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PLASMONIC NANOPARTICLES FOR VIRUS DETECTION

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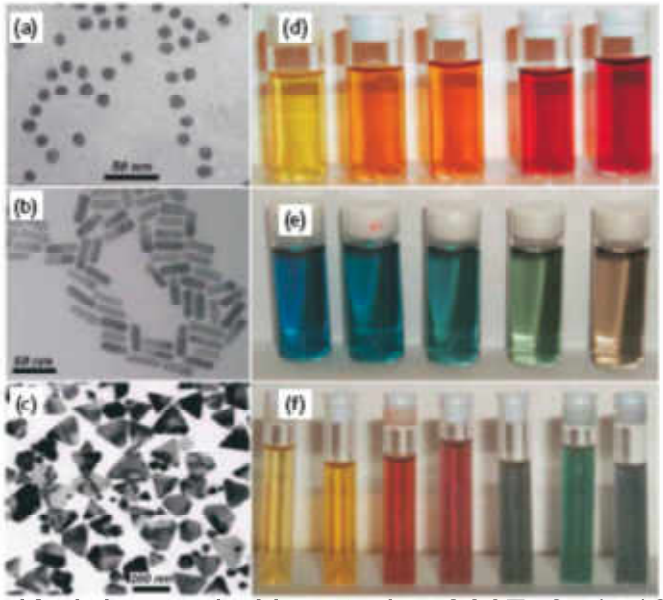
Outline

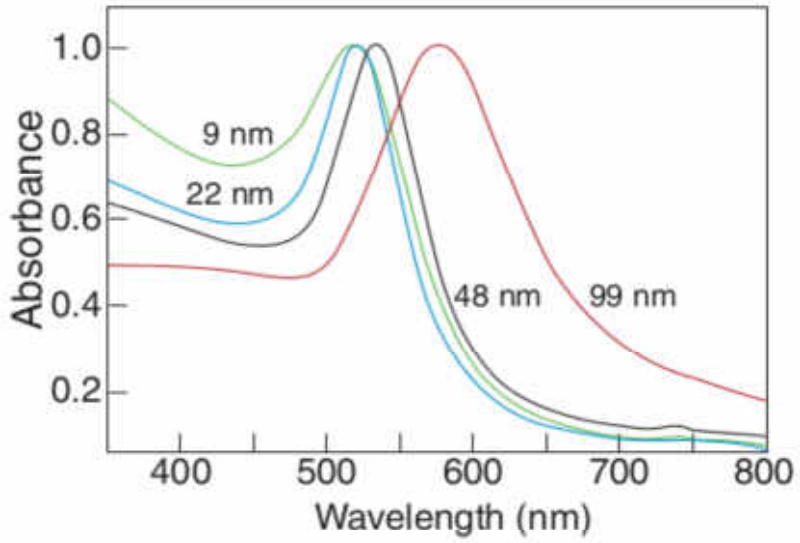
1. Metal nanoparticles and its localized surface plasmon resonance (LSPR)
2. Synthesis and characterization of metal nanoparticles
3. Development of metal nanoparticles application in virus detection
4. Colorimetric plasmon sensor with multilayer metallic nanoparticles sheet

Metal Nanoparticles

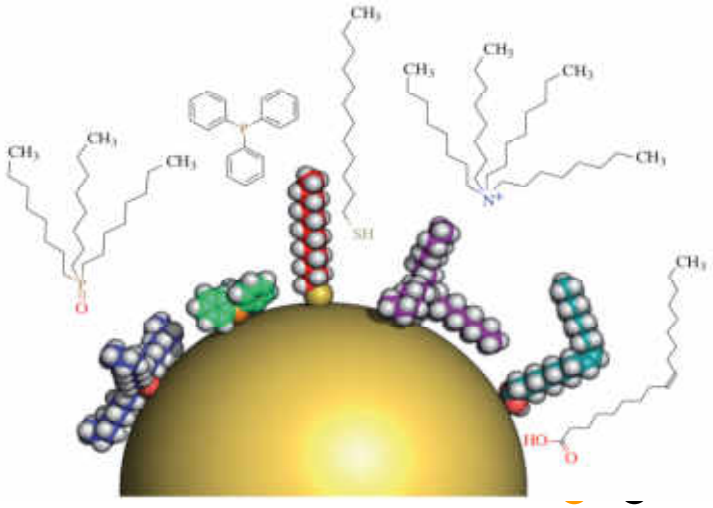
Metal Nanoparticles (NPs) → Unique physical and chemical properties which different from those of the bulk materials depending on their size (quantum size effect).



P. K. Jain et. al., Nanotoday ***2007,*** *2, 1, 18-29*



Capping molecules → For surface-passivation to avoid coagulation and fusion of metal cores.



