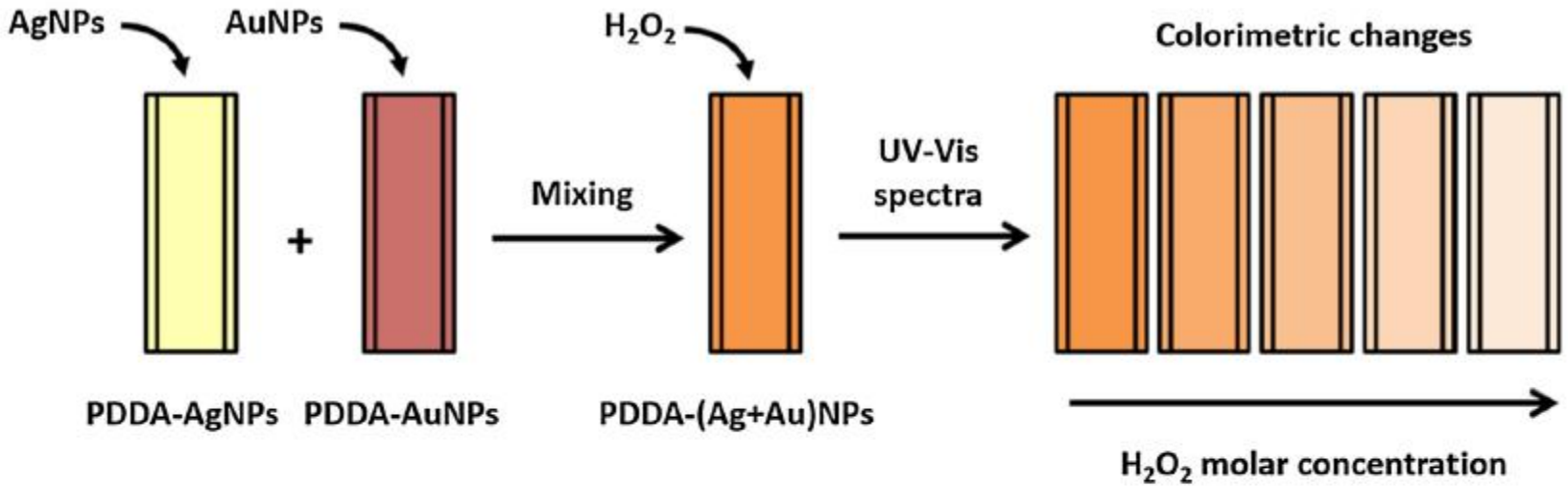


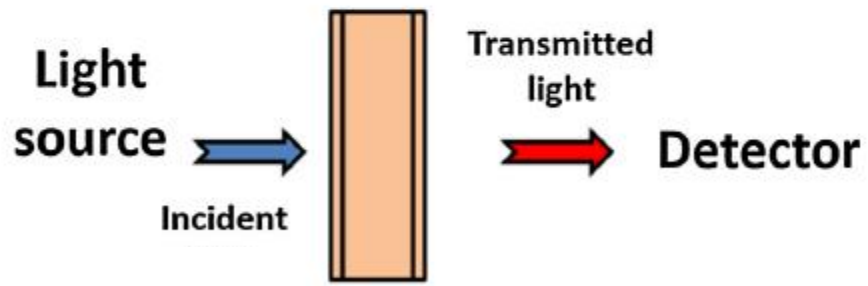


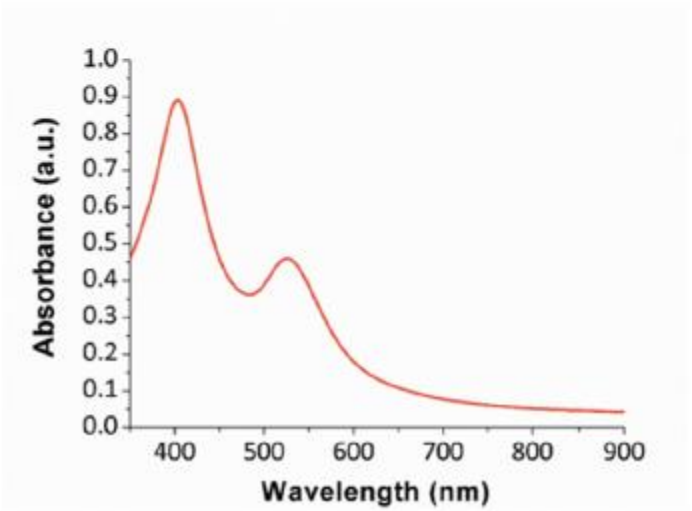
Metal nanoparticles etching

H_2O_2 determination trough MNPs etching

PDDA- Poly(diallyldimethylammoniumchloride)







Sensors and Actuators B 251 (2017) 624–631

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

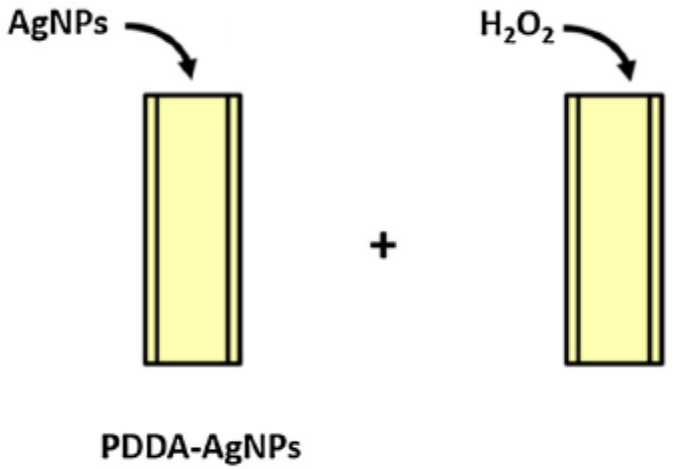
journal homepage: www.elsevier.com/locate/snb

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

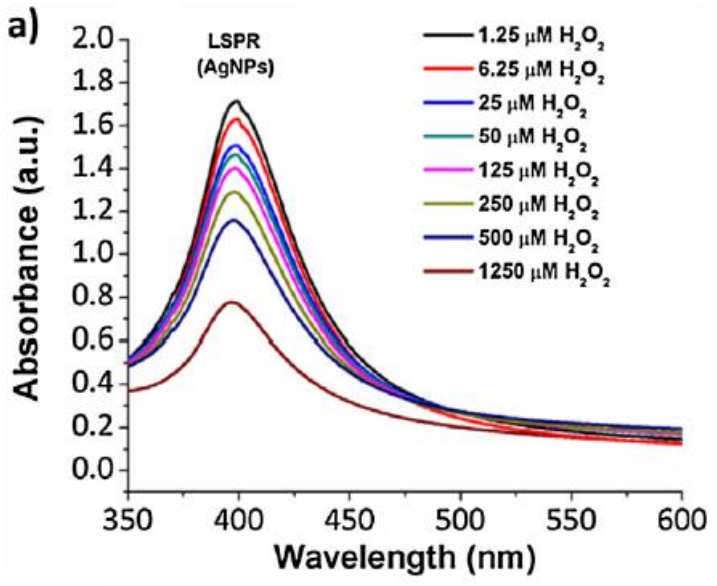
Pedro J. Rivero[a,*], Elia Ibañez[b], Javier Goicoechea[b], Aitor Urrutia[b], Ignacio R. Matias[c], Francisco J. Arregui[b]

