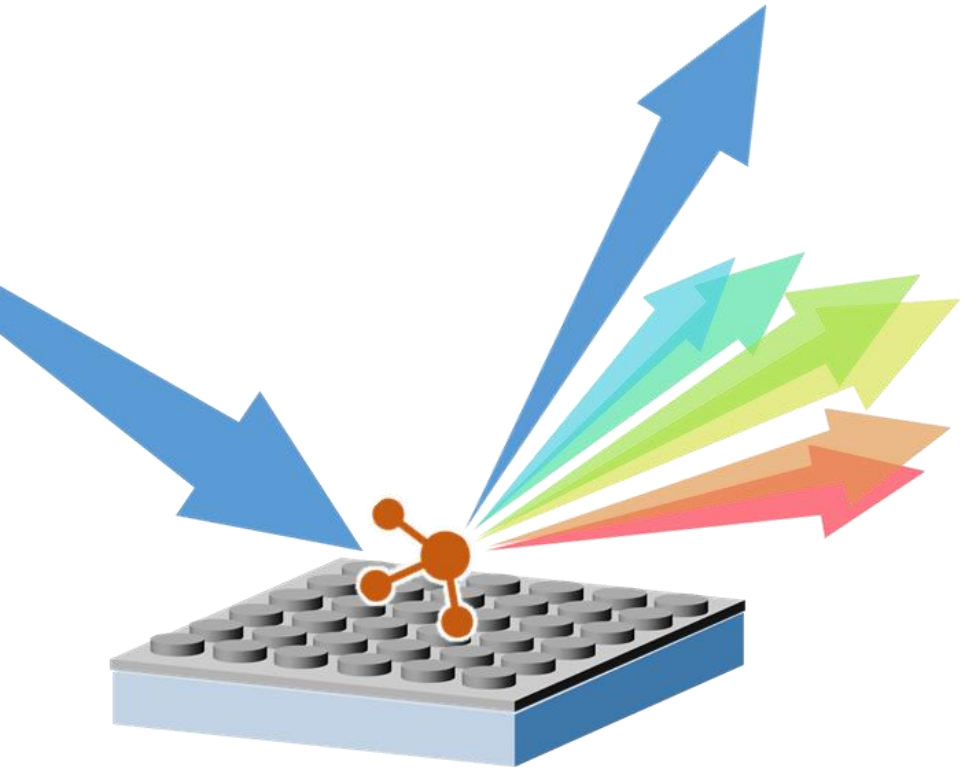
nanotechnology meets photonics

biomedical applications of Surface-Enhanced Raman Scattering (SERS)