Specific properties of nanoparticles (NPs) are determined by nano-thickness interfacial region

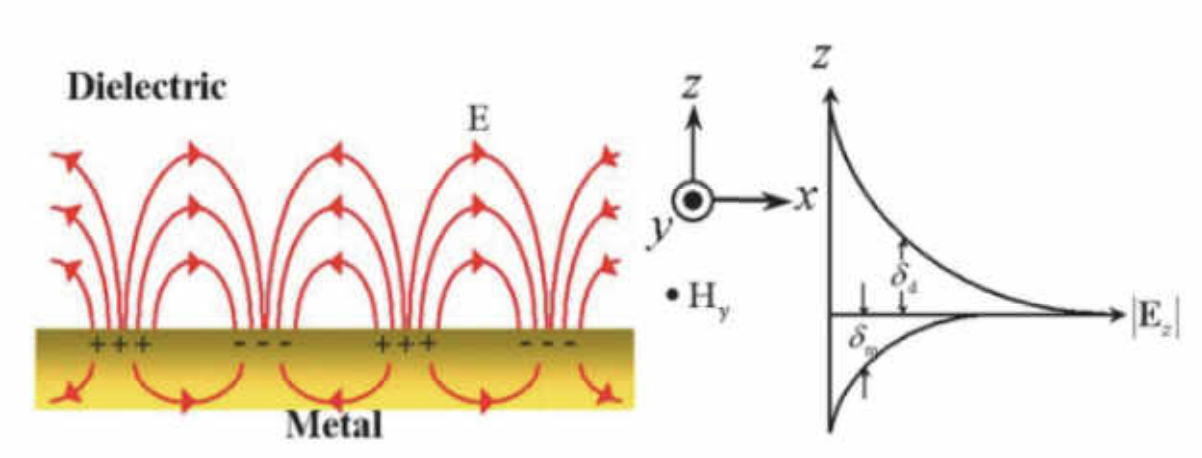
- Dispersibility in solvent
- Localized surface plasmon resonance (LSPR)

R.A. Sperling et.al., Phil. Trans.R. Soc. A ***2010****, 368, 1333-1383*

Surface plasmon polariton

Non-radiative electromagnetic surface wave that propagates in a direction parallel to the dielectric material interface.

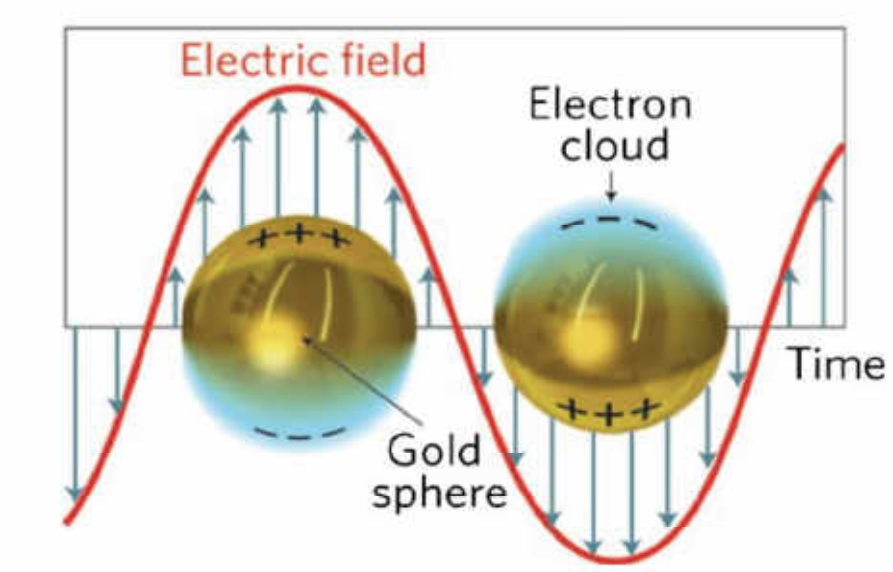
$$\beta_{SP} = k_0 \sqrt{\frac{\varepsilon_d \, \varepsilon_m}{\varepsilon_d + \varepsilon_m}}$$



Localized surface plasmon resonance

Collective electron charge oscillations in metallic nanoparticles that are excited by light. They exhibit enhanced near-field amplitude at the resonance wavelength.

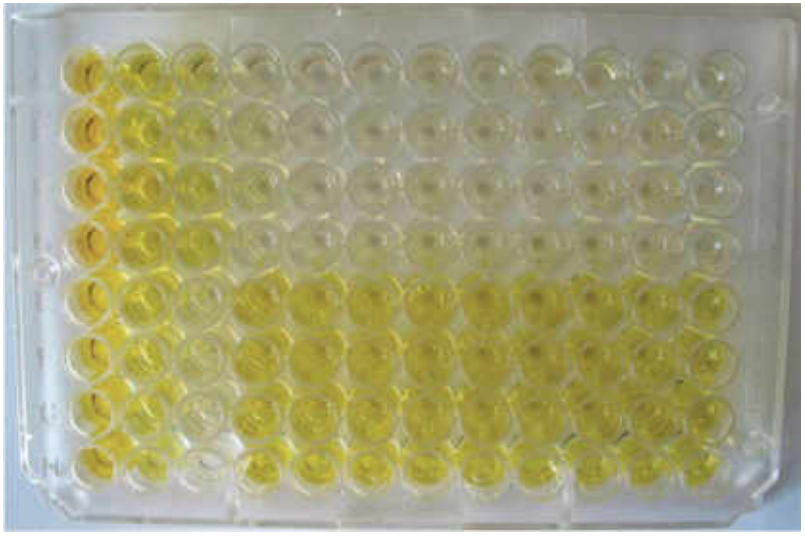
AuNPs dan AgNPs with diameter size 1-20 nm (<< λ) → the suspension display a strong SPs around 510 nm.



