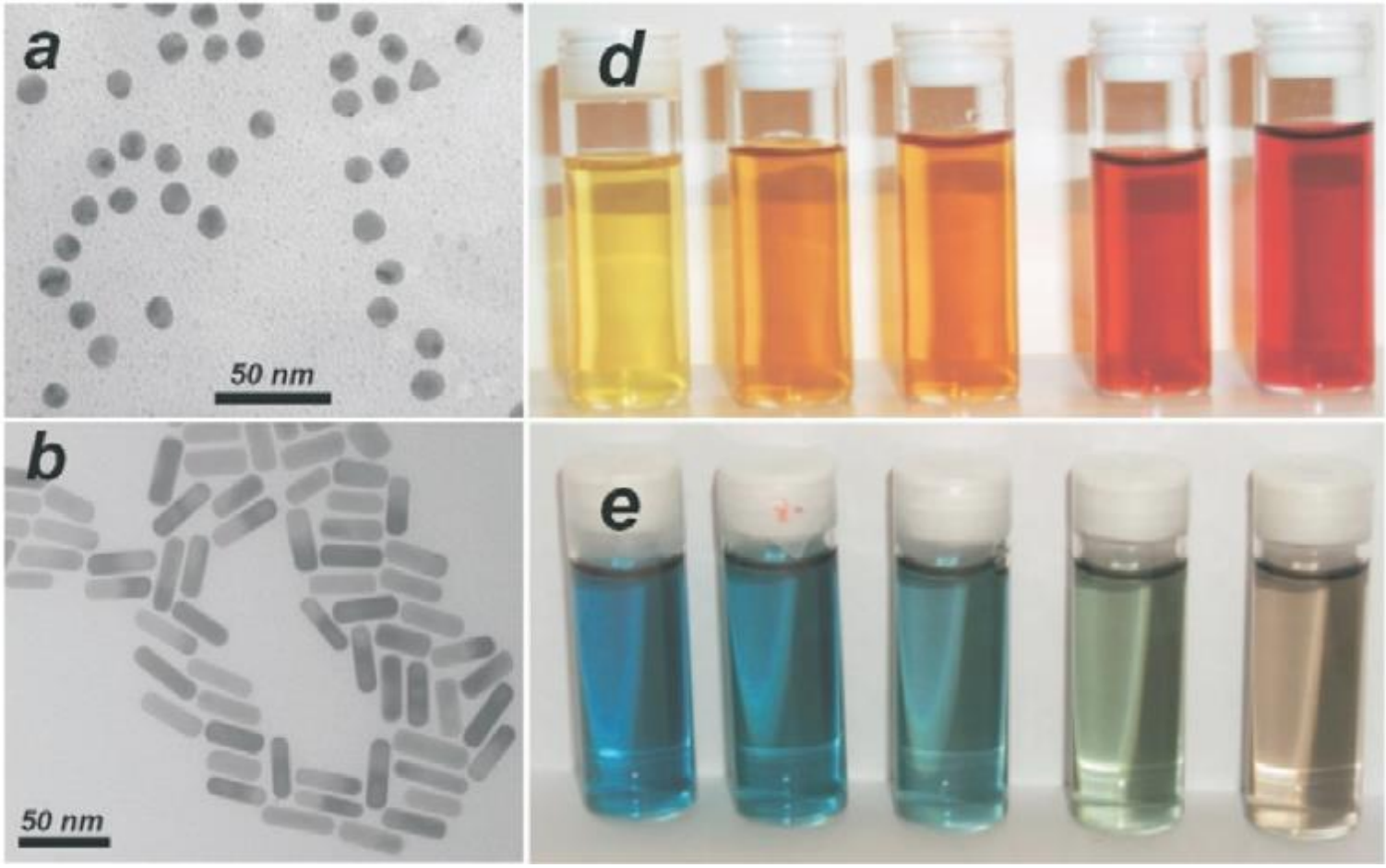
2. L-SPR control

non interacting NPs

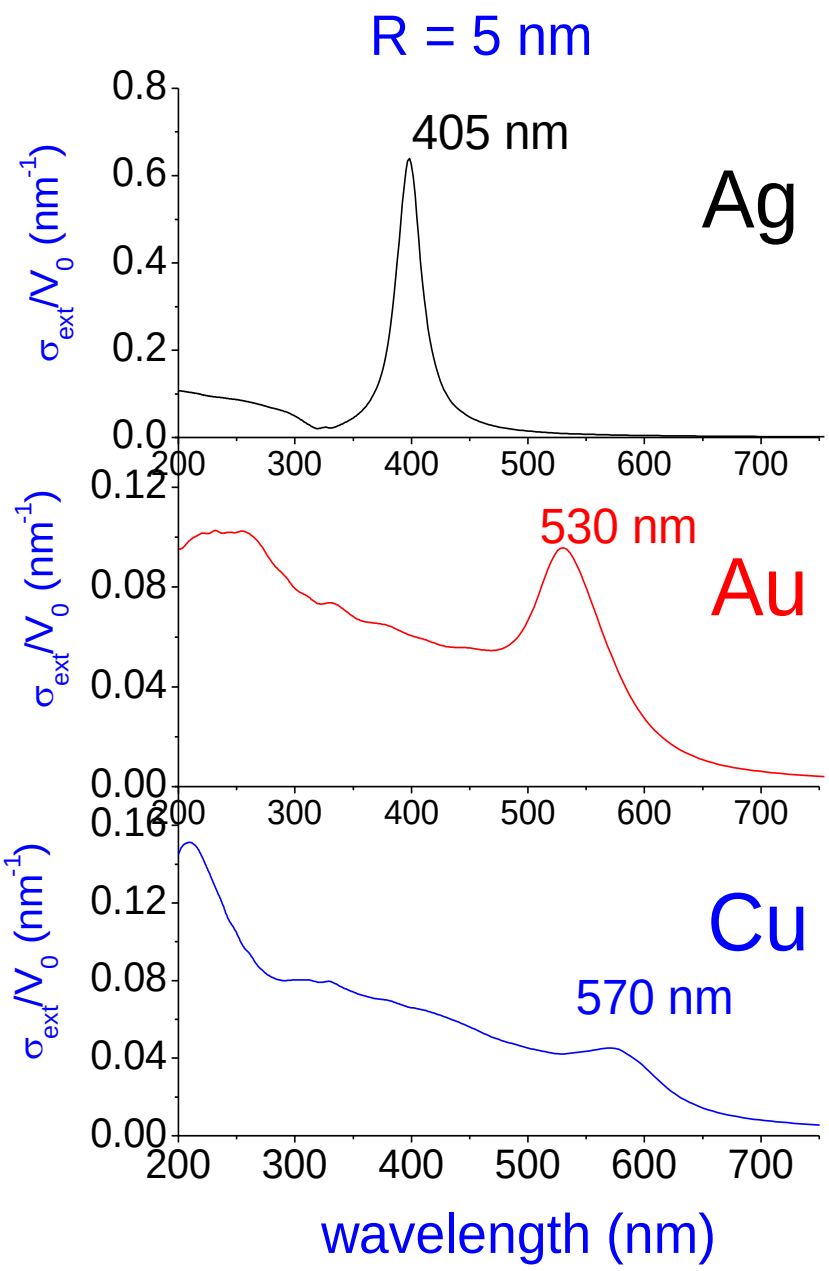