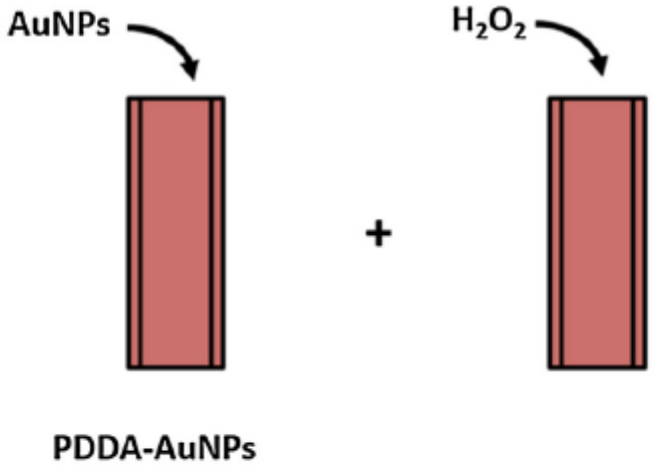
Metal nanoparticles etching

Etching phenomena study

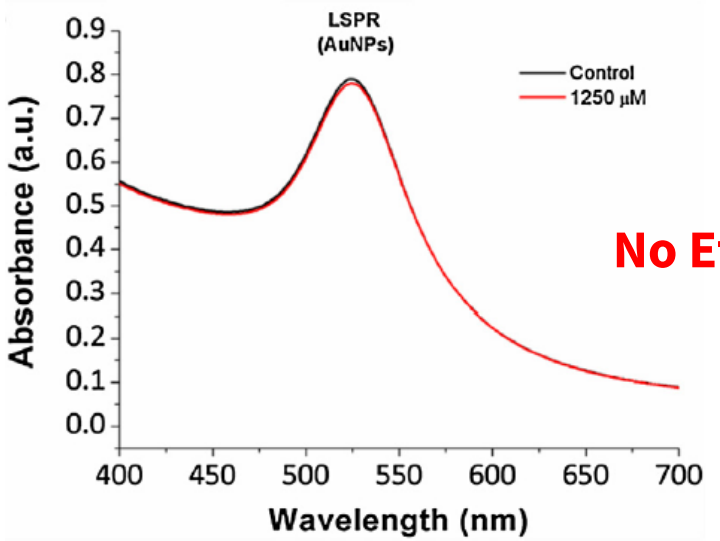


UV-Vis spectra →





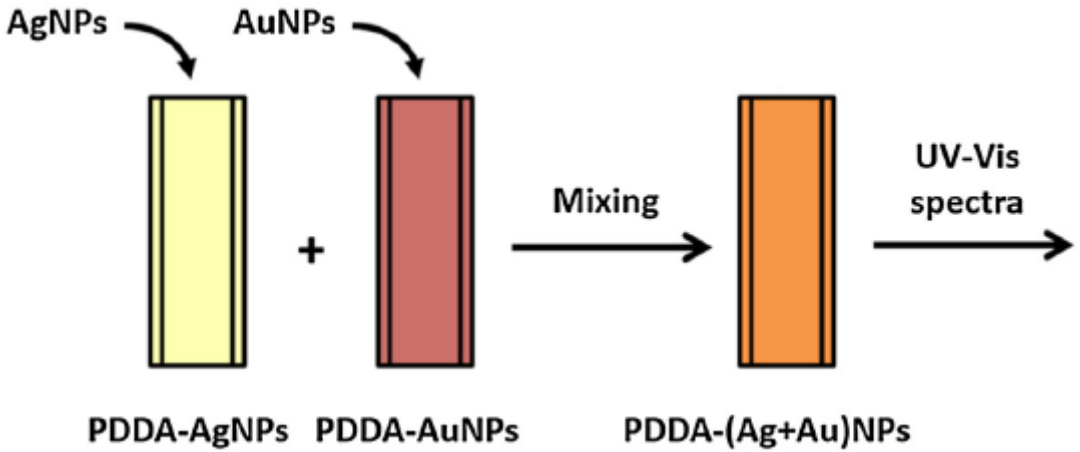
UV-Vis spectra →

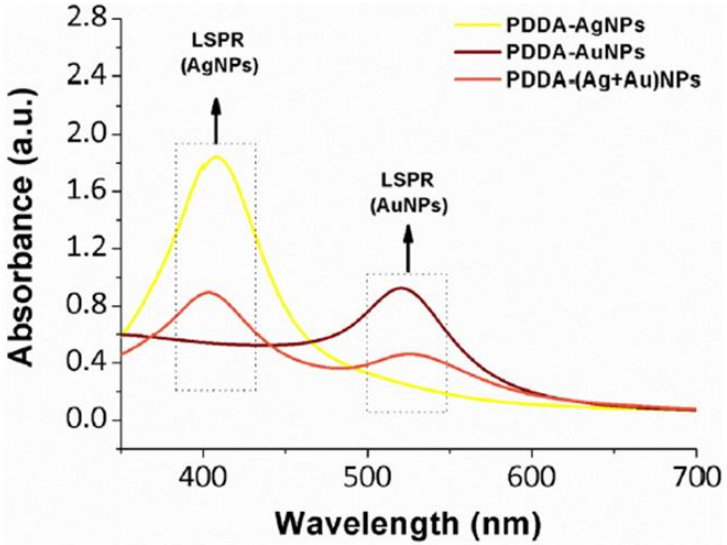


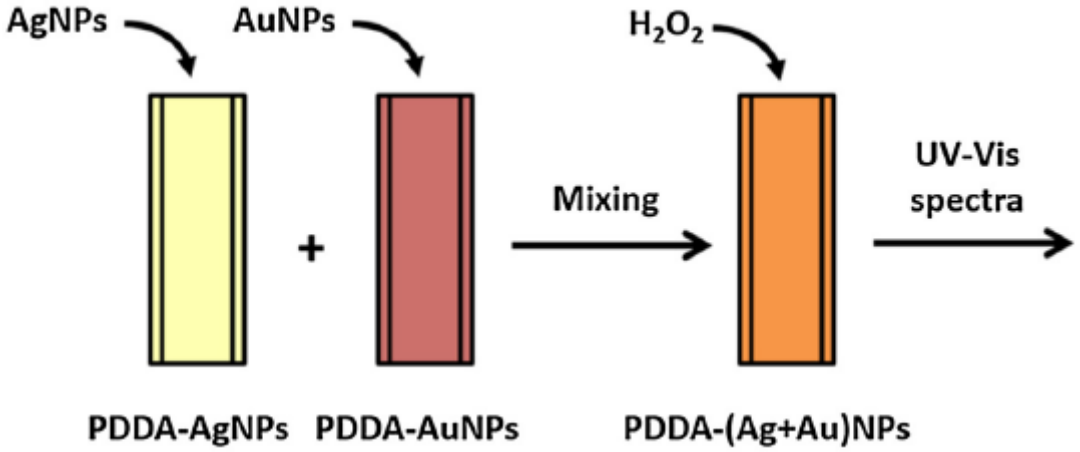
No Etching phenomena

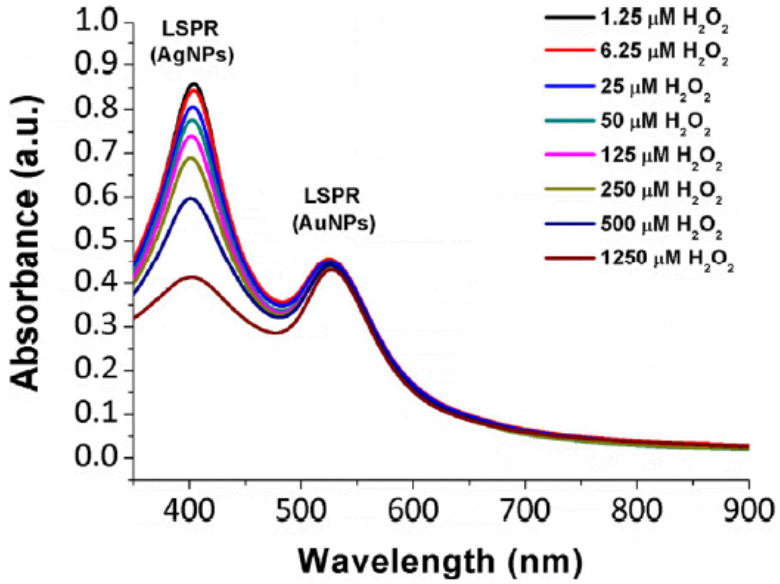
Metal nanoparticles etching

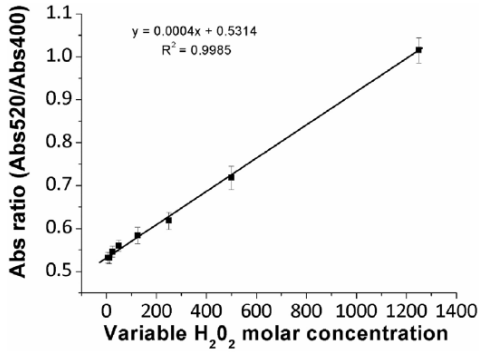
Etching phenomena study. H_2O_2 determination

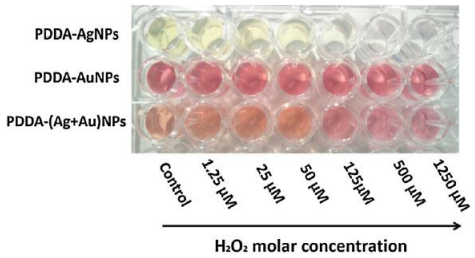










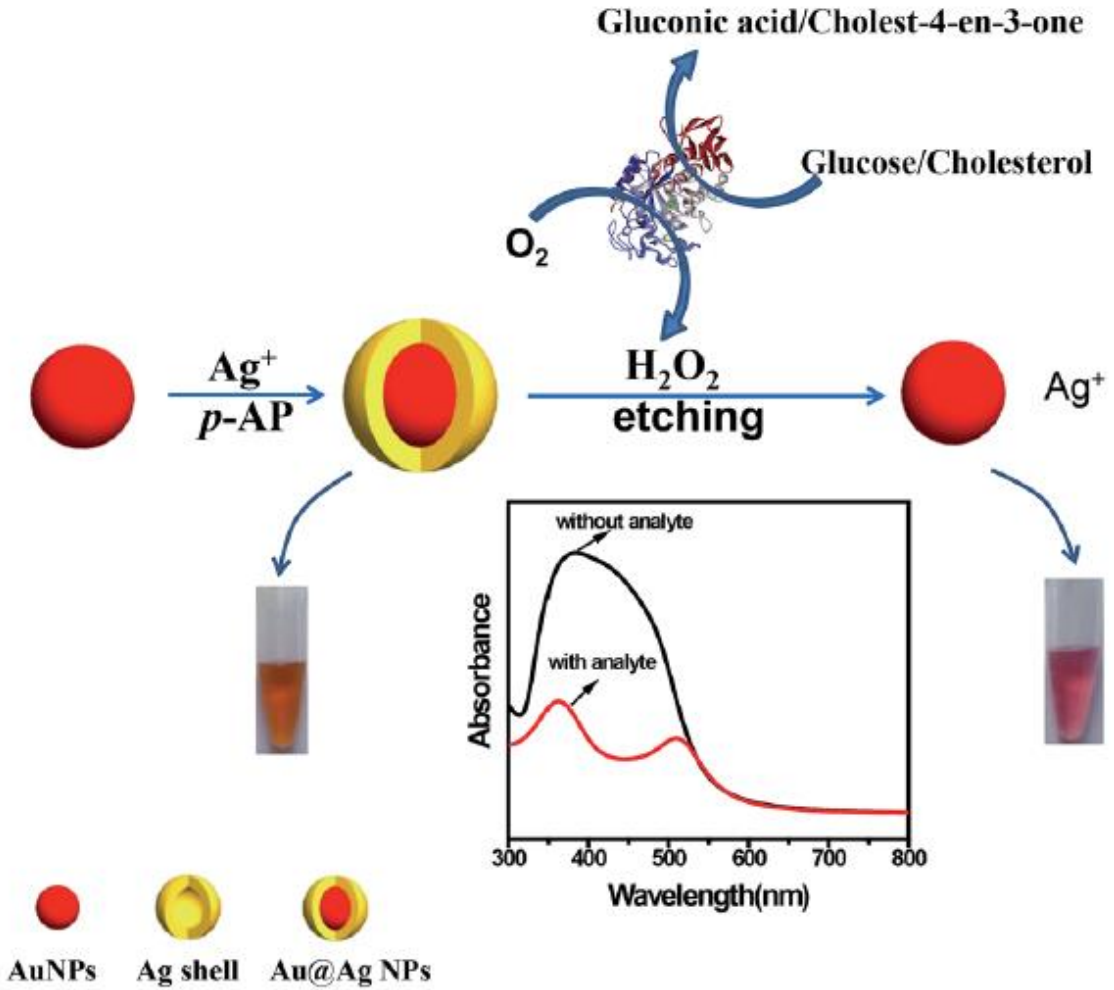


Metal nanoparticles etching

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

PAPER View Article Online View Journal | View Issue

Cite this: RSC Adv., 2016, 6, 35001

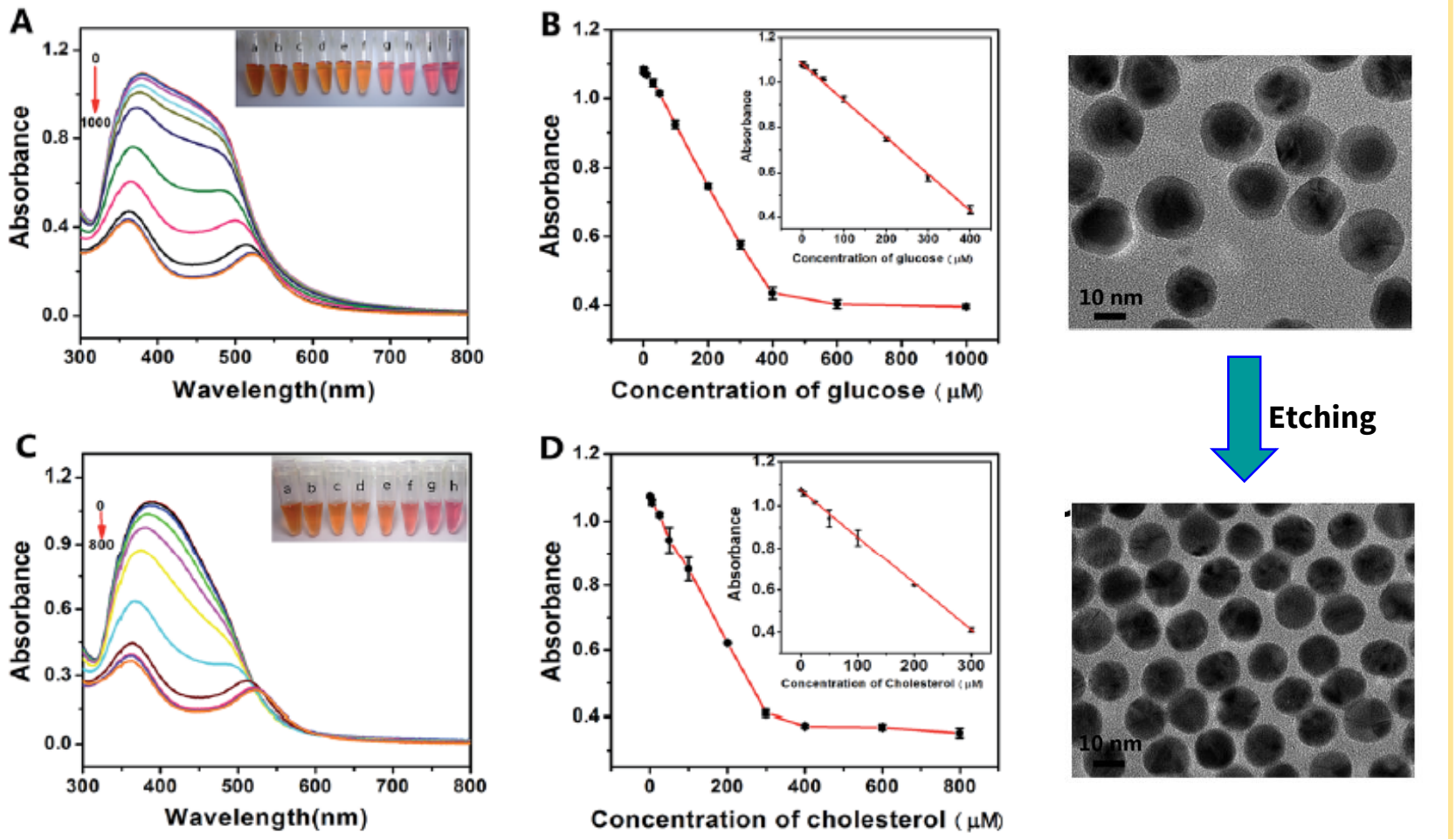
Sensitive colorimetric detection of glucose and cholesterol by using Au@Ag core–shell nanoparticles†

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

Metal nanoparticles etching

Glucose and cholesterol detrmination trough MNPs etching

Dose-response curve



Recovery study

Table 1 Recovery measurements of glucose in human urine samples and free cholesterol in human serum samples

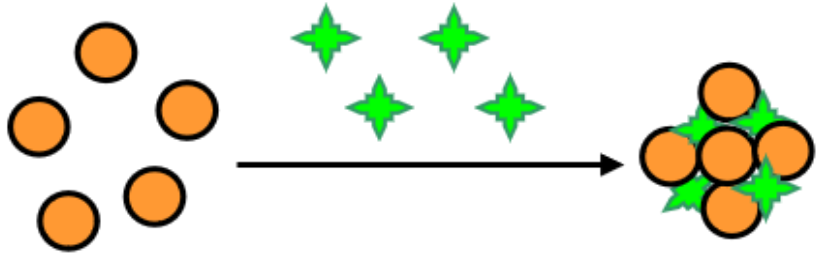
Analytes	Spiked (mM)	Found (mM)	Recovery (%)	RSD (%) ($n = 3$)
Glucose	0	0.580	—	0.84
	1	1.552	97.2	0.51
	5	5.530	99.0	1.02
	10	11.041	104.6	2.66
	30	31.037	101.5	3.83
Cholesterol	0	1.544	—	0.90
	1	2.610	106.6	0.43
	5	6.320	95.6	2.69
	10	11.715	101.7	1.88
	30	31.283	99.1	5.88