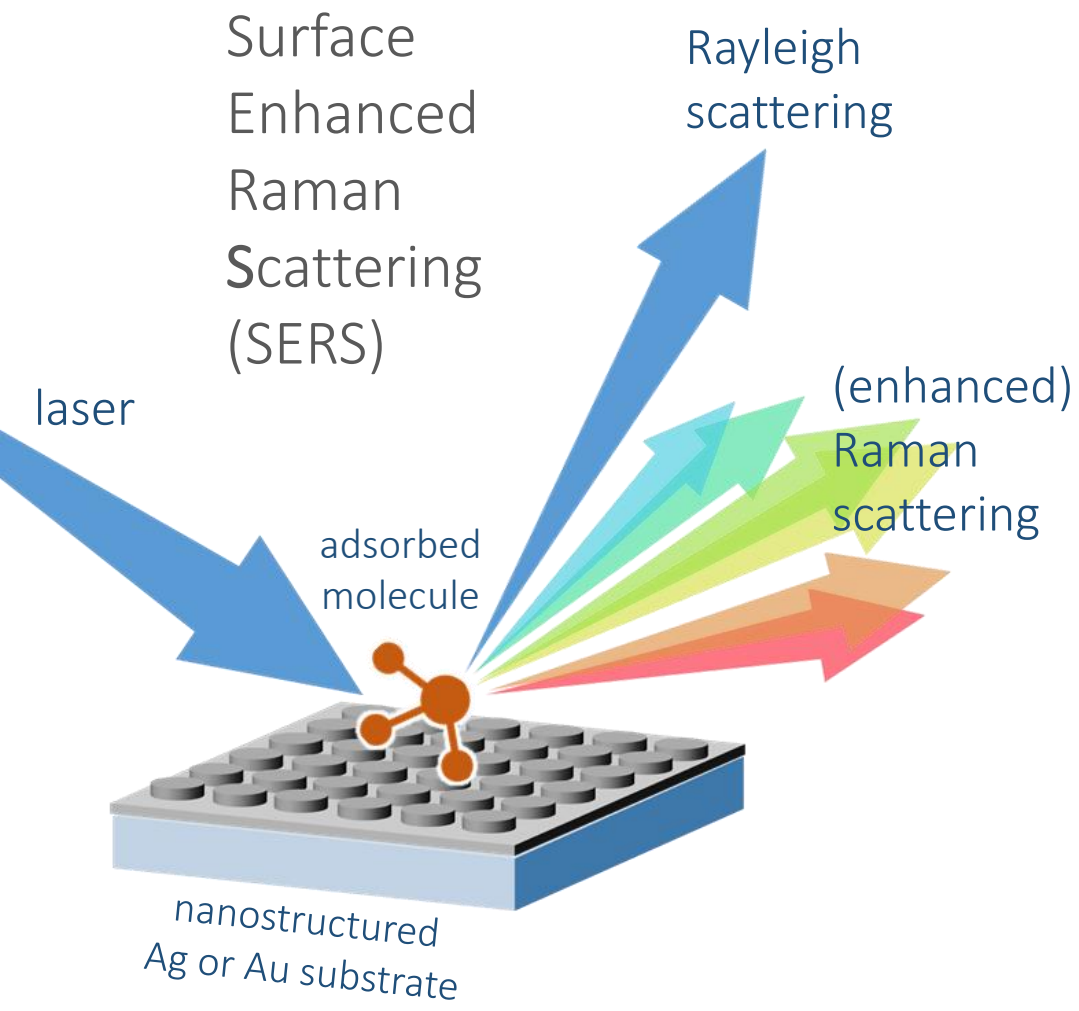


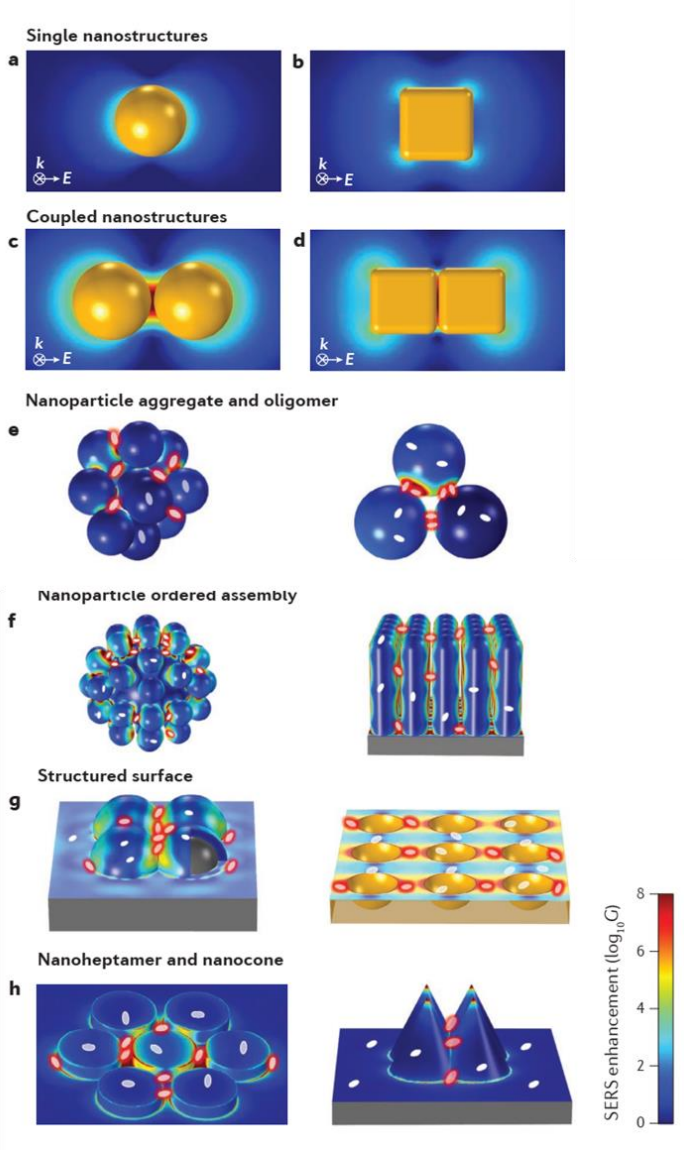
Stefano Fornasaro – sfornasaro@units.it
Alois Bonifacio – abonifacio@units.it

UNIVERSITÀ
DEGLI STUDI DI TRIESTE
Dipartimento di Ingegneria e Architettura

plasmonic nanostructures

as substrates for SERS sensors

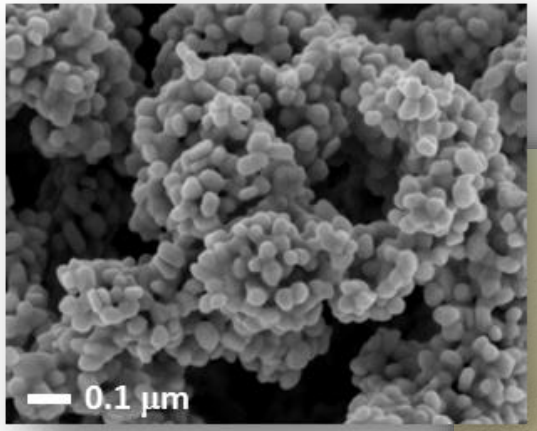




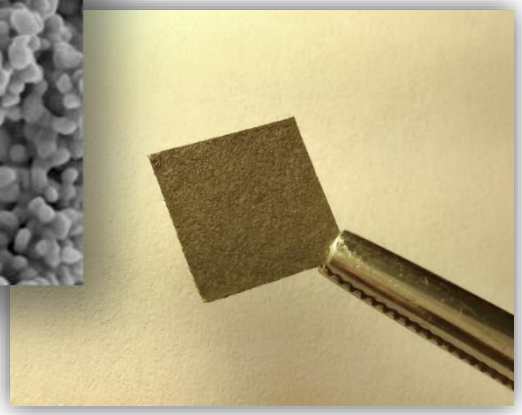
from Ding et al. *Nat. Rev. Mat.* (2016) 1, 16021

nanostructures prepared/used in our lab

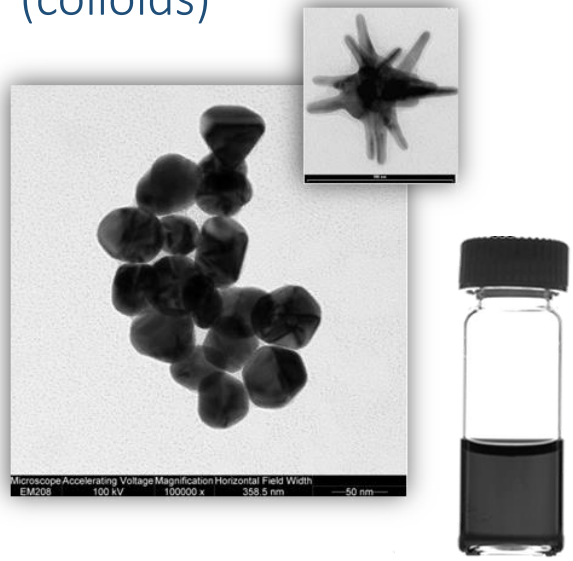
some examples



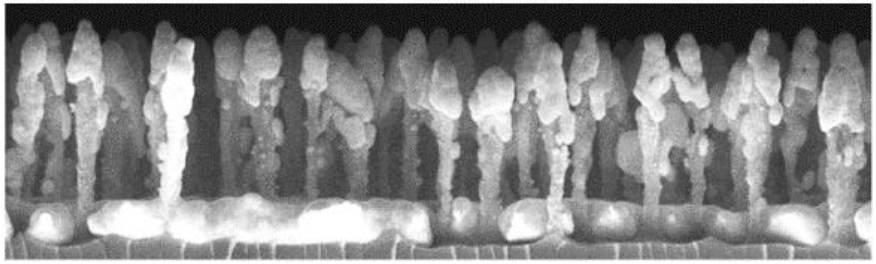
Ag and Au plasmonic paper



Ag, Au nanoparticles (colloids)



Ag/Au-capped Si nanopillars

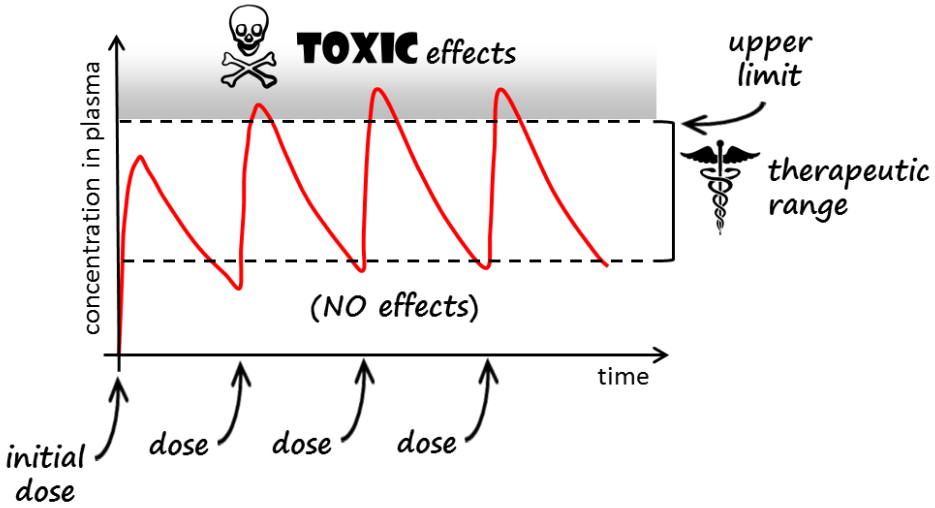


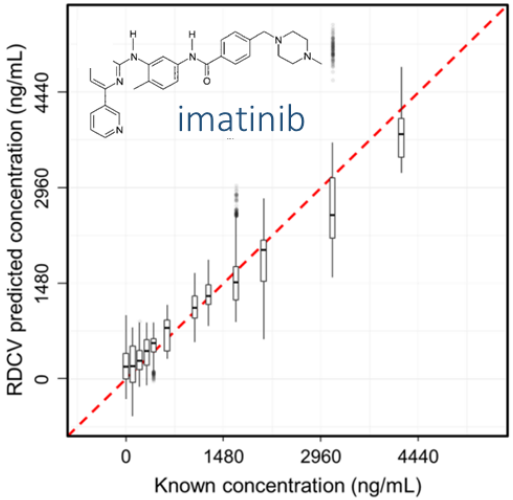
(from Silmeco ApS, DK)