Liang et.al., Plasmonic ***2014****, 9, 859-866*

Metal Nanoparticles and Biosensor

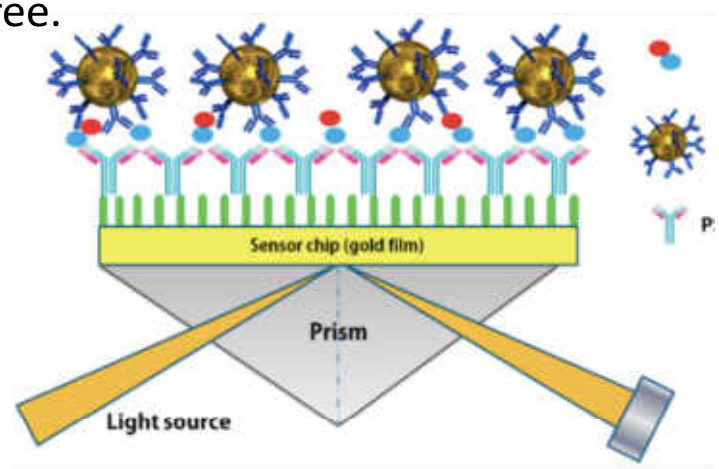
The commonly used biosensing technique are **fluorescence immunoassay** and **enzyme-linked immunosorbent assay (ELISA)**.

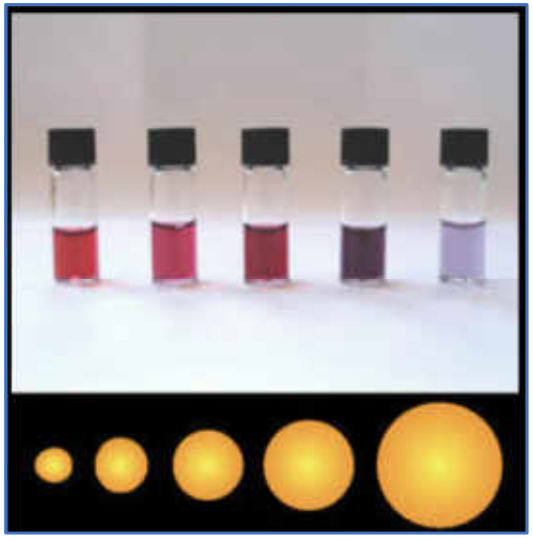


Metallic nanoparticles have been utilized to enhance the signal intensity and improve the reliability of the diagnostics

Colorimetric detection by naked eye is the most simple and convenient diagnostic method (It does not require any complex optical and electric system).

Surface plasmon resonance (SPR) and **quartz crystal microbalance (QCM)** sensors have been develop as an alternative label free.





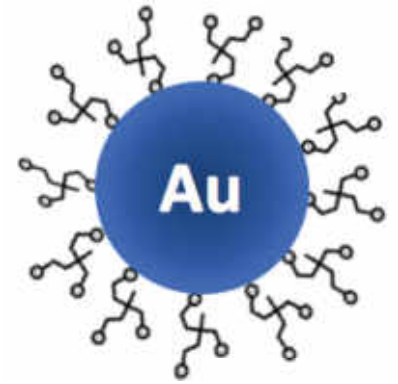
Synthesis and Characterization of Metal Nanoparticles

Synthesis of gold nanoparticles capped by citrate (AuCA)

Chloroauric acid ($HAuCl_4$) in water

(i) Heat to 100°C, 1 h under reflux

(ii) Add aqueous Trisodium citrate dihydrate ($C_6H_5Na_3O_7.2H_2O$)



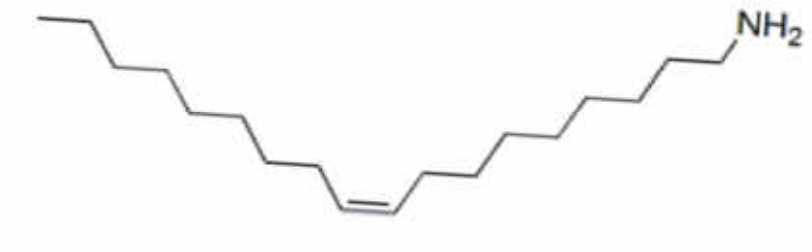
Turkevich et.al., Discuss. Faraday. Soc.(1951),11,55.
Frens et. al., Nat. Phys. Sci. (1973), 241, 20.

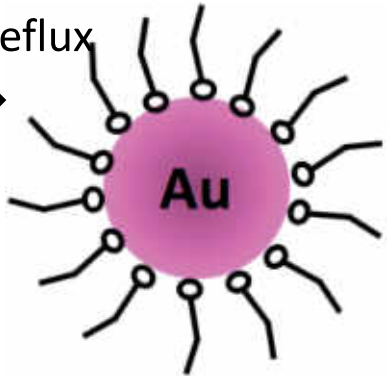
Synthesis of gold nanoparticles capped by Oleylamine (AuOA)

Chloroauric acid ($HAuCl_4$) in water + Oleylamine ($C_{18}H_{35}NH_2$)