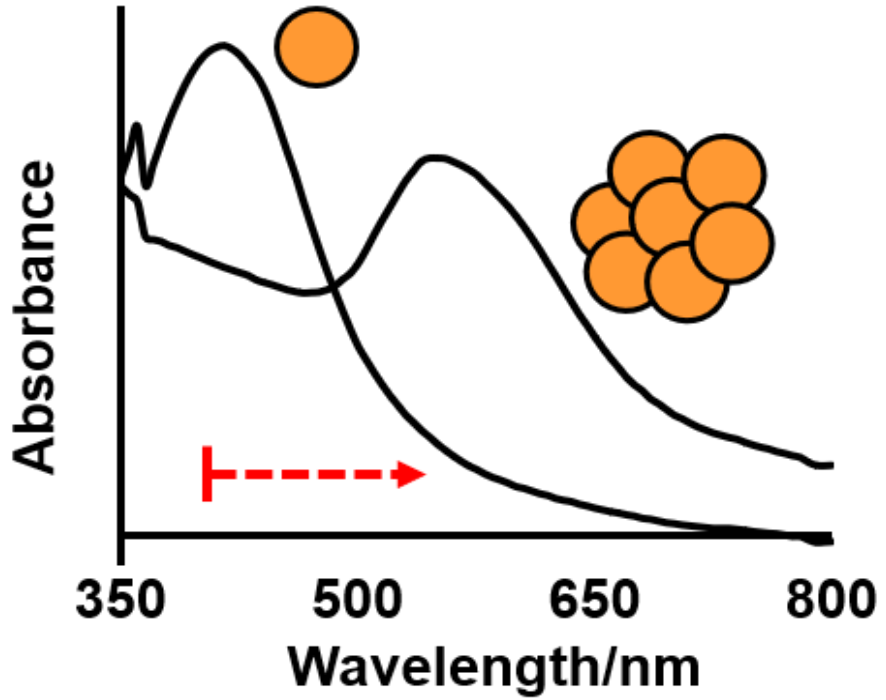
Sample analysis

Table 2 Determination of glucose concentration in human serum samples

Sample	This work (mM)	RSD (%) ($n = 3$)	Glucometer (mM)	RSD (%) ($n = 3$)
1	4.83	2.69	4.70	4.26
2	7.30	4.46	7.53	3.34
3	8.79	4.82	8.97	1.70
4	10.36	3.09	10.23	2.46