Anal. Chem. 2018, 90, 12670
J. Nanopart. Res. 2014, 16, 2729
Materials 2017, 10 (12), 1365

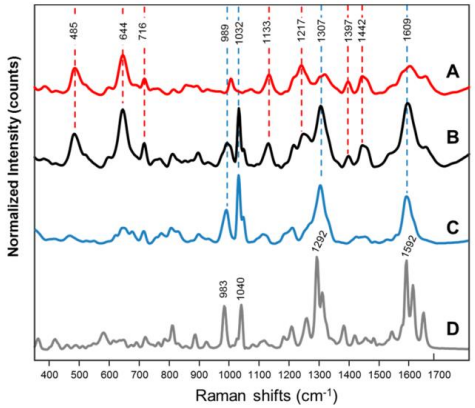
label-free SERS in clinical pharmacology

drug quantification for therapeutic monitoring





drug quantified in plasma from patients



in collaboration with

SILMECO SERS substrates

CRO AVIANO

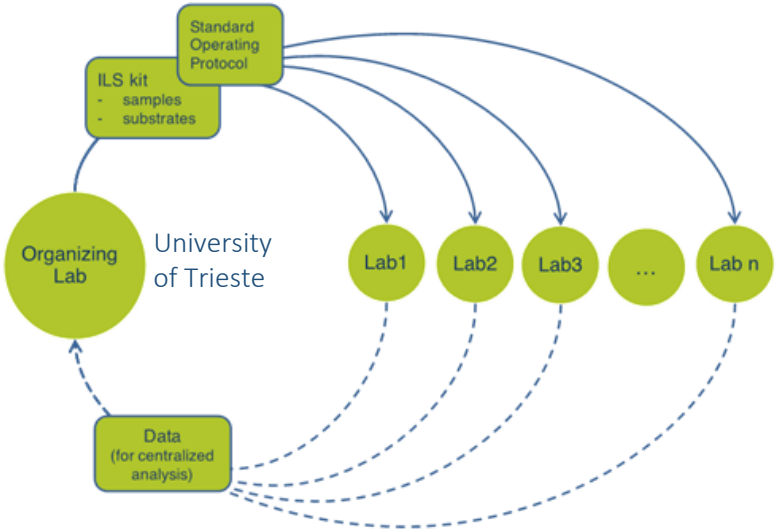
DTU Technical University of Denmark

Anal. Chem. 2018, 90, 12670
Faraday Discuss. 2016, 187, 485
Biosensors 2016, 6 (3), E47

inter-laboratory study

within a large European network of SERS labs

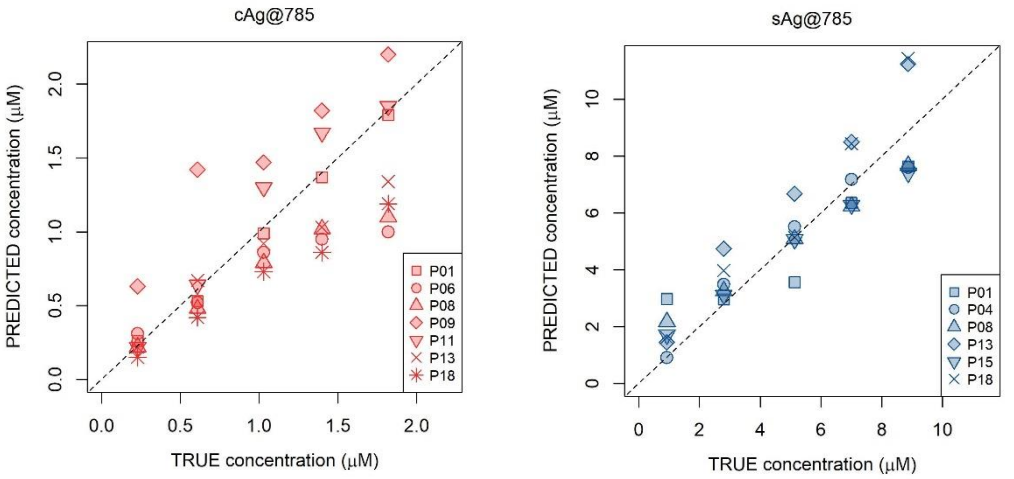
laboratories involved:	15
researchers involved:	44
European countries involved:	11
SERS protocols tested:	6
single SERS substrates used:	1080
metal colloids used (mL):	488
spectra delivered:	3694
spectra analyzed:	3516



Raman4Clinics

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

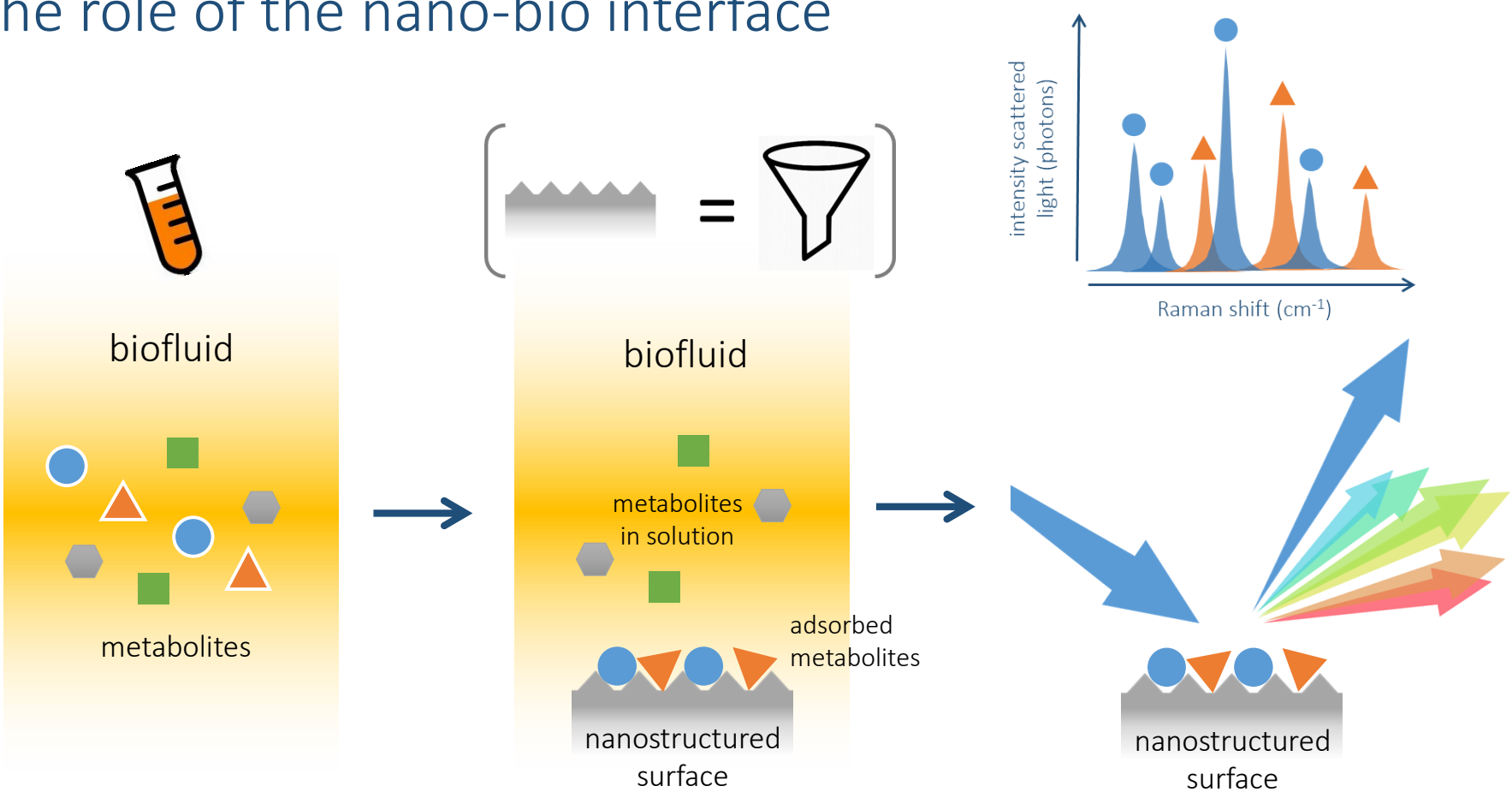
quantification of adenine
average **standard error** of
prediction (SEP) of **12%**