SPR Control

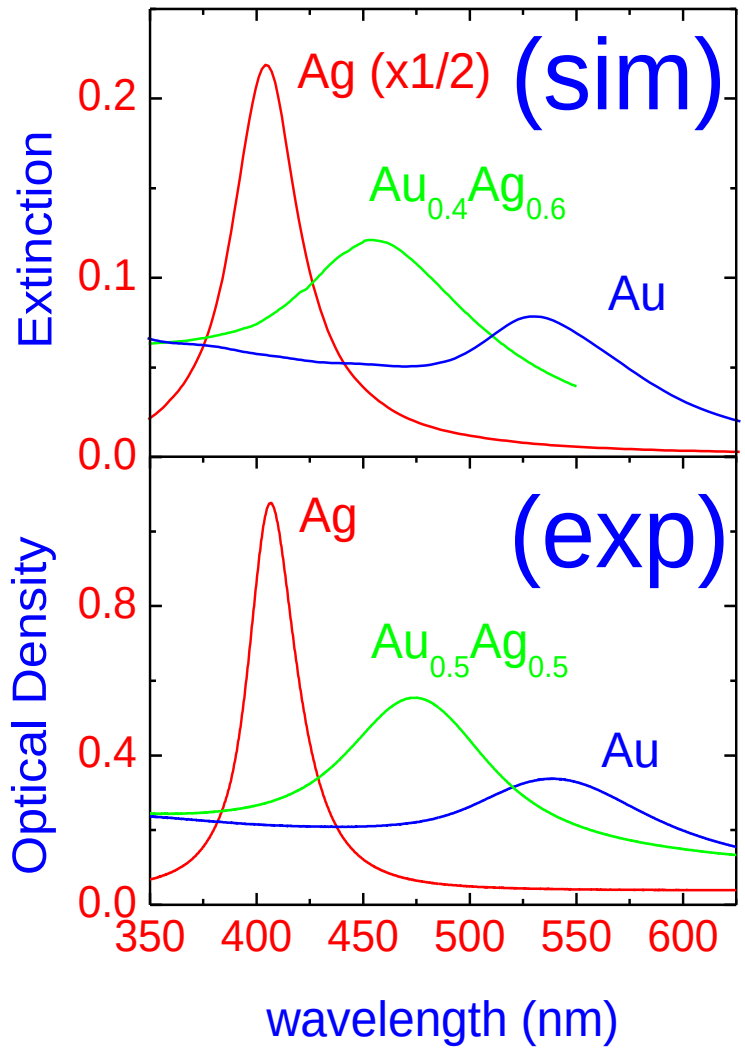


Concentration
(Interaction)

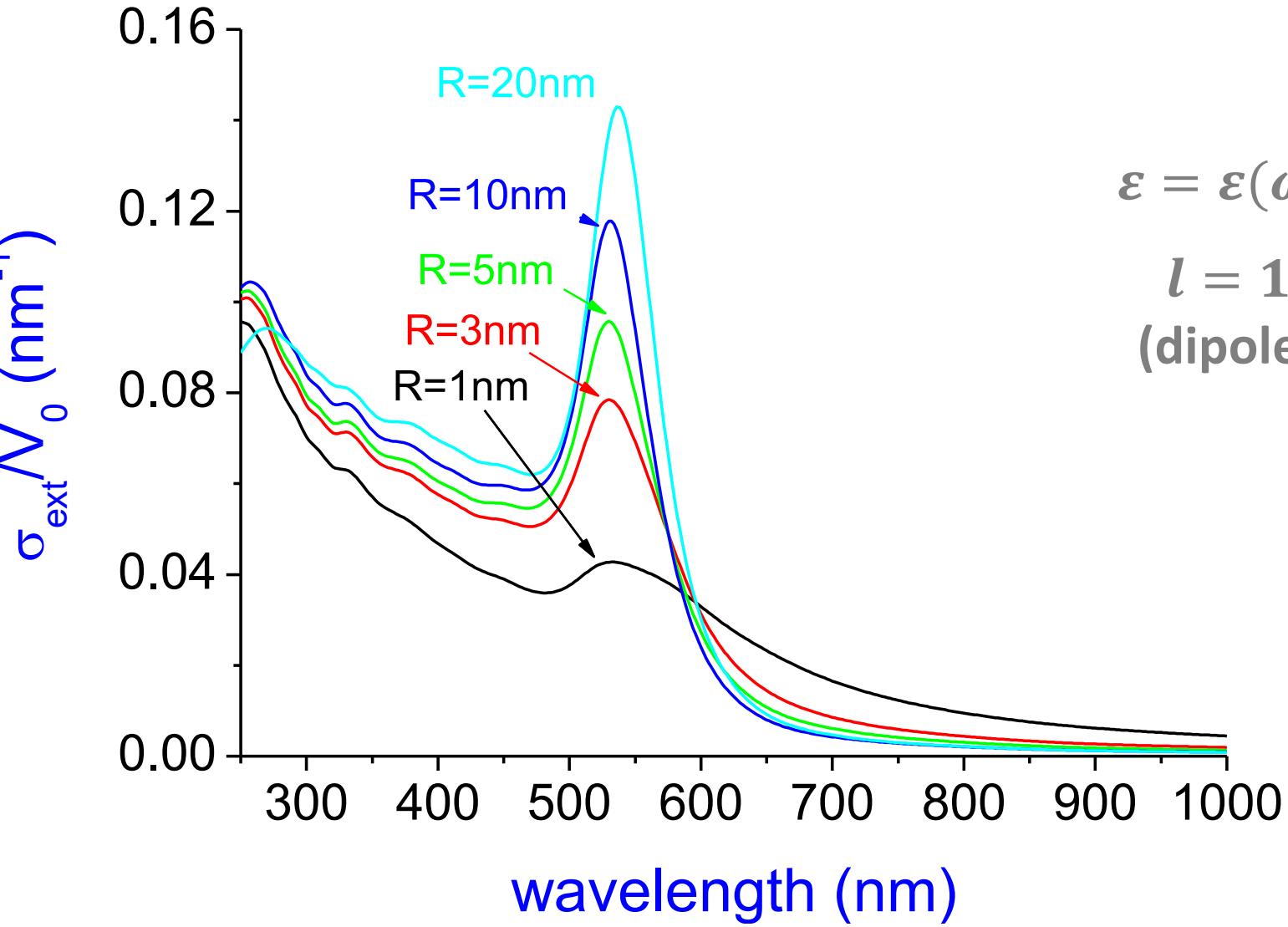
Aspect ratio

Au NCs


R = 5 nm
405 nm
Ag
530 nm
Au
Cu
570 nm
σext/V0 (nm-1)
wavelength (nm)