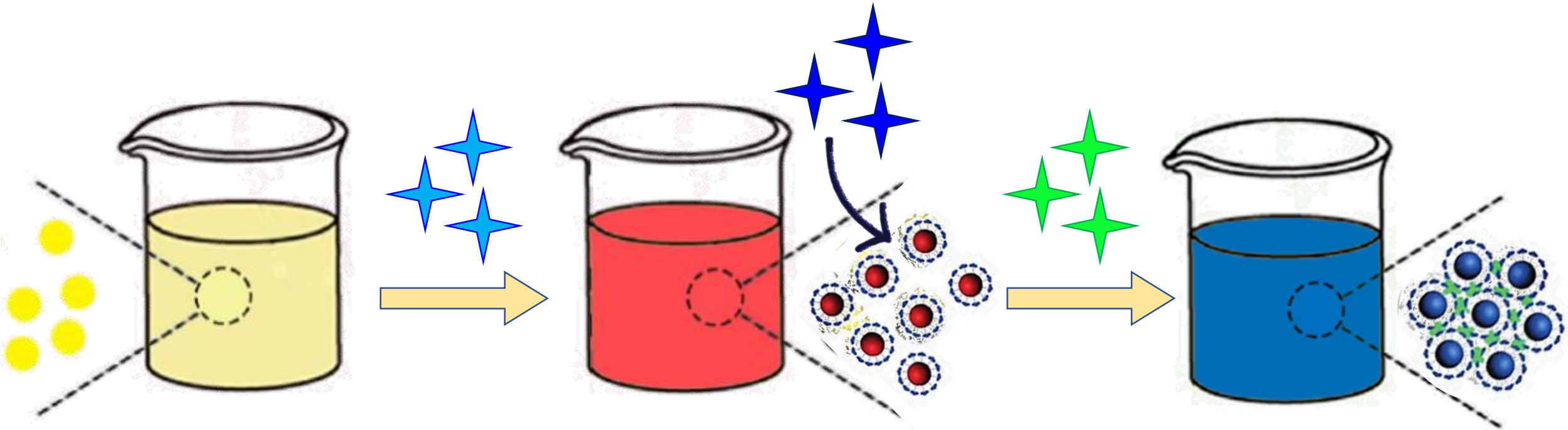
Metal nanoparticle aggregation





Metal nanoparticles aggregation

Main strategy



Metal salts

MNPs

Analytes

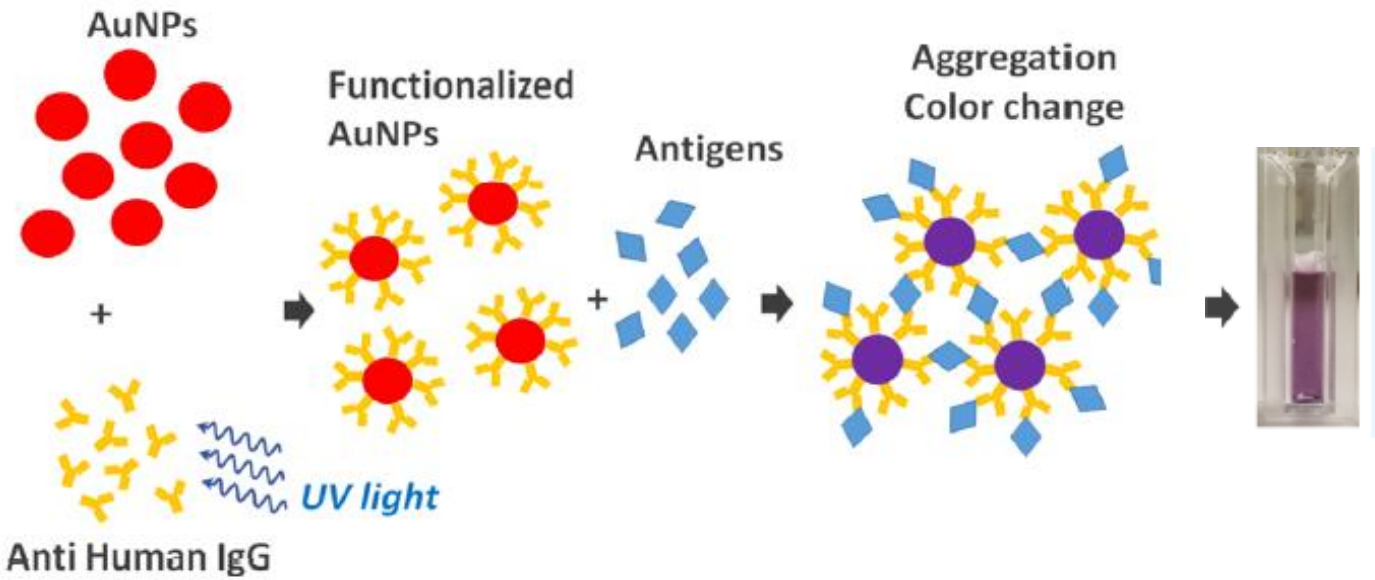
Reductant

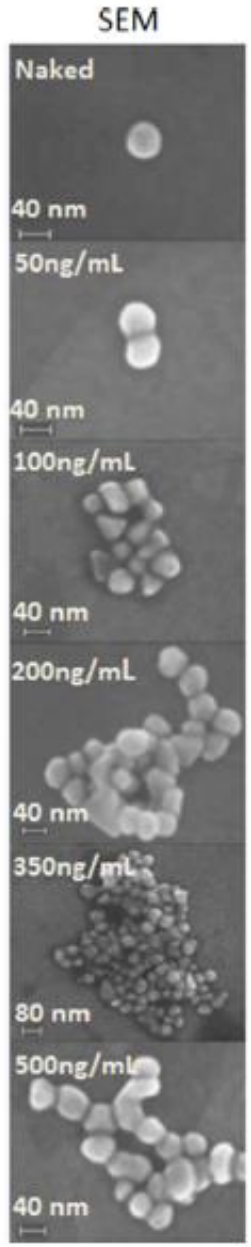
Functionalization

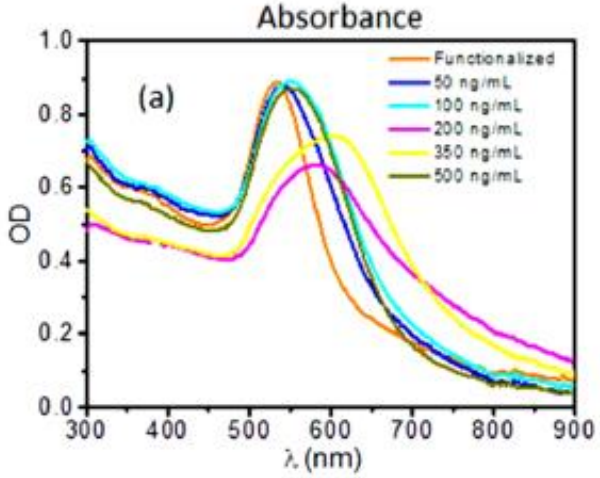
Aggregated MNPs

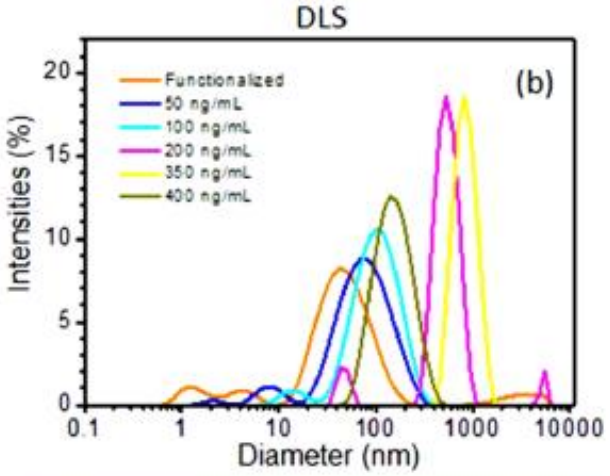
Metal nanoparticles aggregation

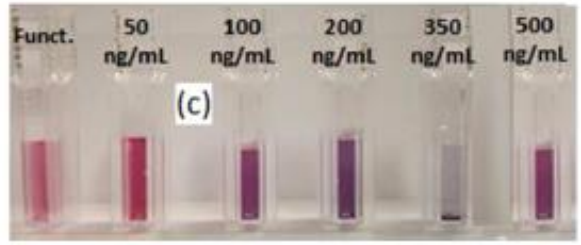
Immuno-based determination of HIgG









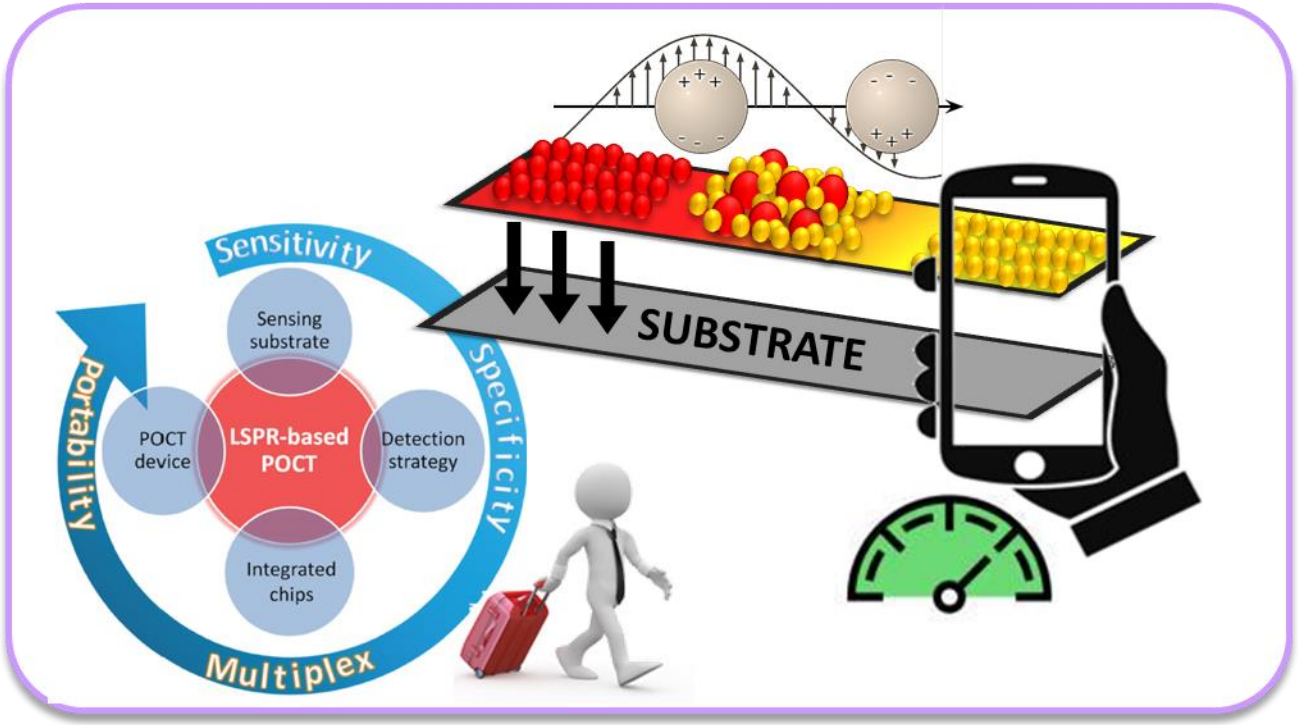


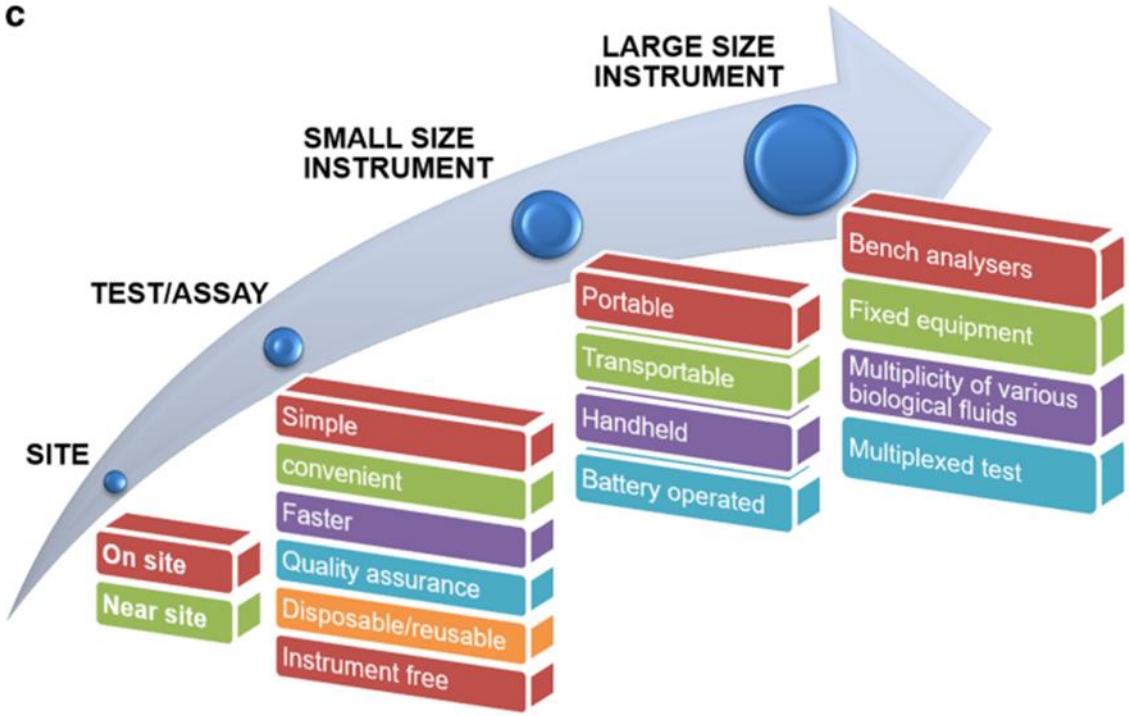
ACS OMEGA
Article
Cite This: ACS Omega 2018, 3, 3805−3812

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 integration onto solid substrates

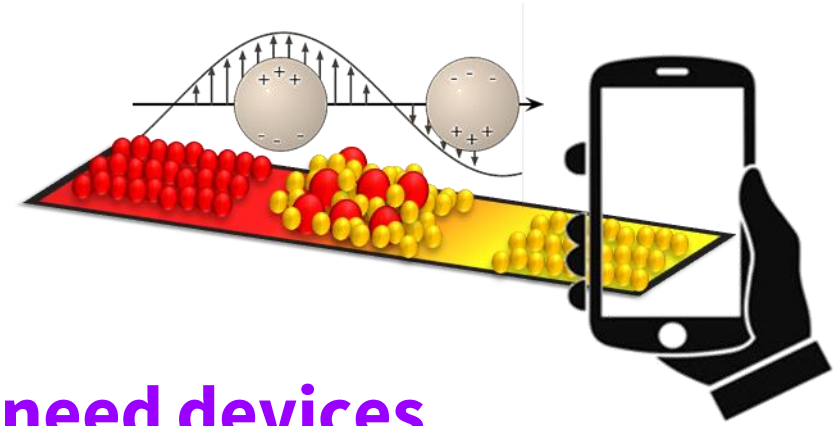




!!! Lab-on-a-strip Device !!!

Metal nanoparticles integration onto solid substrates

Main POC and PON requirements



Point of care/need devices

- **A** ffordable
- **S** ensitive
- **S** pecific
- **U** ser friendly
- **2 x R** apid & **r**obust
- **E** quipment-free
- **D** elivered

Cost performance

Manufacturing

Mass production

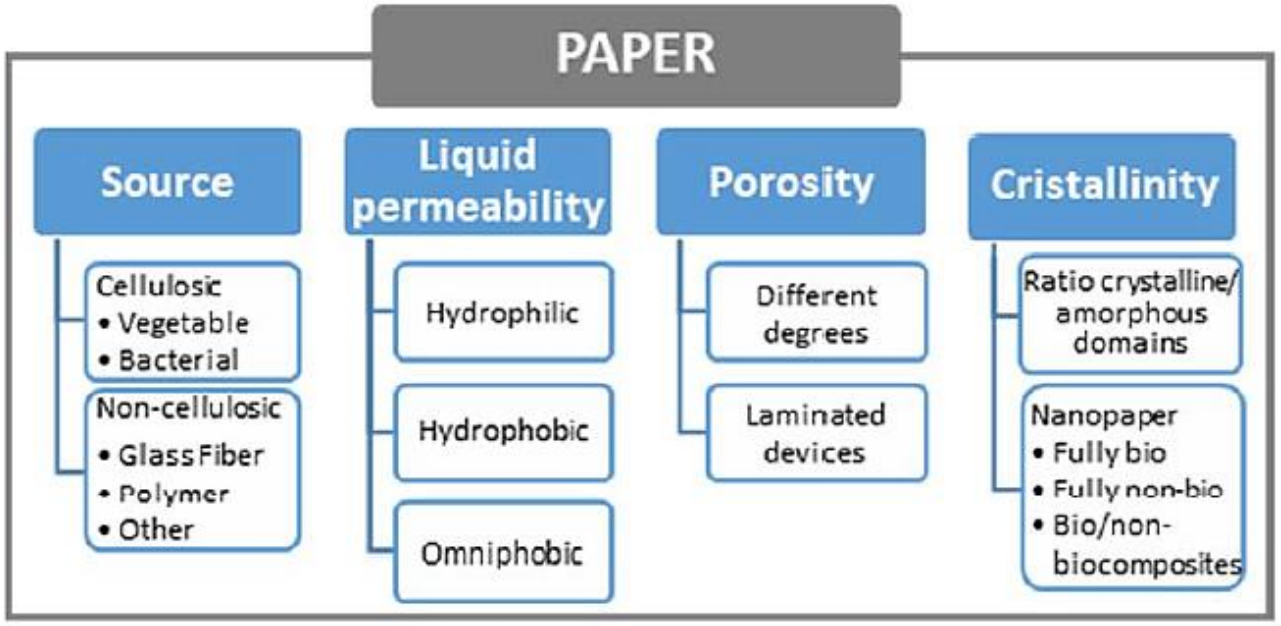
Paper as elective substrate

Paper as substrate

Paper can…
Store
Filter
React

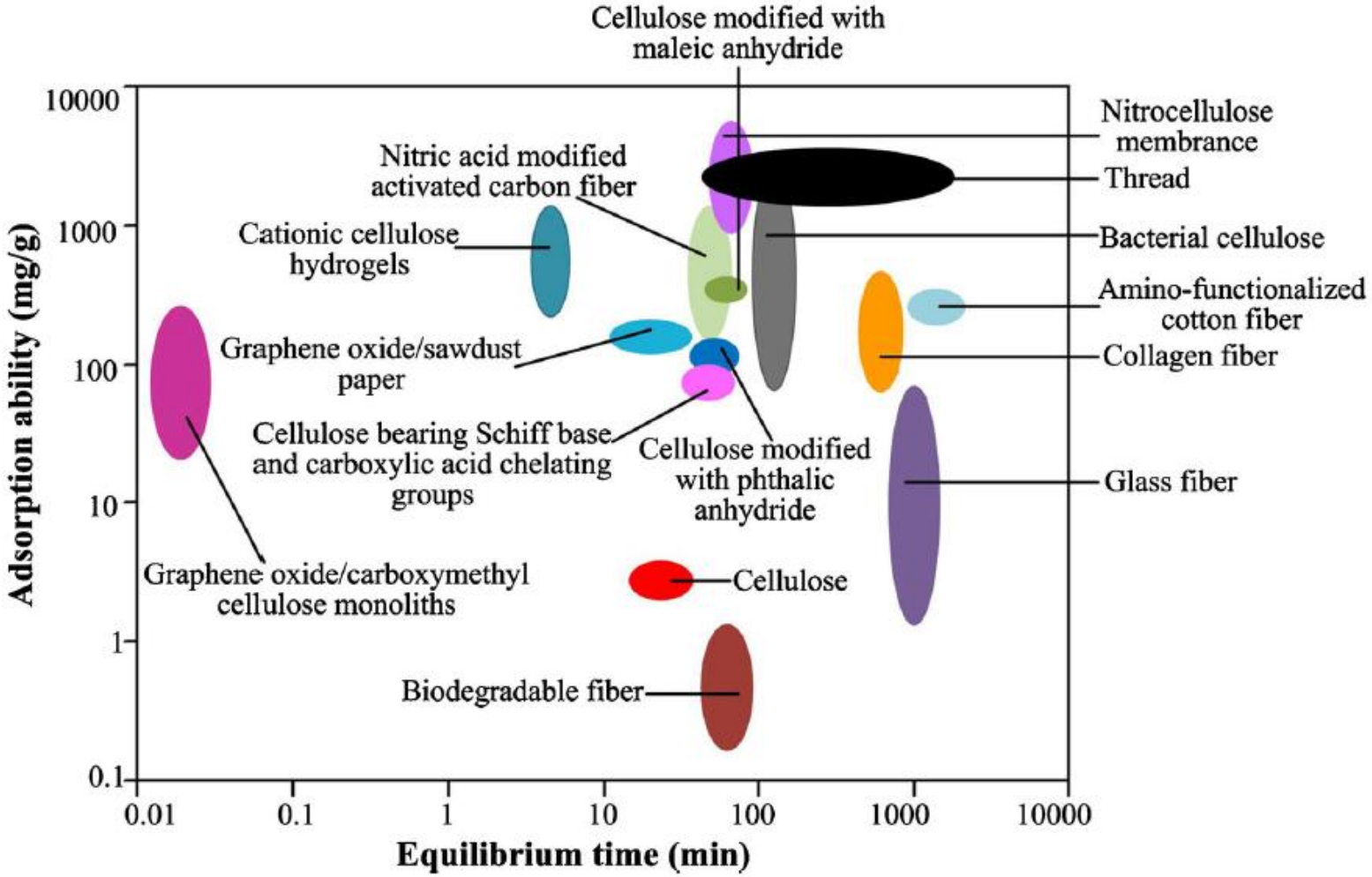
Drawbacks…
Reagents diffusion…
Electrical noise! ☹