(2020, revision submitted to Anal.Chem.)

label-free SERS of biofluids

the role of the nano-bio interface



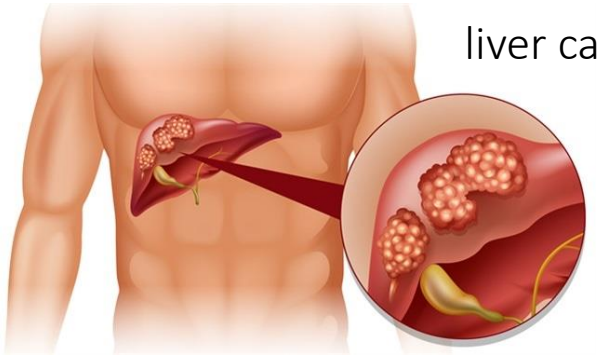
complex
biochemical mix

nanostructured
surfaces act as a **filter**

only **adsorbed**
metabolites are detected

label-free SERS in diagnostics

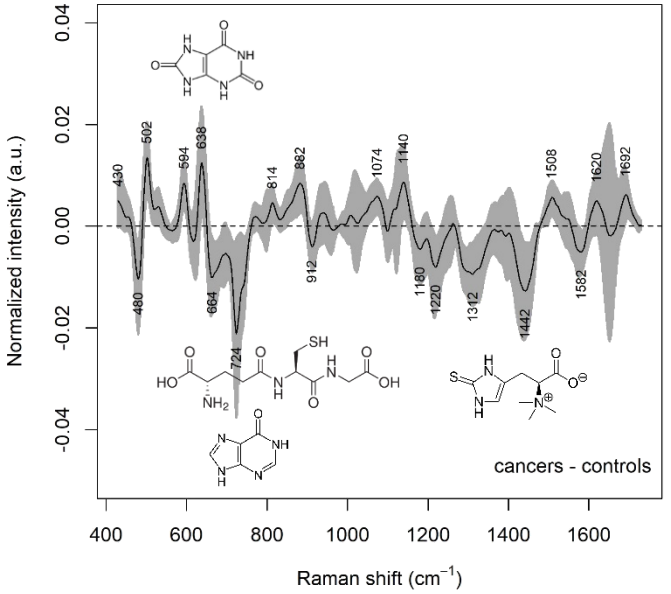
an un-targeted metabolomics approach



liver cancer

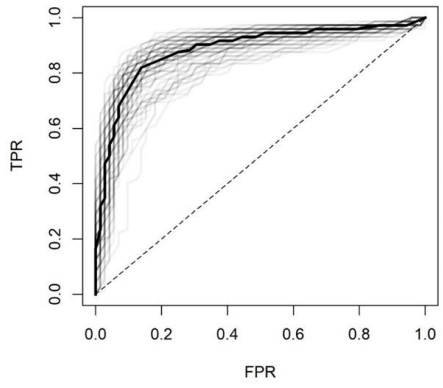
serum

from 144 subjects



in collaboration with

Fondazione Italiana Fegato ONLUS



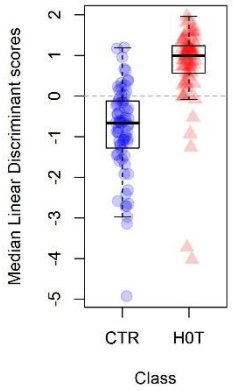


figure of merit	average (95% C.I.)
accuracy	81.1 (74.7 – 87.3)
sensitivity	85.9 (77.8 – 93.4)
specificity	75.9 (66.1 – 85.4)
PPV	78.2 (68.5 – 87.4)
NPV	84.3 (74.6 – 93.3)
AUC	87.6 (87.0 – 88.2)

(2020, paper in preparation)