(i) Heat to 110°C, 1 h under reflux

(ii) Add toluene as solvent

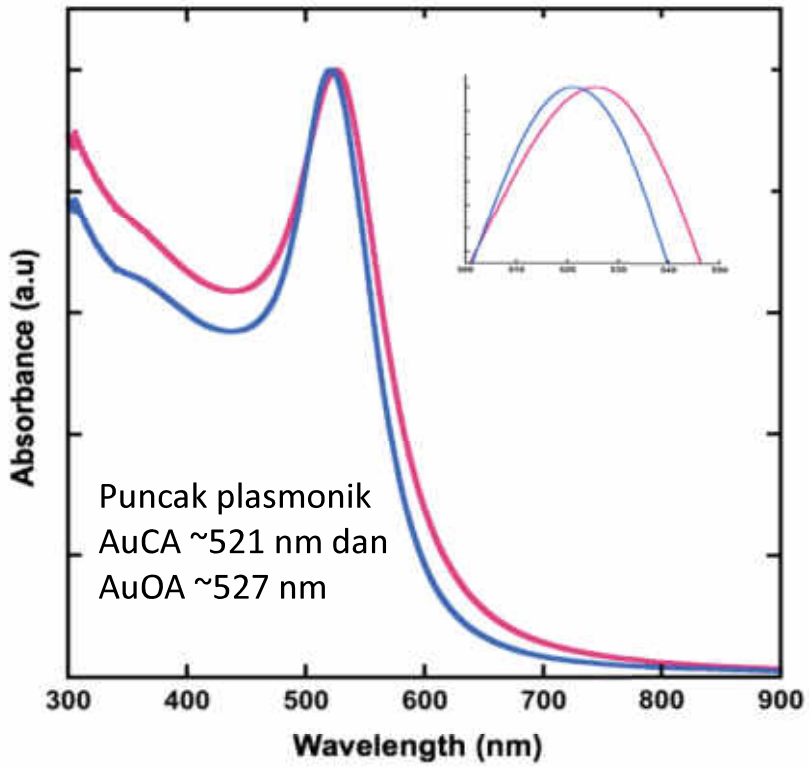




Hiramatsu et.al., Chem. Mater (2014),16,2509.
Masuda et. al., Sci. Rep. (2017), 7, 3720.

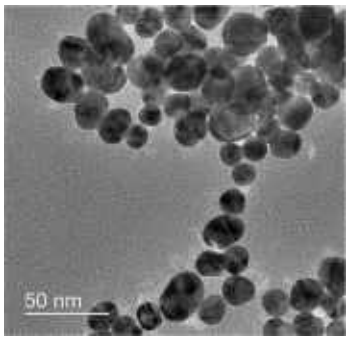
Synthesis and Characterization of Metal Nanoparticles

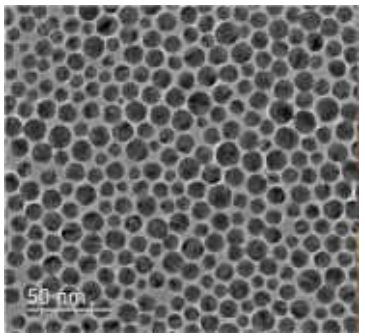
UV-Vis spectra of AuCA and AuOA in solution



- The conformation of citrates on Au nanoparticles is different from that of trisodium citrate.
- The enhancement of peak intensities due to effect of LSPR from Au nanoparticles.