An hydrophobic barrier is needed…



Paper as elective substrate

Kind of paper based substrates



Paper as elective substrate

Paper ca be tailored

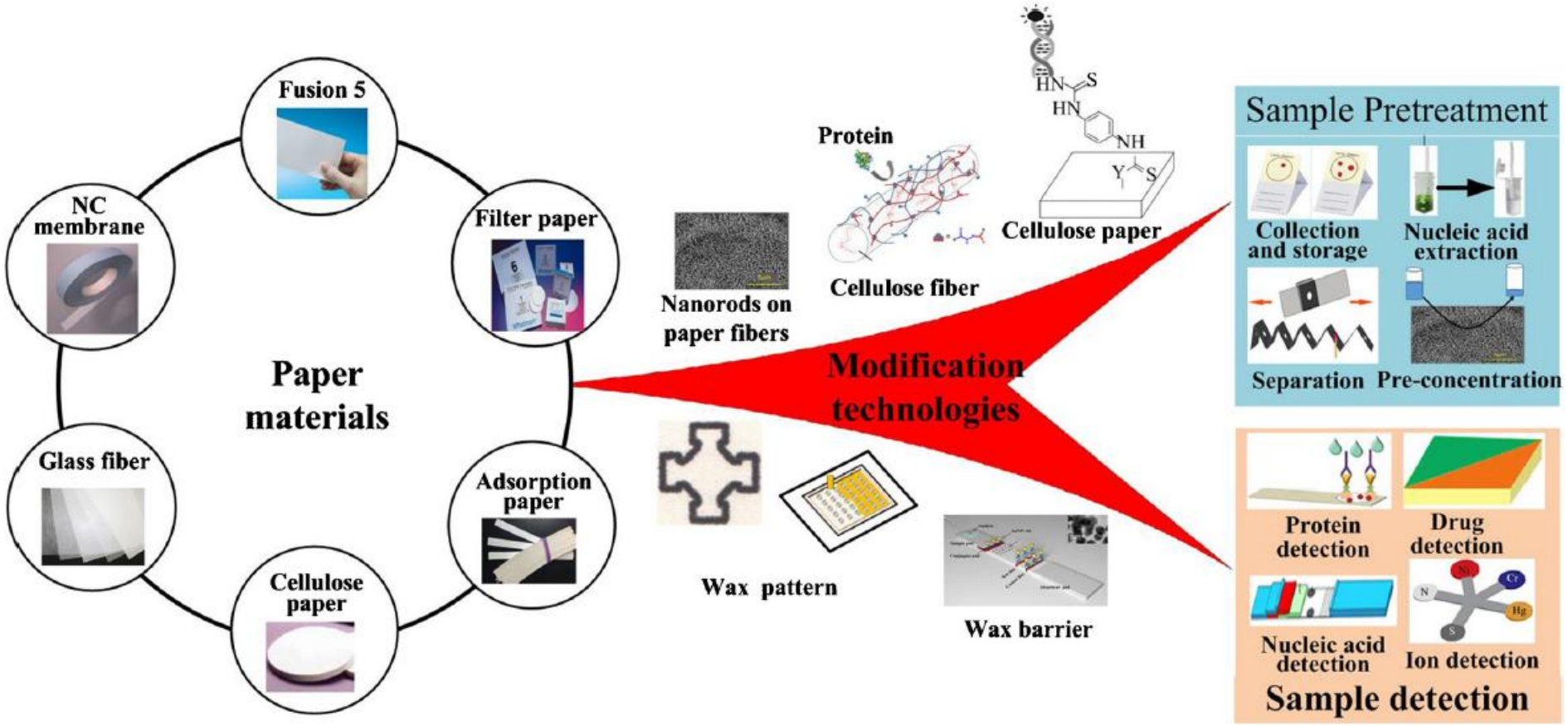
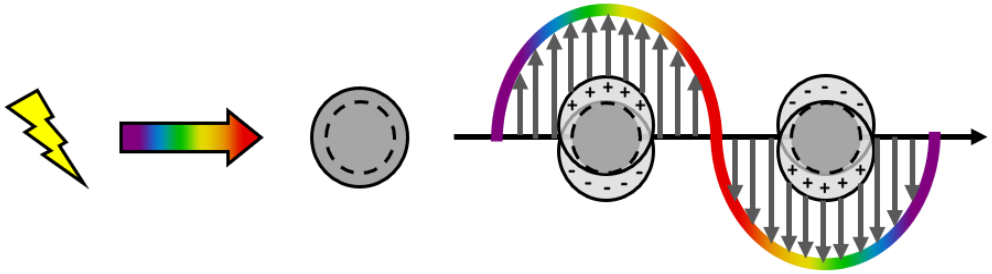


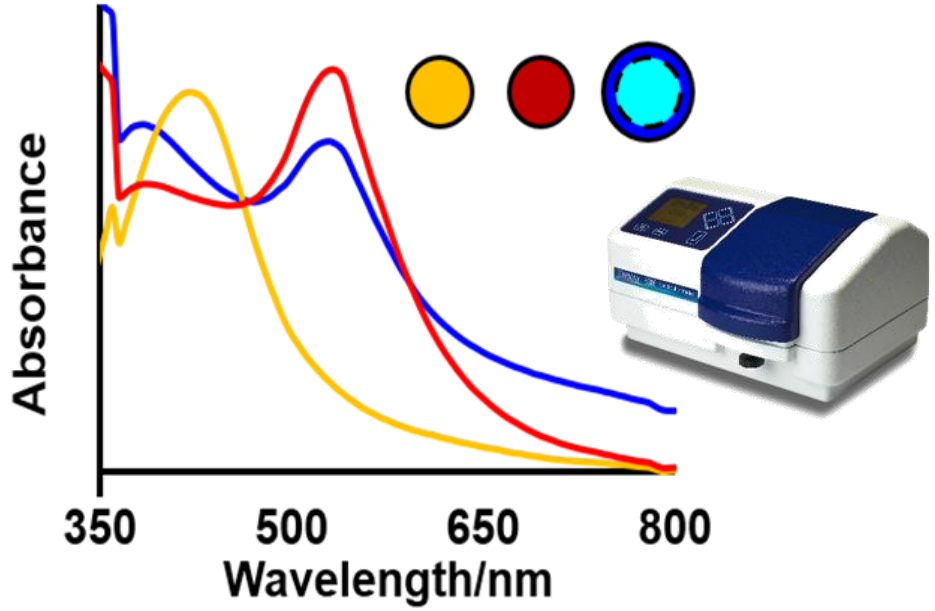
Fig. 1 Existing paper modification approaches for paper-based POCT. Different paper materials, including Fusion 5, filter paper, chromatography paper, cellulose paper, Whatman® No.1 filter paper and NC membrane, have been modified with various reagents for paper-based sample pretreatment and paper-based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