Anal. Bioanal. Chem. 2015 407, 8265

Anal. Bioanal. Chem. 2015 407, 3271

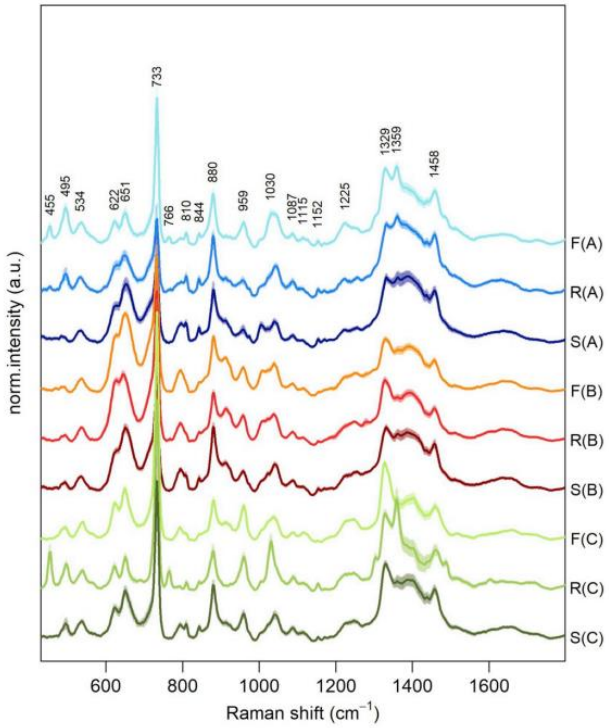
label-free SERS in food science

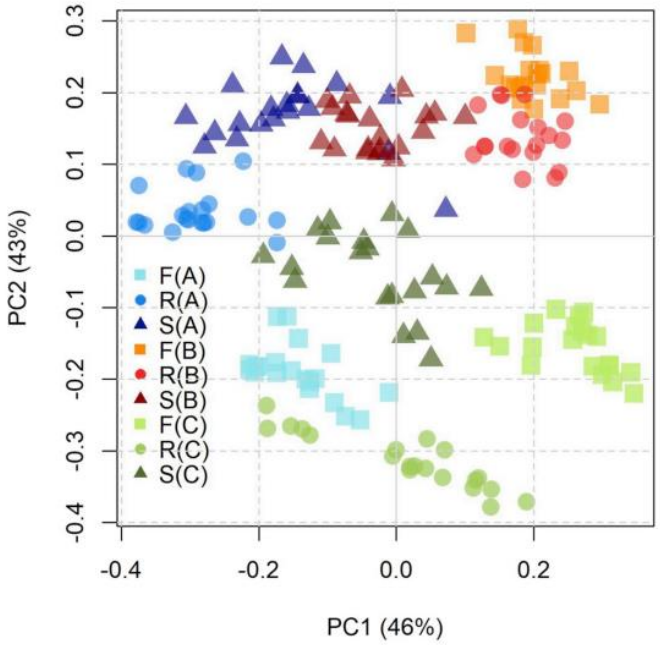
an un-targeted metabolomics approach to wine

Friulano

Sauvingon

Ribolla



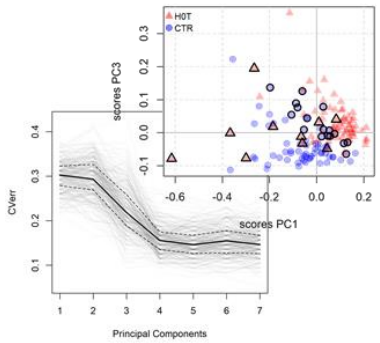


90% average classification accuracy

Talanta 2019, 203, 99

available equipment & expertise

Raman spectroscopy and multivariate data analysis



design of experiments (DoE)

predictive modelling

SVM

PCA PLS

regression

model validation

neural networks

classification

UNIVERSITÀ DEGLI STUDI DI TRIESTE
Dipartimento di Ingegneria e Architettura

group members

Valter **Sergo**

Alois **Bonifacio**

Stefano **Fornasaro**

Alessandro **Esposito**

2 portable Raman spectrometers
B&W Tek i-Raman plus
excitation: 785, 532 nm

Raman microscope
Renishaw InVia
excitaton: 785, 633,
532 and 405 nm

needed expertise & facilities

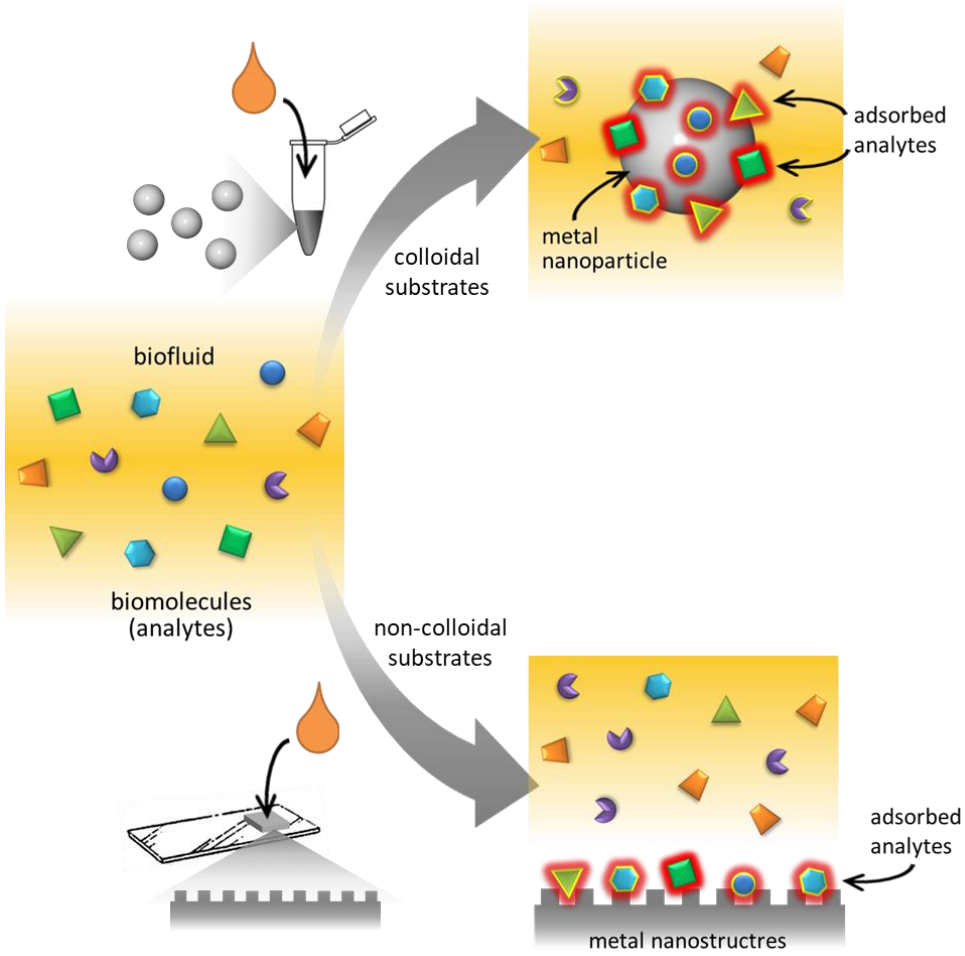
- plasmonics modelling, design (e.g. COMSOL Multiphysics)
- scalable nano-fabrication (e.g. nano-imprinting)
- nanostructure characterization (e.g. FE SEM, STM, etc.)
- surface analysis (e.g. SIMS)
- microfluidics for sample pre-treatment

need for **reproducible**, **stable**, **inexpensive** **nanostructured silver** or **gold** surfaces as SERS substrates to be produced in **large quantities** (hundreds)