TEM images of AuCA and AuOA

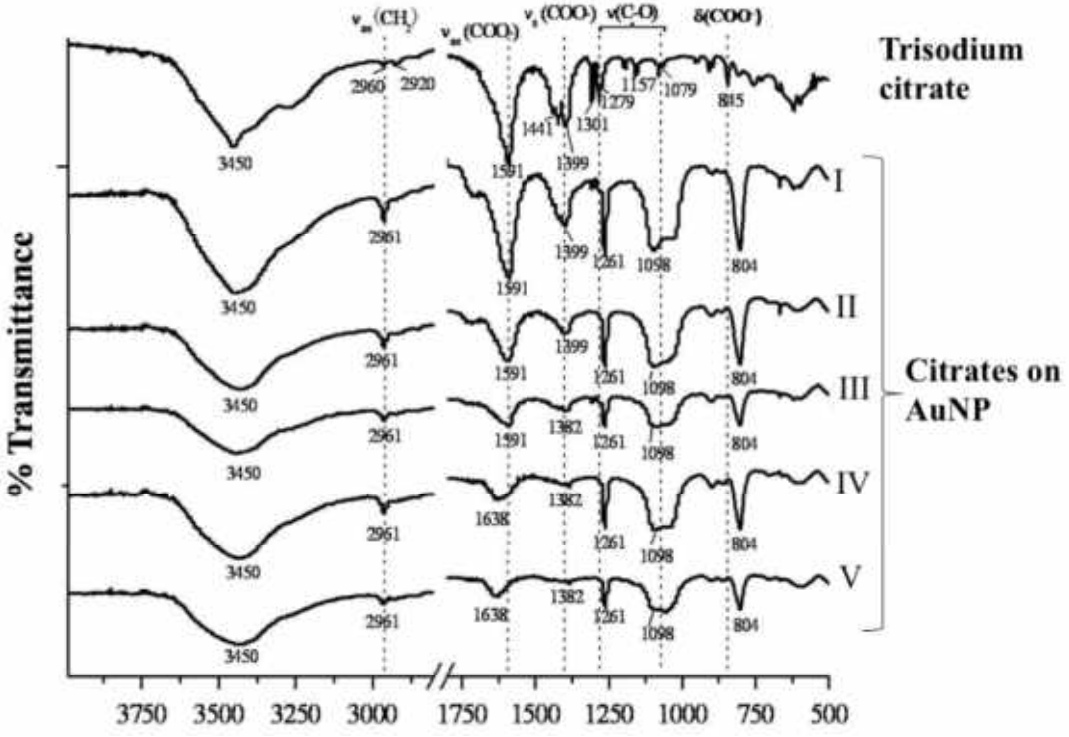




$d_{Au\text{-}CA}$ ~ 15 nm

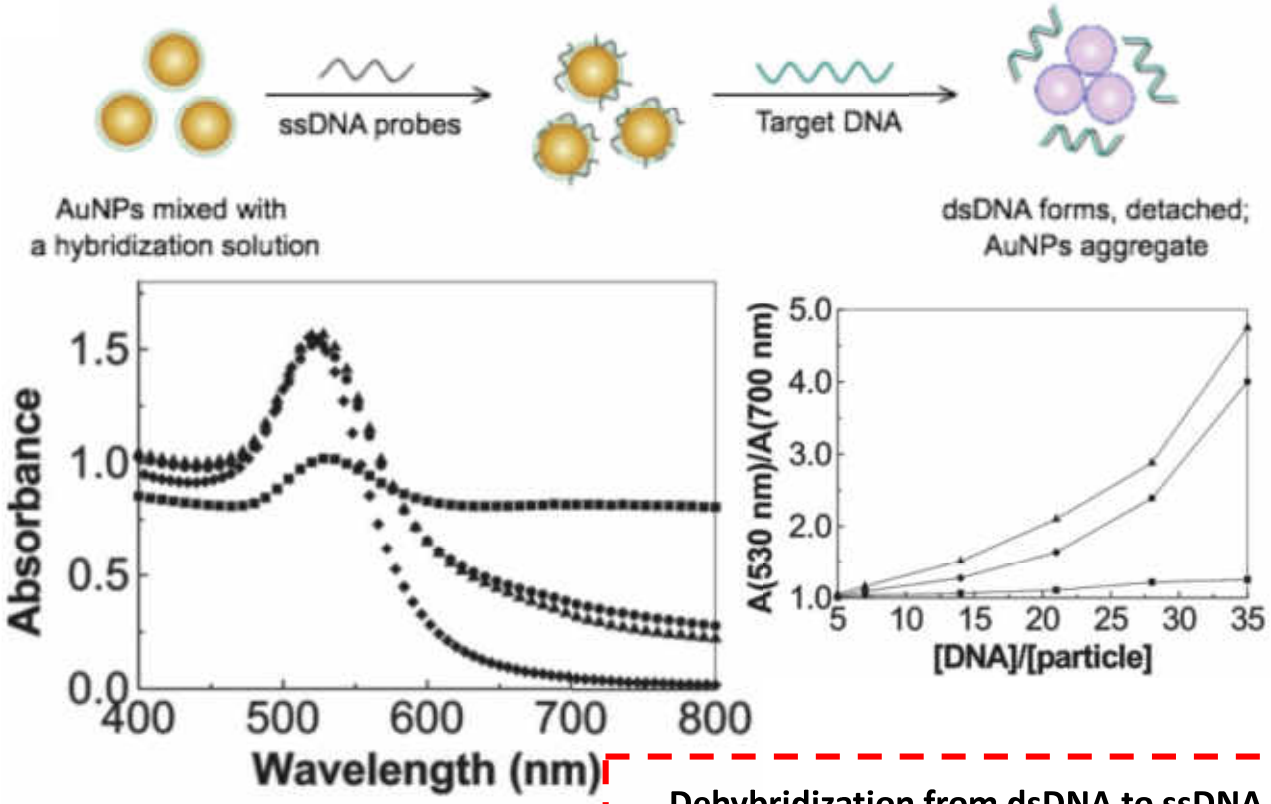
d_{AuOA} ~ 10 nm

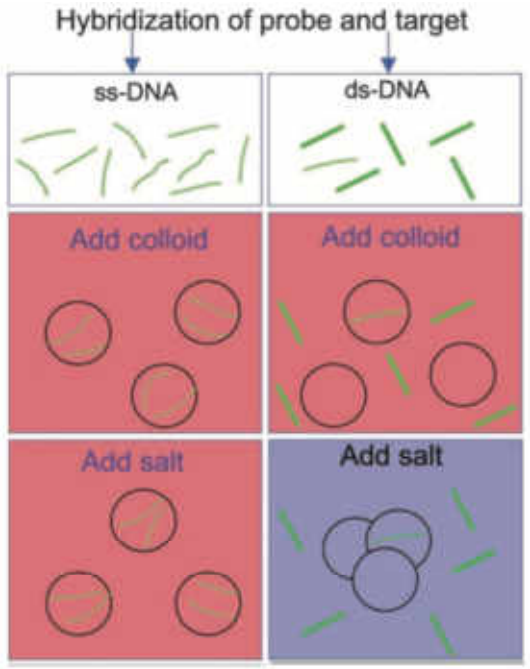
FT-IR spectra of AuCA before and after purification