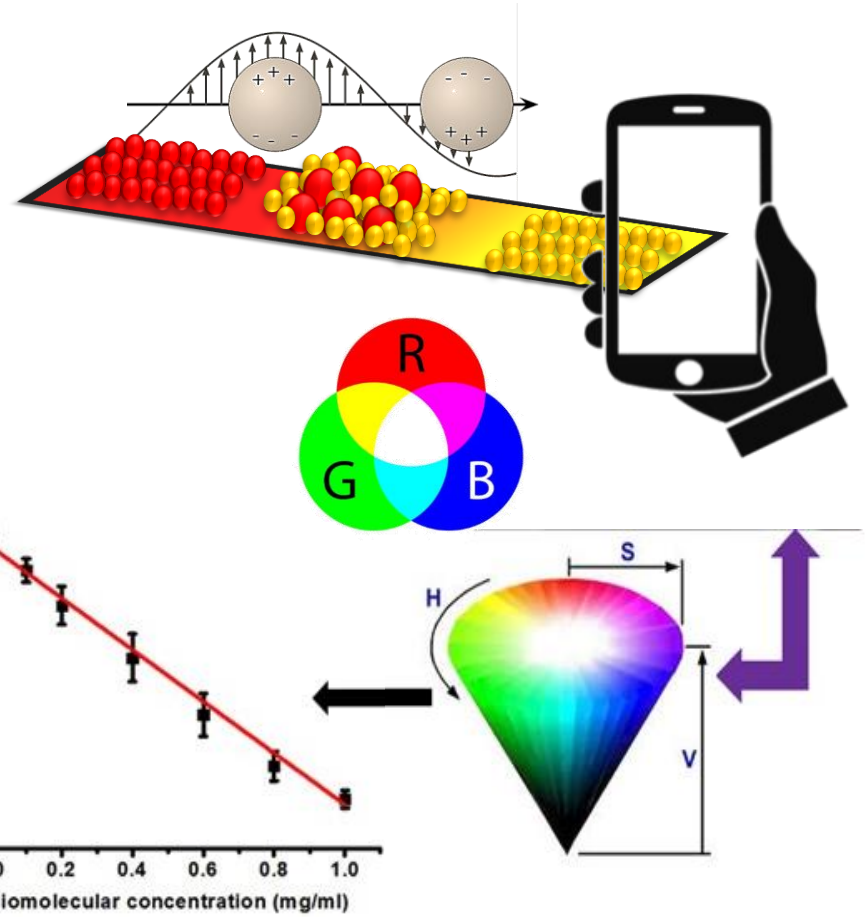
Paper as elective substrate

From plasmonic… Towards colorimetric strategies



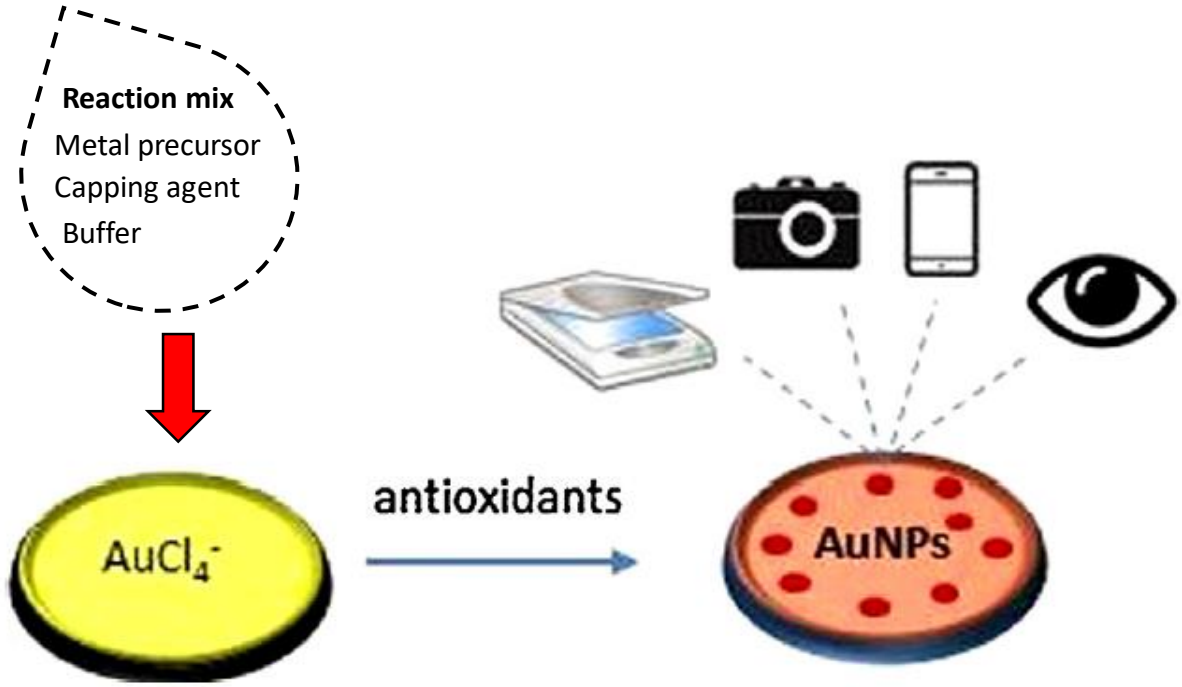
Localized Surface Plasmon Resonance

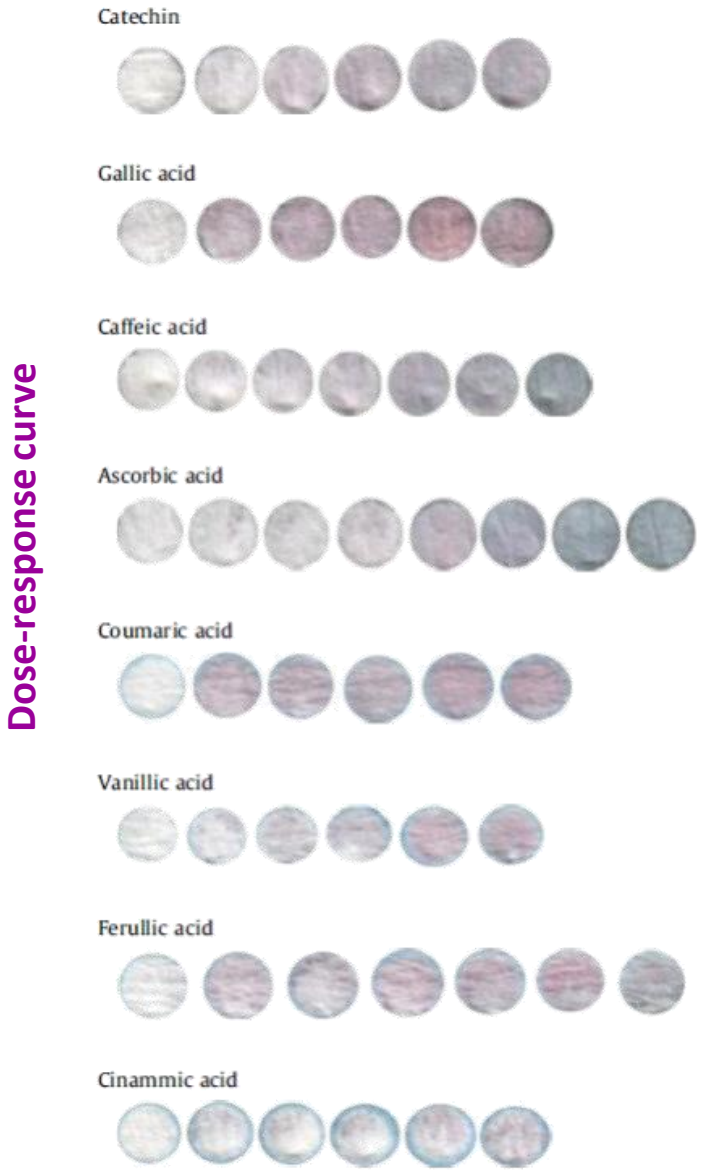




Paper-based colorimetric sensor

Phenolic content and antioxidant capacity evaluation trough AuNPs formation





Analytica Chimica Acta 860 (2015) 61–69

Contents lists available at ScienceDirect

Analytica Chimica Acta

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

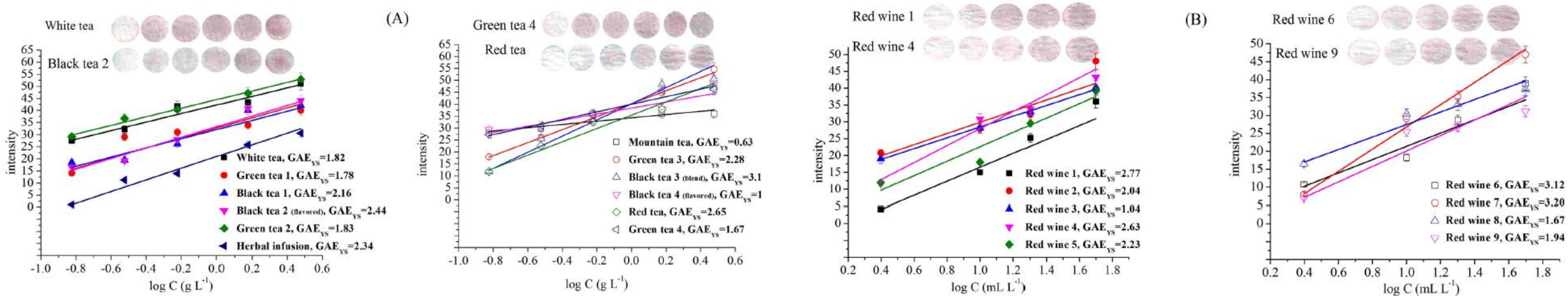
Paper-based assay of antioxidant activity using analyte-mediated on-paper nucleation of gold nanoparticles as colorimetric probes

Tatiana G. Choleva, Foteini A. Kappi, Dimosthenis L. Giokas *, Athanasios G. Vlessidis

Paper-based colorimetric sensor

Phenolic content and antioxidant capacity evaluation trough AuNPs formation

Sample dose-response curve



Sample analysis

Evaluation of antioxidant activity of commercial teas by the Au–AuNP paper sensor and comparison with conventional assays. RSD range between 2.9 and 14.4%.

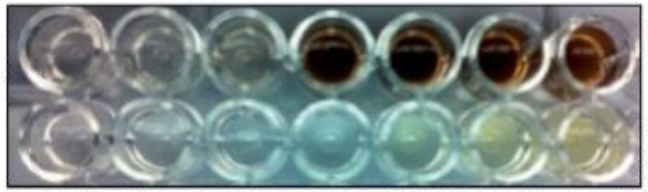
Tea sample	Au sensor Antioxidant activity (mg catechin g^{-1})	Au sensor Antioxidant activity (mg gallic acid g^{-1})	Folin–Ciocalteu Total phenolic content (mg gallic acid g^{-1})	CUPRAC Total antioxidant activity (mg Trolox g^{-1})	Aluminum assay Total flavonoid content (mg catechin g^{-1})
White tea	59.49	6.52	91.00	196.54	31.63
Green tea 1	56.81	5.76	95.30	208.61	26.76
Black tea 1	39.09	2.10	42.46	95.01	15.06
Black tea 2 (flavored)	24.26	0.58	52.72	114.28	18.47
Green tea 2	59.19	6.43	100.83	232.42	31.63
Herbal infusion	14.27	0.14	33.58	67.04	16.04
Mountain tea	60.44	6.80	31.54	67.83	21.88
Green tea 3	89.78	19.80	79.43	180.87	24.32
Black tea 3 (blend)	55.86	5.50	41.44	97.52	16.52
Black tea 4 (flavored)	44.12	2.91	69.83	147.97	23.35
Red tea	38.03	1.95	52.29	119.45	22.37
Green tea 4	120.60	43.93	107.53	231.87	60.87

Paper-based colorimetric sensor

Phenolic content and antioxidant capacity evaluation trough NanoCeria formation

$[CeO_2]$ 0.0025, 0.005, 0.01, 0.1, 1, 2, and 4%

Optimization



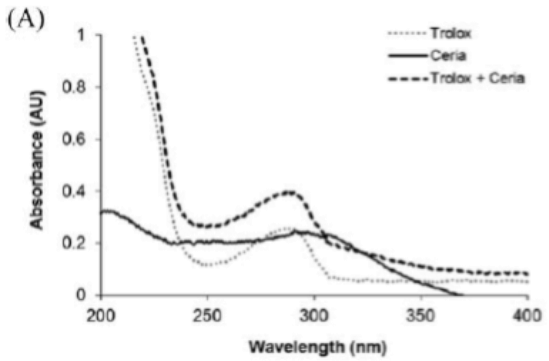
Caffeic acid (0,45 mM) reacted $[CeO_2]$

$[CeO_2]$= 4%

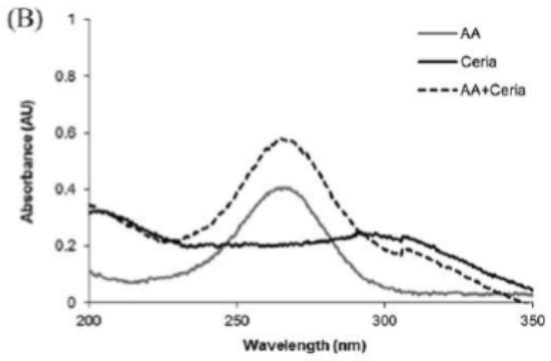
Analyst RSCPublishing
PAPER View Article Online View Journal
Portable ceria nanoparticle-based assay for rapid detection of food antioxidants (NanoCerac)
Cite this: DOI: 10.1039/c2an36205h
Erica Sharpe, Thalia Frasco, Daniel Andreescu and Silvana Andreescu*

Uv-vis spectra of ceria nanoparticles dispersion (13 ppm) in the presence and abesence of selected antioxidants.

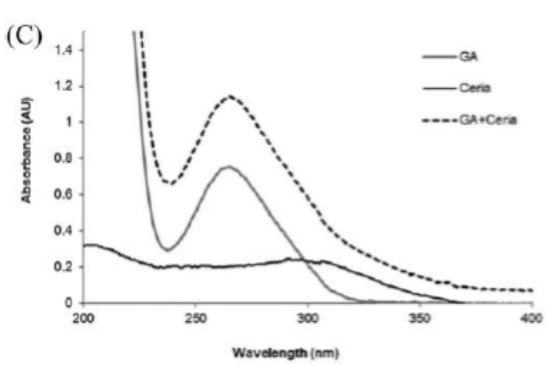
Trolox



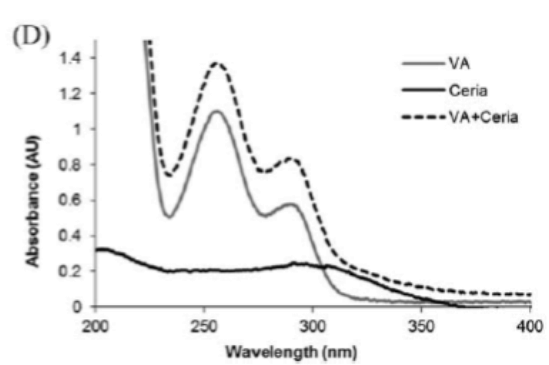
Ascorbic acid



Gallic acid



Vanillic acid



$2\ CeO_2 + 3\ C_6H_8O_6 \rightarrow Ce_2O_3 + 3\ C_6H_6O_6 + 2\ H_2O$

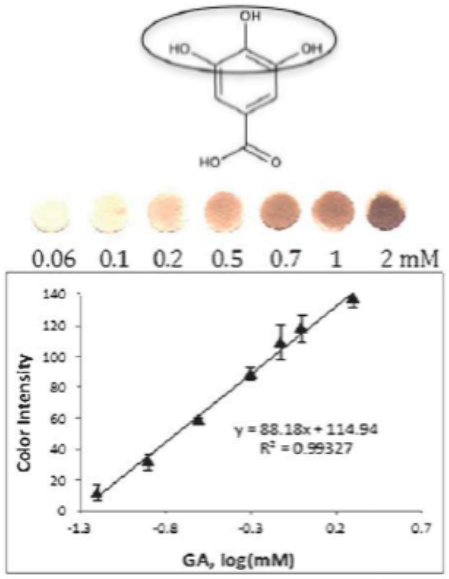
From dispersed system

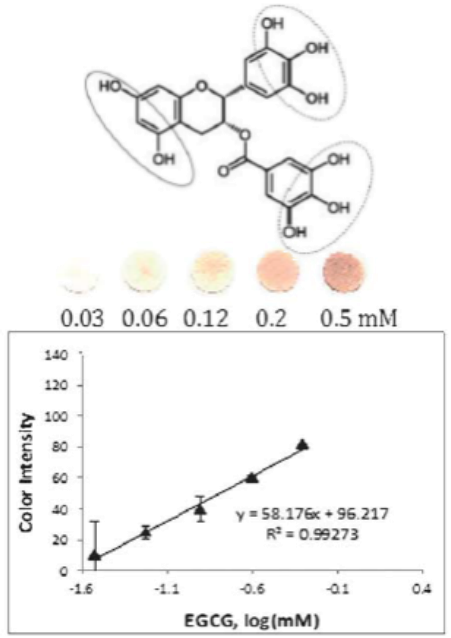
to paper support

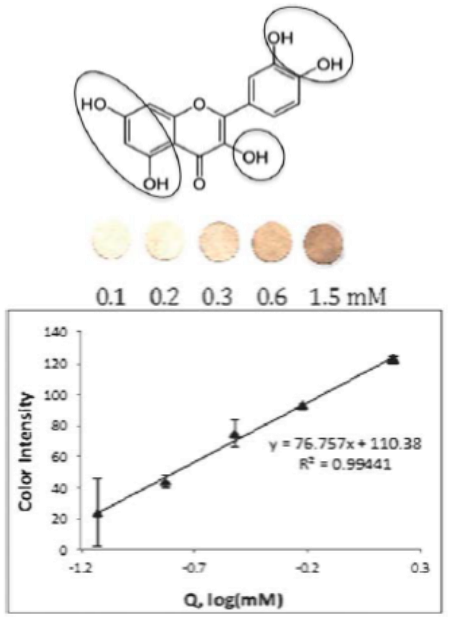
Paper-based colorimetric sensor

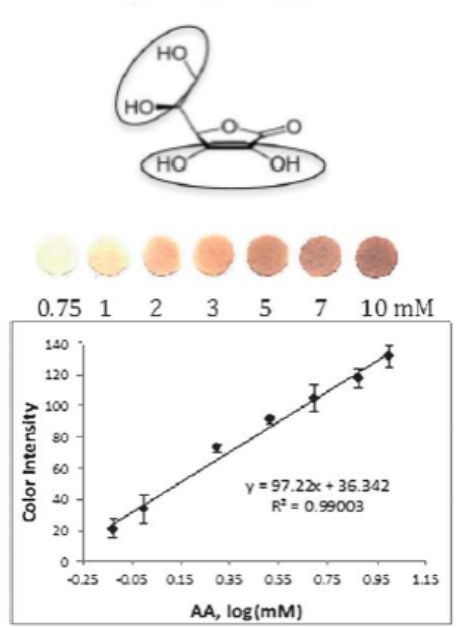
Phenolic content and antioxidant capacity evaluation trough NanoCeria formation