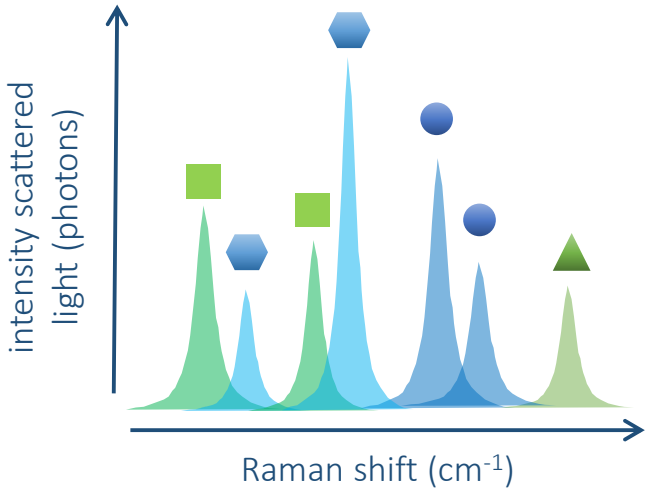
label-free SERS

direct analyte detection

in complex biological matrices



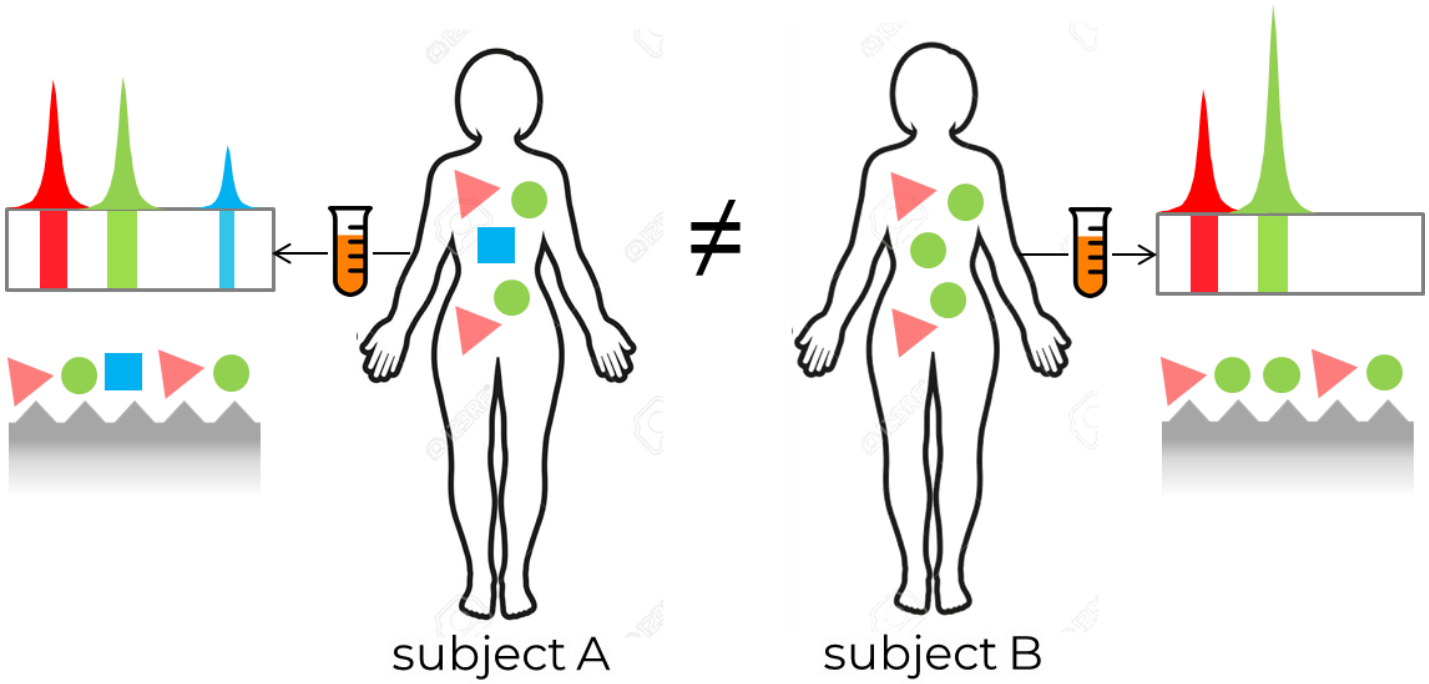
vibrational spectrum of
adsorbed molecules
(analytes)



Anal. Bioanal. Chem. 2015 407, 8265

label-free SERS in diagnostics

an un-targeted metabolomics approach



Anal. Bioanal. Chem. 2015 407(27): 8265

label-free SERS in cell analysis

results from cellular lysates

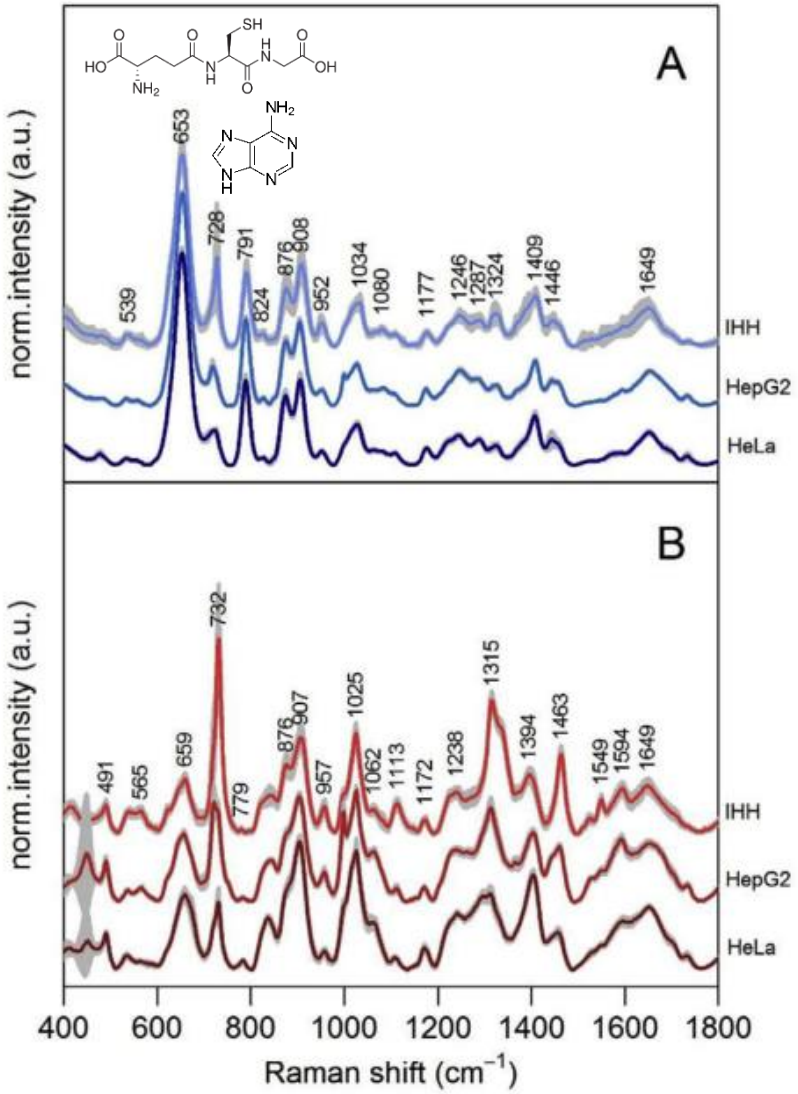


Fig. 3. Comparison between average normalized SERS spectra of filtered lysates from different cells lines (i.e. IHH, HepG2 and HeLa) with silver (A) and gold (B) substrates. For all lysates, the same lysis buffer, i.e. sodium citrate, was used. Each average spectrum is obtained from N independent measurements (N = 24 for IHH and 12 for other cell lines) out of several (2–4) different non-synchronous cell culture flasks, containing cells of the same cell-line and grown using the same method. Beside each average spectrum, intensity standard deviation (±1 SD) is shown in shaded grey.