Application of metal nanoparticles

1. Colorimetric detection of DNA sequences based on electrostatic interactions with unmodified gold nanoparticles





Dehybridization from dsDNA to ssDNA

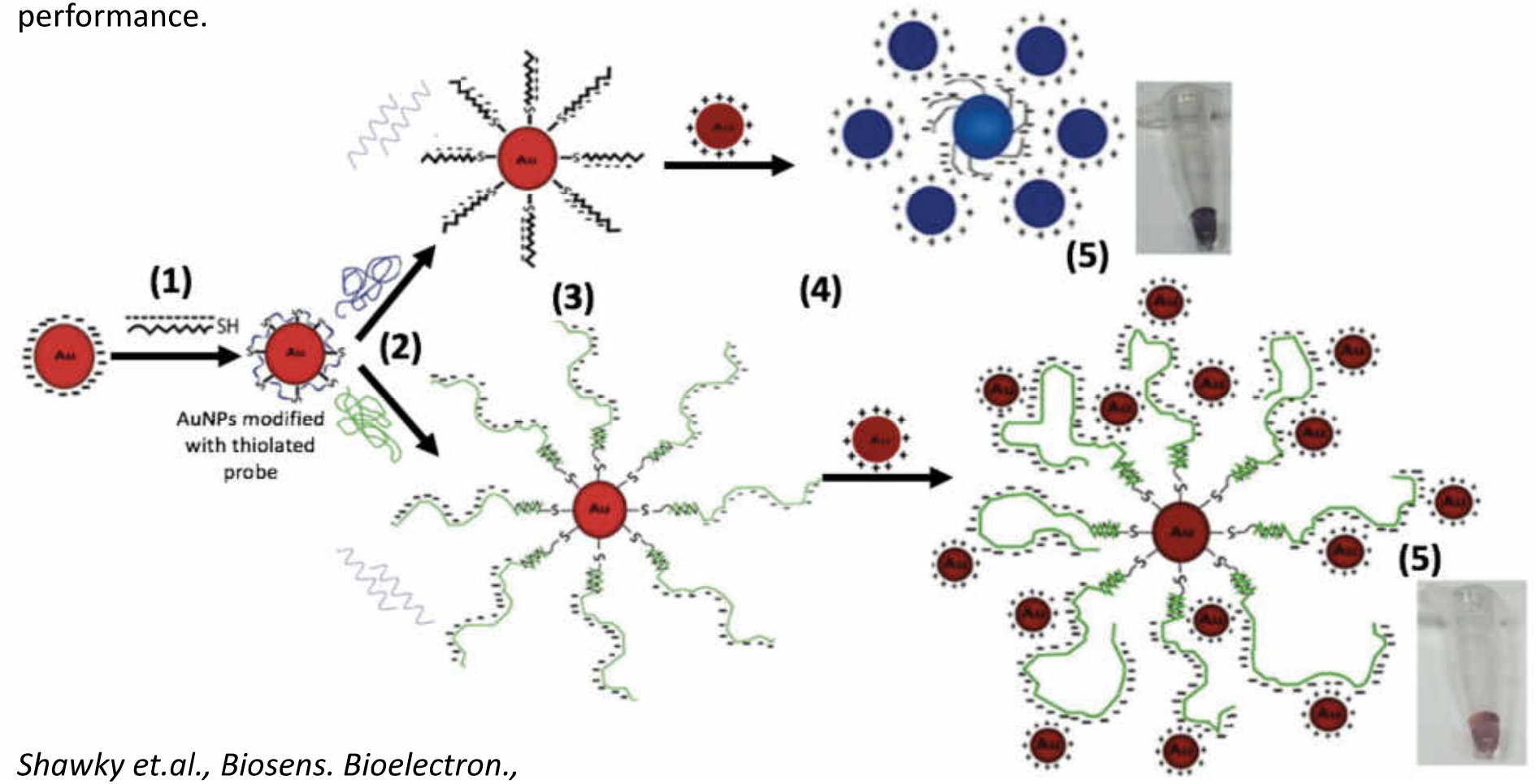
- ssDNA and dsDNA have different propensities to adsorb on AuNP because of their electrostatic properties.
- Hybridization assay is complete within 5 min and <100 femtomoles of target produces color changes observable without instrumentation.