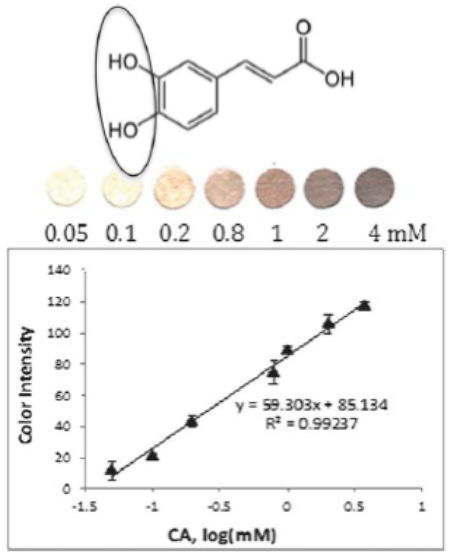
Dose-response curve

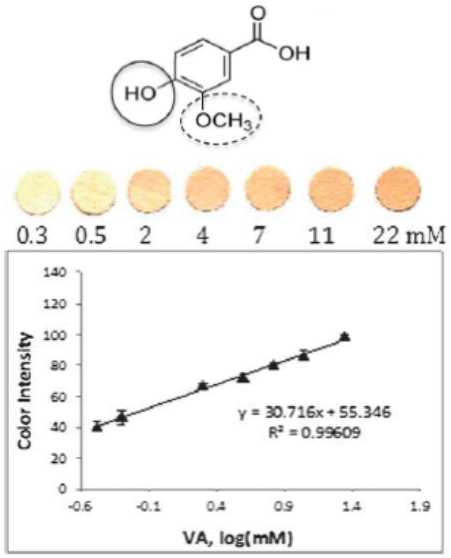




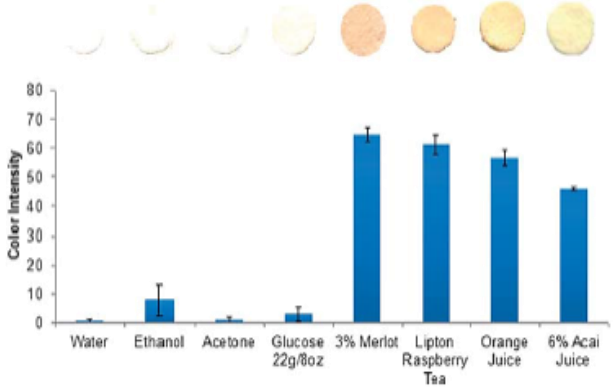








Interferents evaluation



Tested interfering compounds

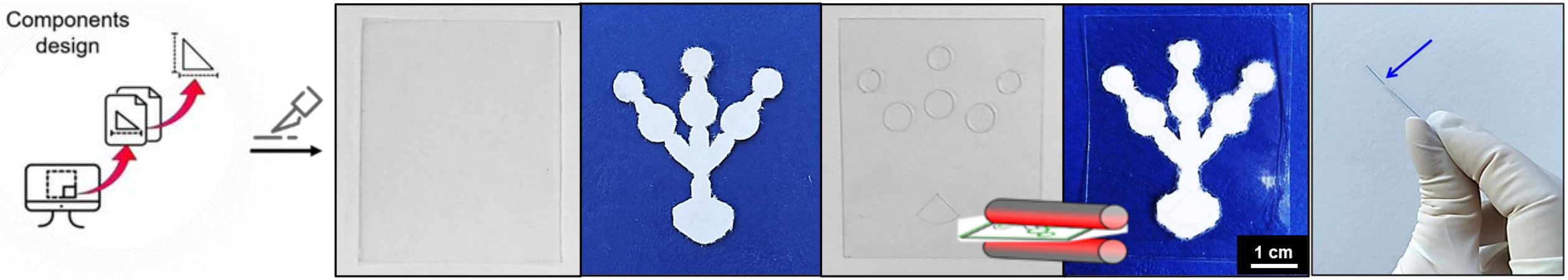
Common lab solvent:
- water,
- ethanol,
- acetone

Common sugar presents in:
- juice,
- wine,
- commercial teas

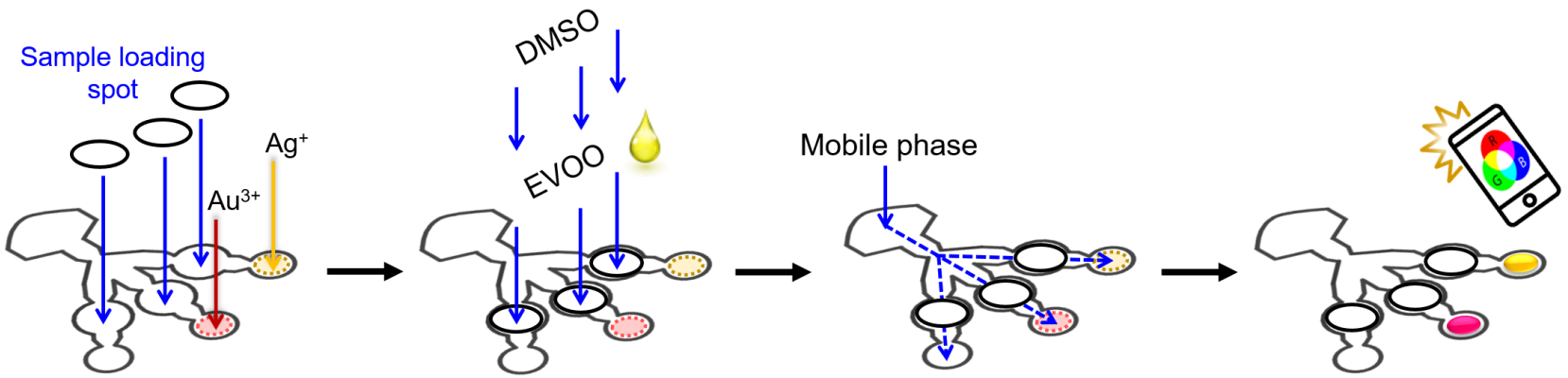
Paper-based colorimetric sensor

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

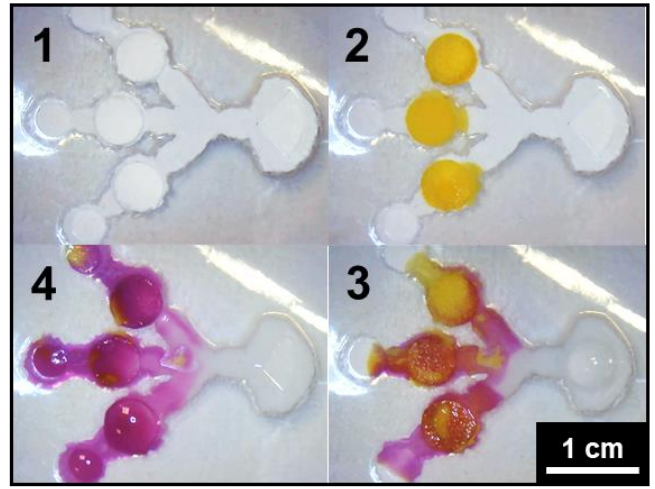
Lab-on-a-strip fabrication



Assay format



Assay simulation with a colorimetric dye

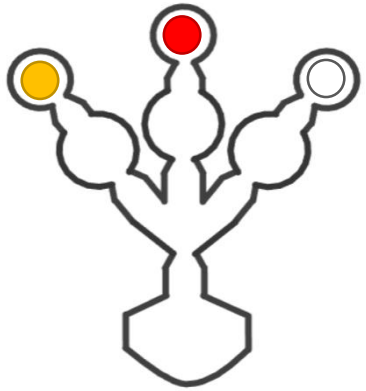


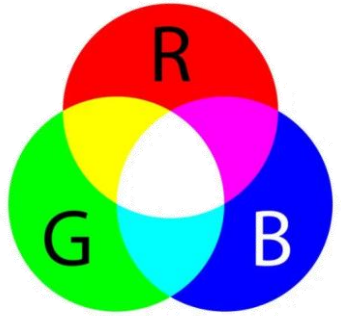
Total assay volume: ~ 80 uL

Paper-based colorimetric sensor

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

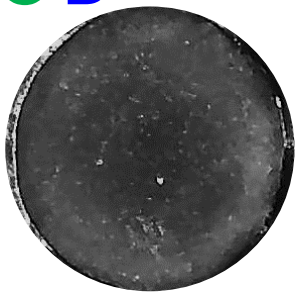
Color analysis

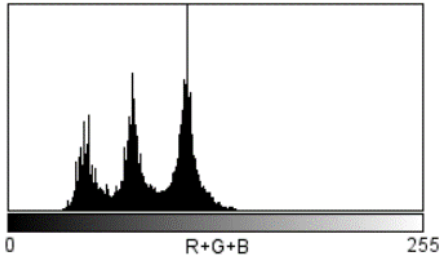




Google Play

R G B

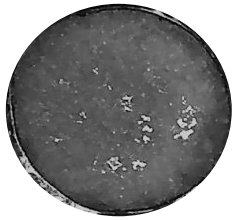


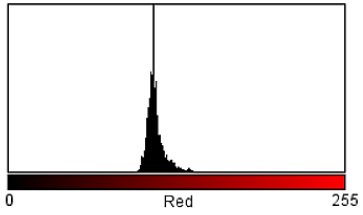


Count: 132192
Mean: 85.191
StdDev: 26.054

Min: 30
Max: 177
Mode: 110 (6566)

R

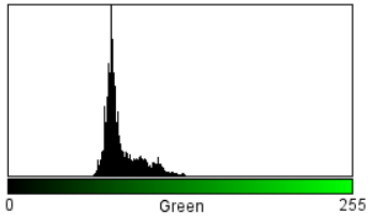




Count: 44064
Mean: 111.774
StdDev: 7.450

Min: 96
Max: 172
Mode: 110 (6143)

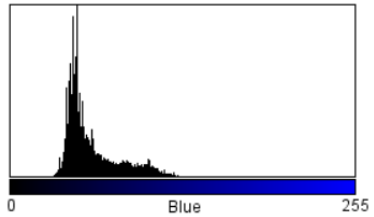
G



Count: 44064
Mean: 83.949
StdDev: 14.490

Min: 61
Max: 177
Mode: 76 (4141)

B



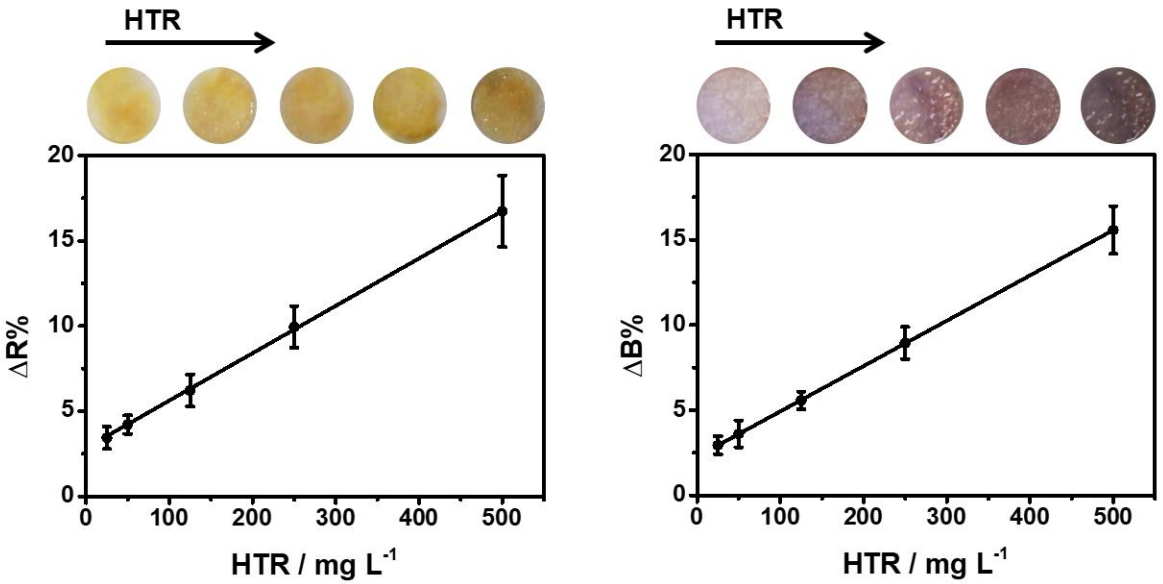
Count: 44064
Mean: 59.850
StdDev: 20.508

Min: 30
Max: 170
Mode: 49 (3039)