Anal. Chim. Acta 2018, 1005, 95

SERS spectra repeatability

with different batches of substrates

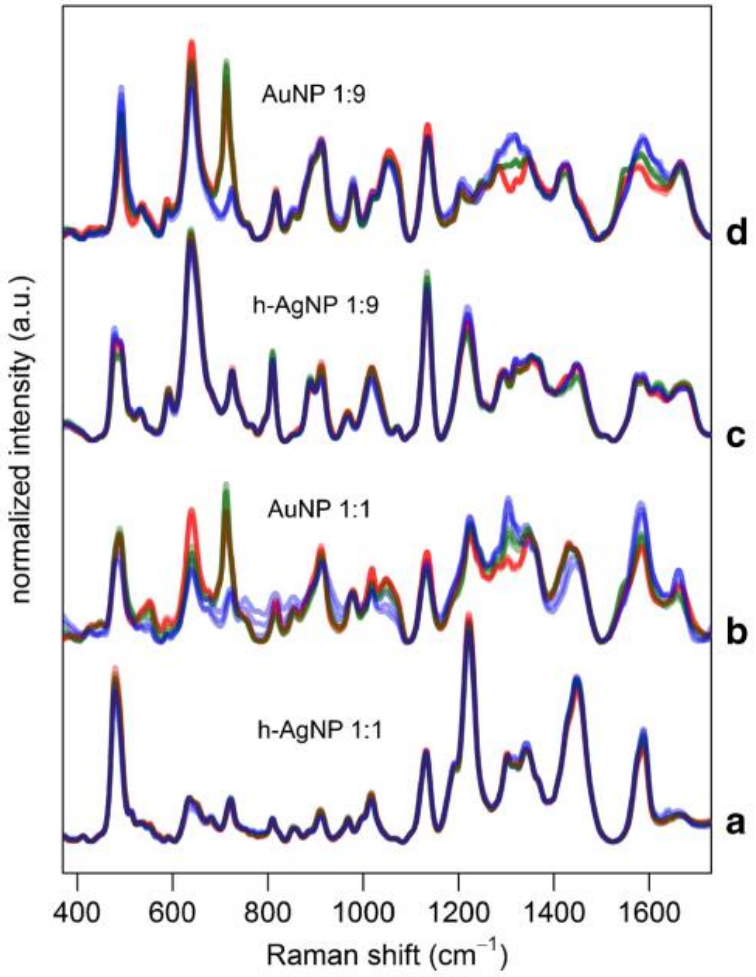
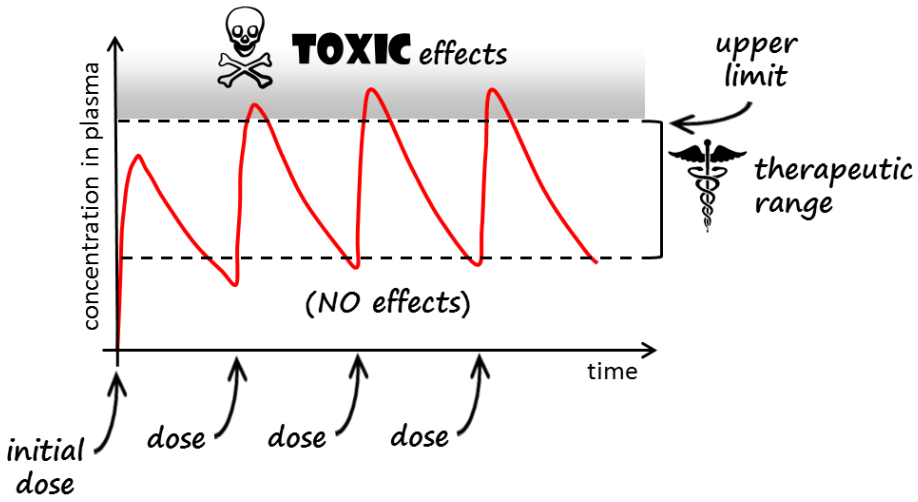


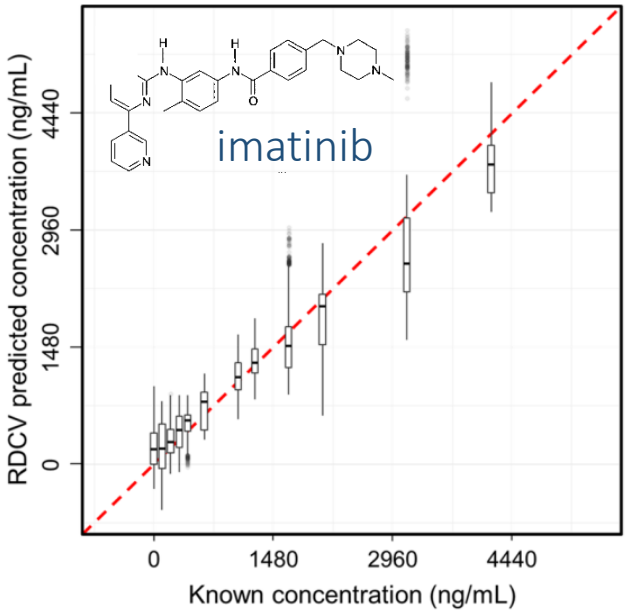
Fig. 5 Repeatability of spectra. Comparison between SERS spectra obtained from the same filtered serum sample (1 healthy subject) but on different substrates and in different serum–substrate ratios: h-AgNP 1:1 (*a*), AuNP 1:1 (*b*), h-AgNP 1:9 (*c*), and AuNP 1:9 (*d*). For each substrate–volume ratio combination, a total of nine spectra are depicted (three spectra/substrate batch, from three different batches), and colored according to the batch used (i.e., *blue* = batch 1, *red* = batch 2, *green* = batch 3). For all spectra, excitation wavelength was at 785 nm, laser power at 170 mW, and acquisition time was 10 s per spectrum

Anal. Bioanal. Chem. 2014, 406, 2355

label-free SERS in clinical pharmacology

drug quantification for therapeutic monitoring





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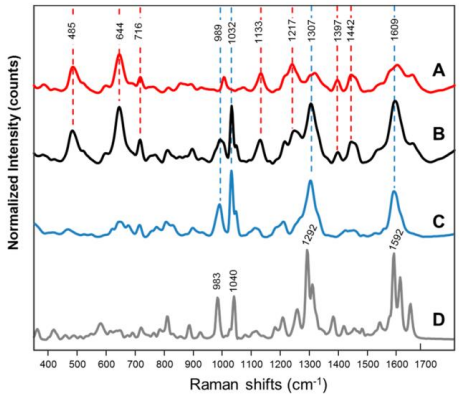

Anal. Chem. 2018, 90, 12670
Faraday Discuss. 2016, 187, 485
Biosensors 2016, 6 (3), E47