Li et.al., Proc. Natl. Sci. USA (2004), 101, 14036

Application of metal nanoparticles

2. Nanoparticles biosensor approach for the direct quantification of Hepatitis C virus RNA in clinical samples

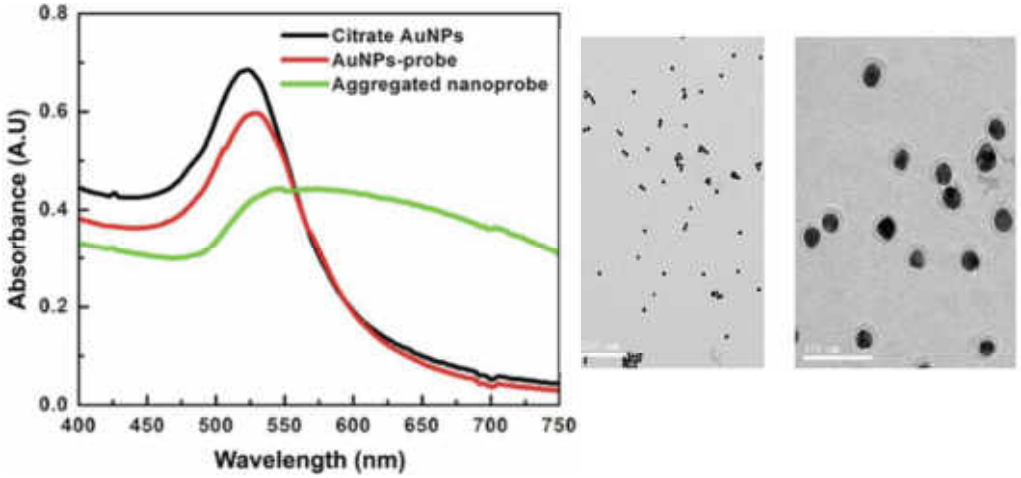
The assay is based on inducing aggregation of citrate AuNPs decorated with a specific nucleic acid probe. Two types of cationic AuNPs, cysteamine and CTAB capped, were compared to achieve maximum assay performance.



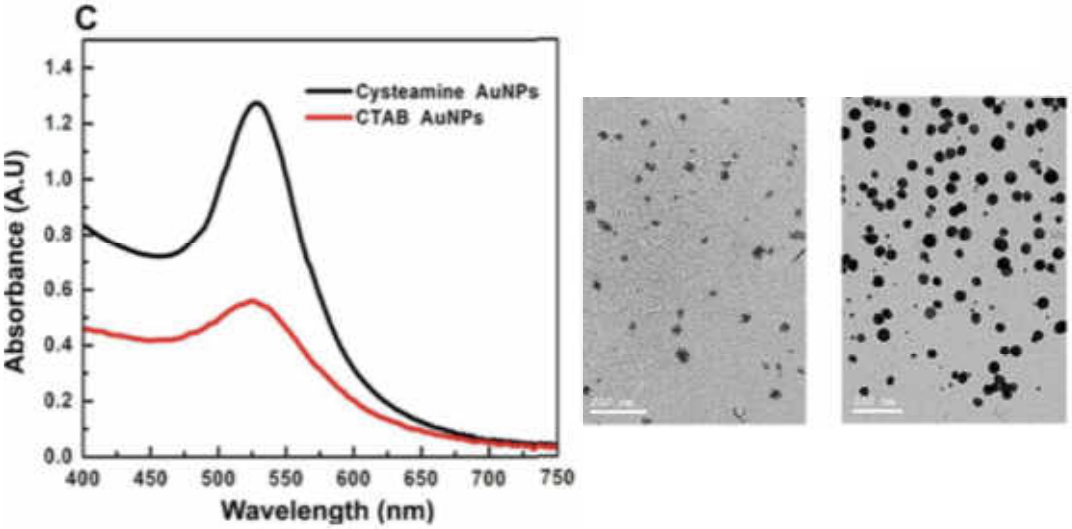
Shawky et.al., Biosens. Bioelectron.,
DOI: j.bios.2016.11.001

Application of metal nanoparticles

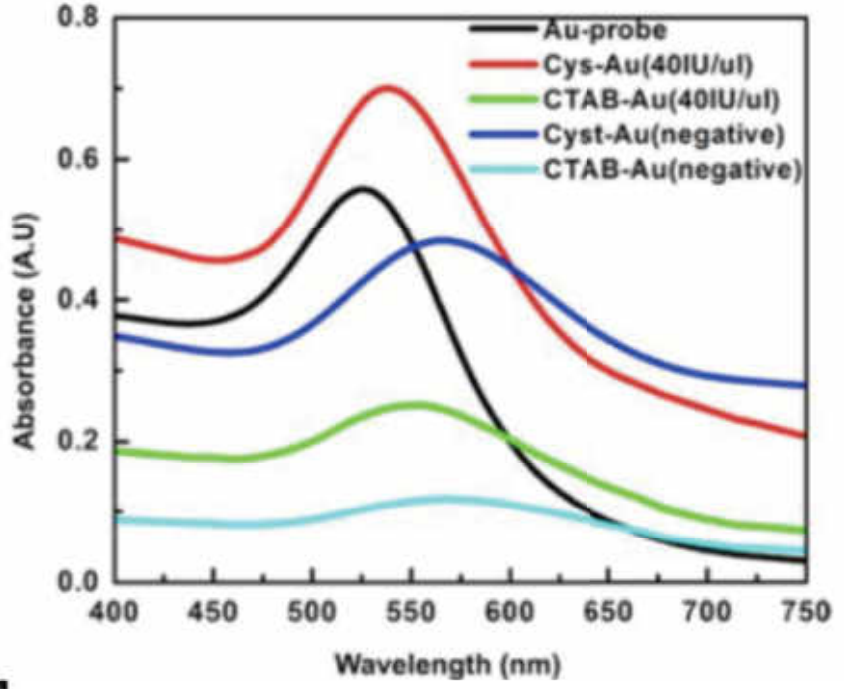
UV-Vis spectra and TEM image of AuNP capped by citrate