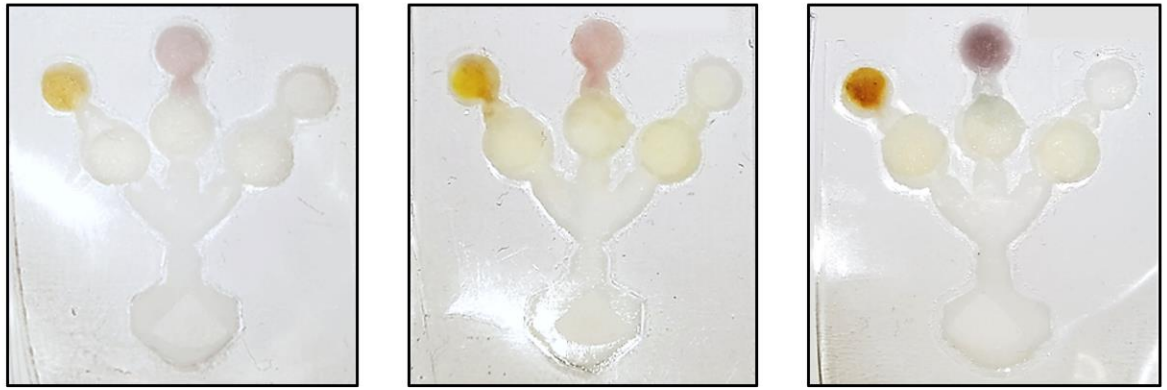
Paper-based colorimetric sensor

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

Dose-response curve

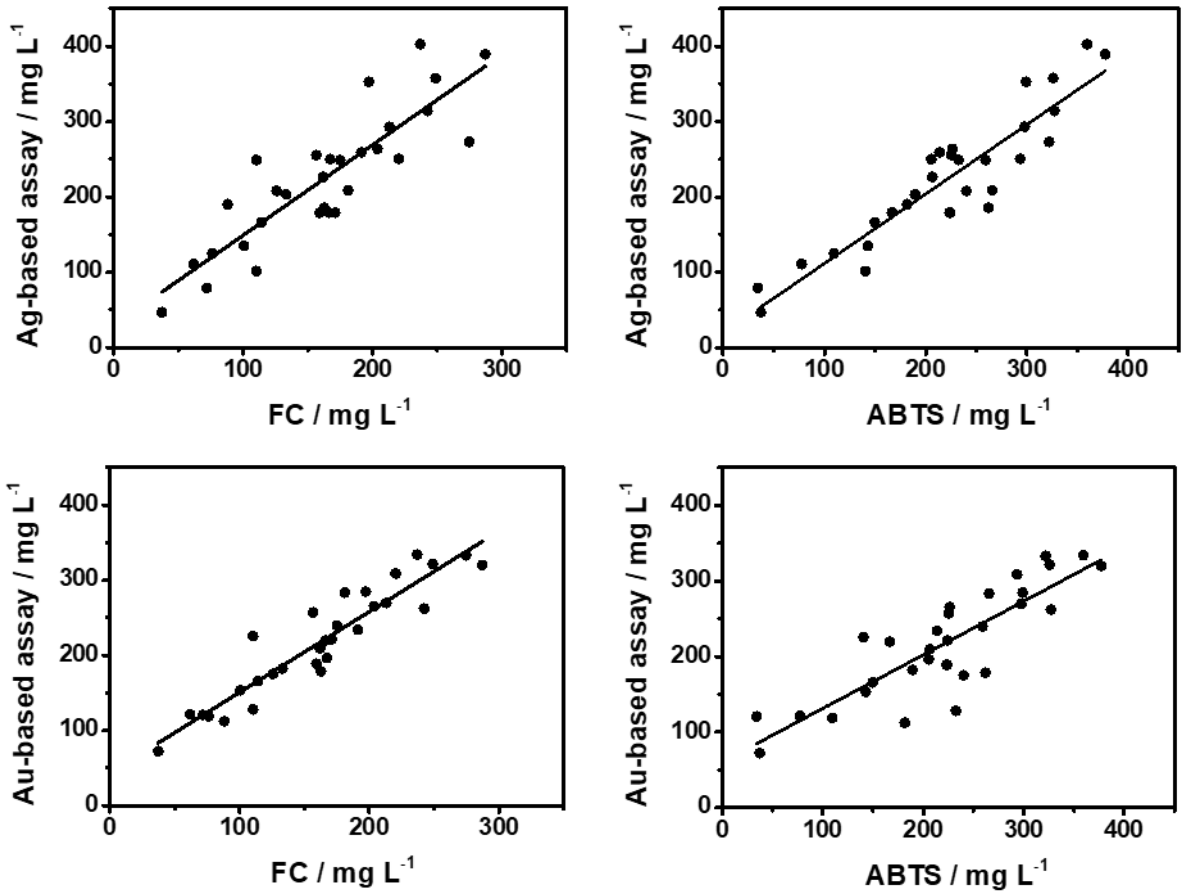


EVOO samples' phenolyc compounds content



Low Mean High

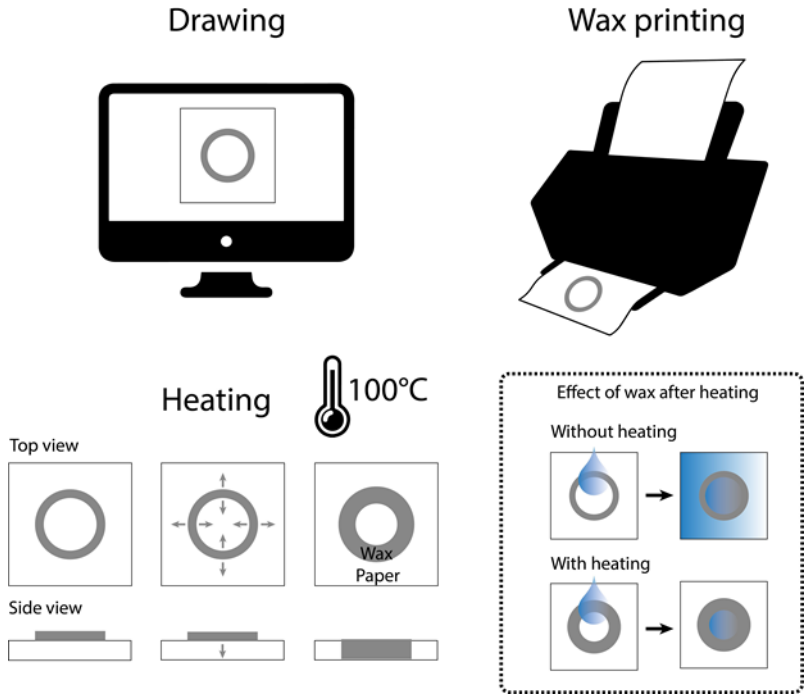
Sample analysis, analytical performances

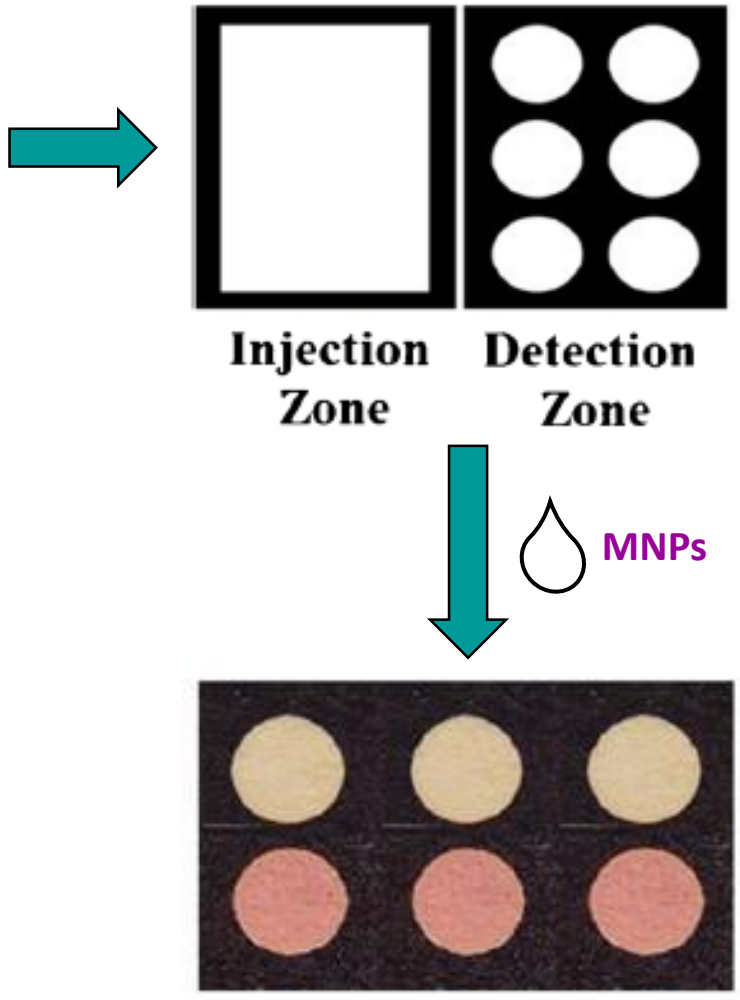


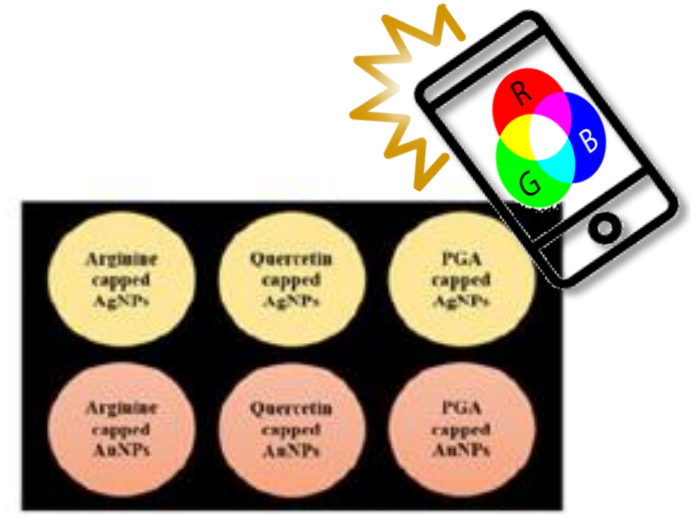
No interterferences by compounds commonly present in EVOO

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

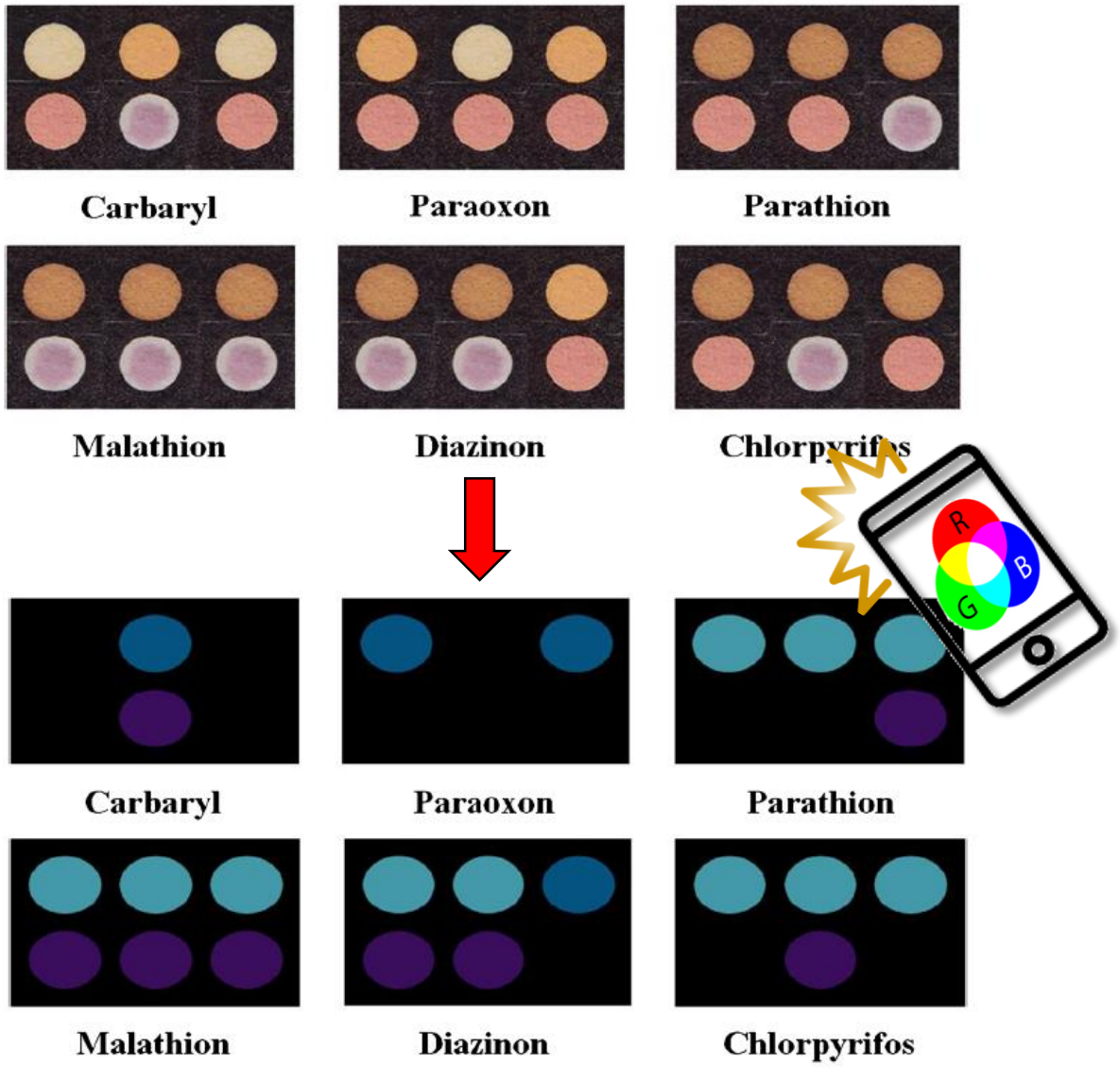
A paper-based colorimetric sensor array for discrimination and simultaneous determination of organophosphate and carbamate pesticides in tap water, apple juice, and rice

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

Paper-based colorimetric sensor

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

Analytes screening



Dose-response curve and analytical parameters