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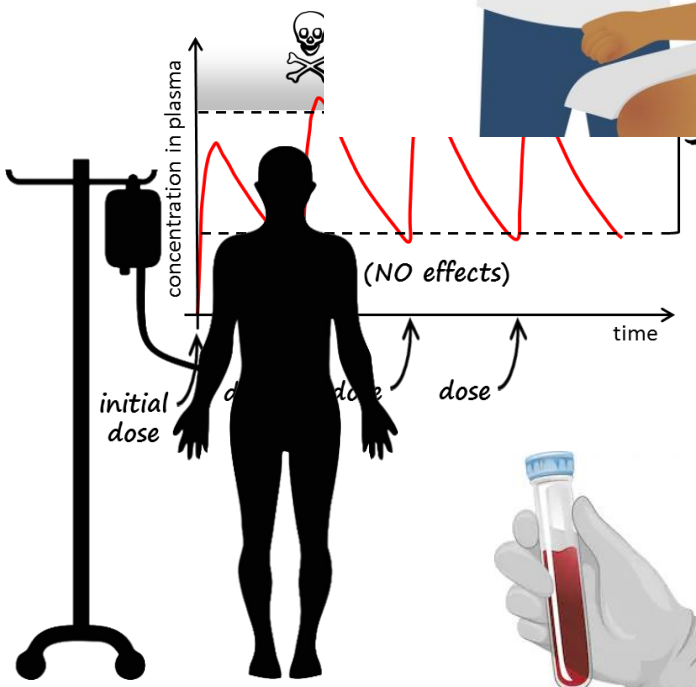
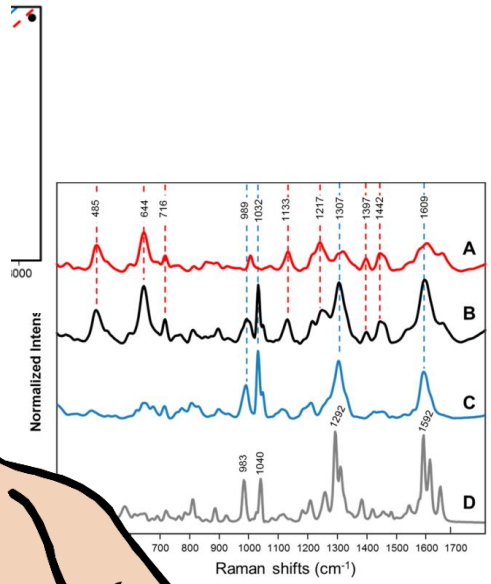
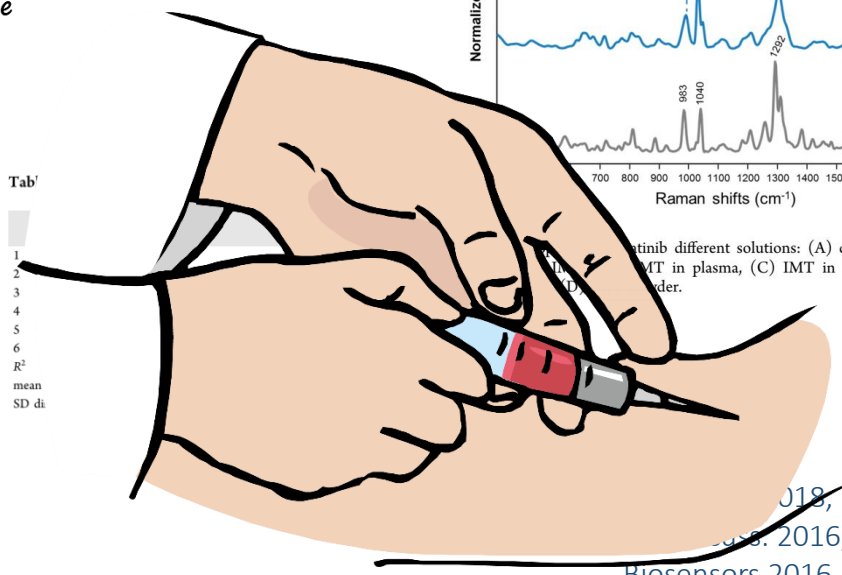
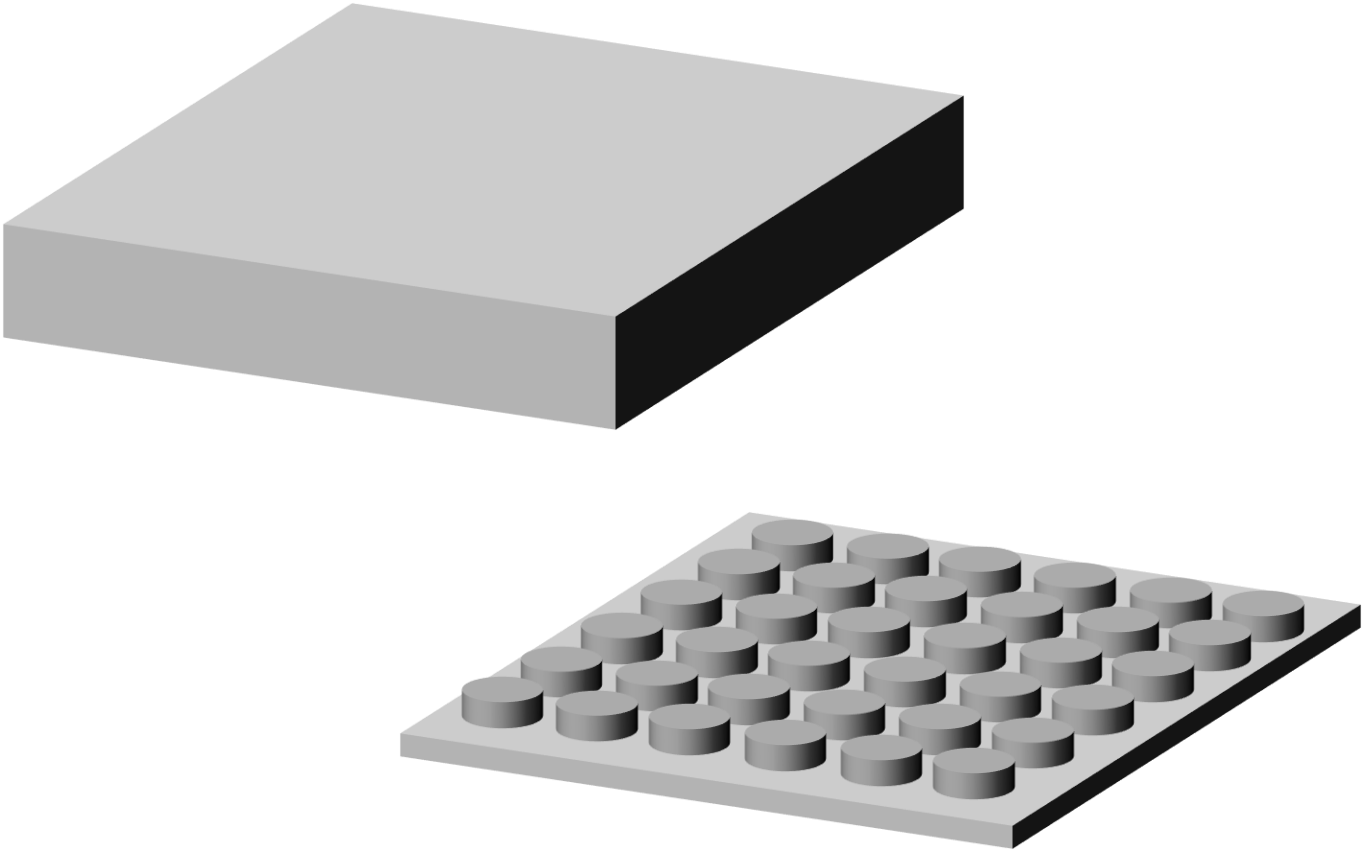






Biosensors 2016, 6 (3), E47



plasmonic nanostructures

as substrates for SERS sensors