UV-Vis spectra and TEM image of AuNP capped by CTAB and Cysteamine

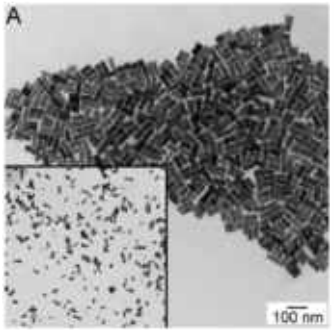


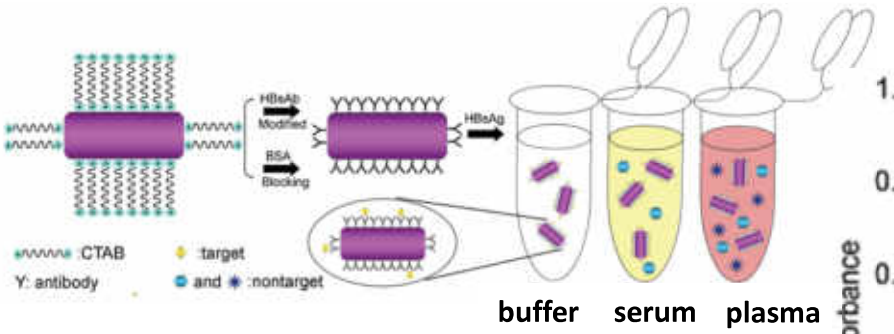
Analysis of HCV clinical samples using cysteamine and CTAB AuNPs



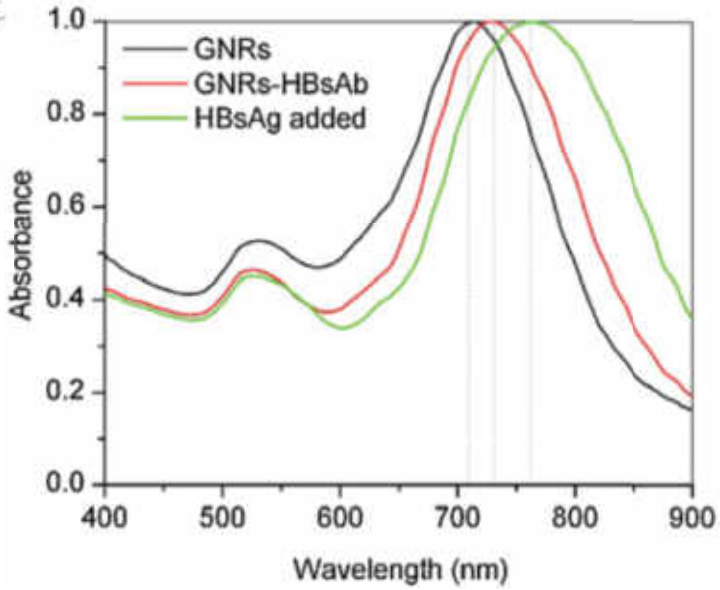
Application of metal nanoparticles

3. Gold nanorod-based LSPR biosensor for sensitive detection of hepatitis B virus in buffer, blood serum and plasma

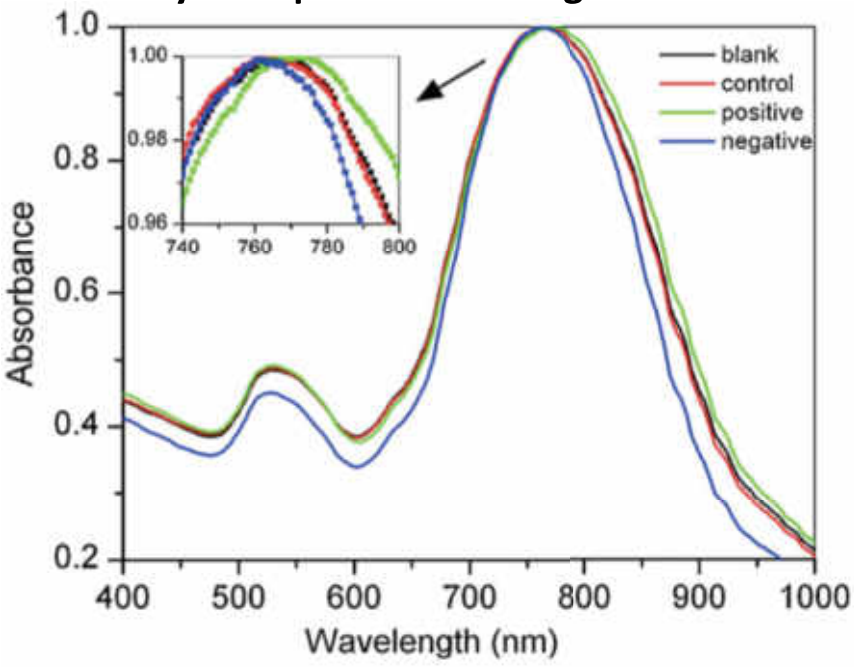




Plasmon absorption spectra for the GNR material before and after HBsAb protein functionalization



The biosensor's behavior in qualitative analysis of positive and negative serum



- The biosensor design based on ELISA and demonstrated that the steric effect would not affect much of the binding affinity of the antigen/antibody pair.
- The sensor response to HBsAg standard material binding to the probe in Tris buffer was concentration-dependent, with the range from 0.01 IU/mL to 1 IU/mL.

Wang et.al., Biosens. Bioelectron.(2014),26,404.

Thank you