NP in SiO2
Ag (x1/2)
(sim)
Au0.4Ag0.6
Au
Ag
(exp)
Au0.5Ag0.5
Au
Extinction
Optical Density
wavelength (nm)

Au NP in SiO_2

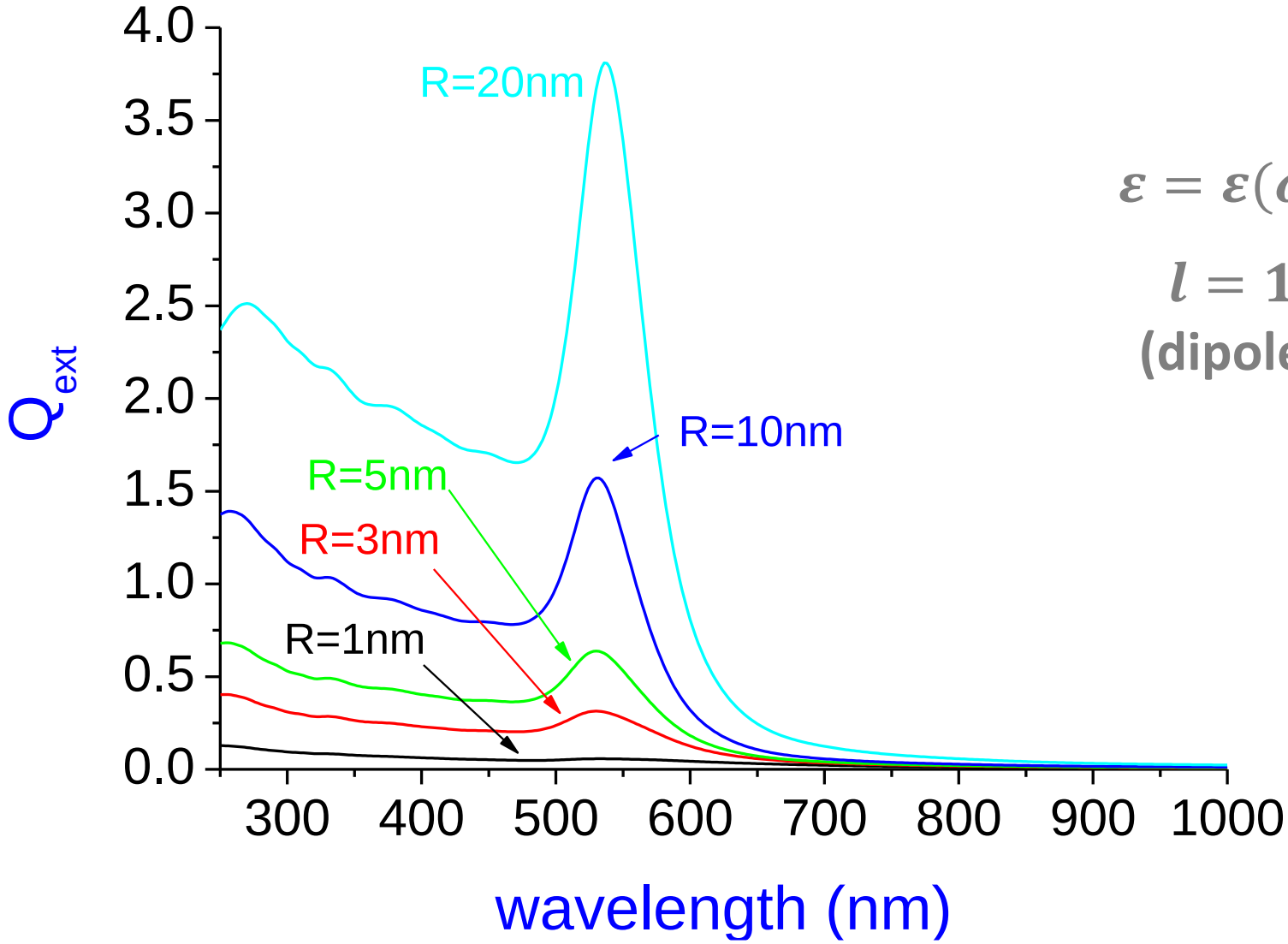


$$\varepsilon = \varepsilon(\omega, R)$$

$$l = 1$$

(dipole)

Au NP in SiO_2(eff.)

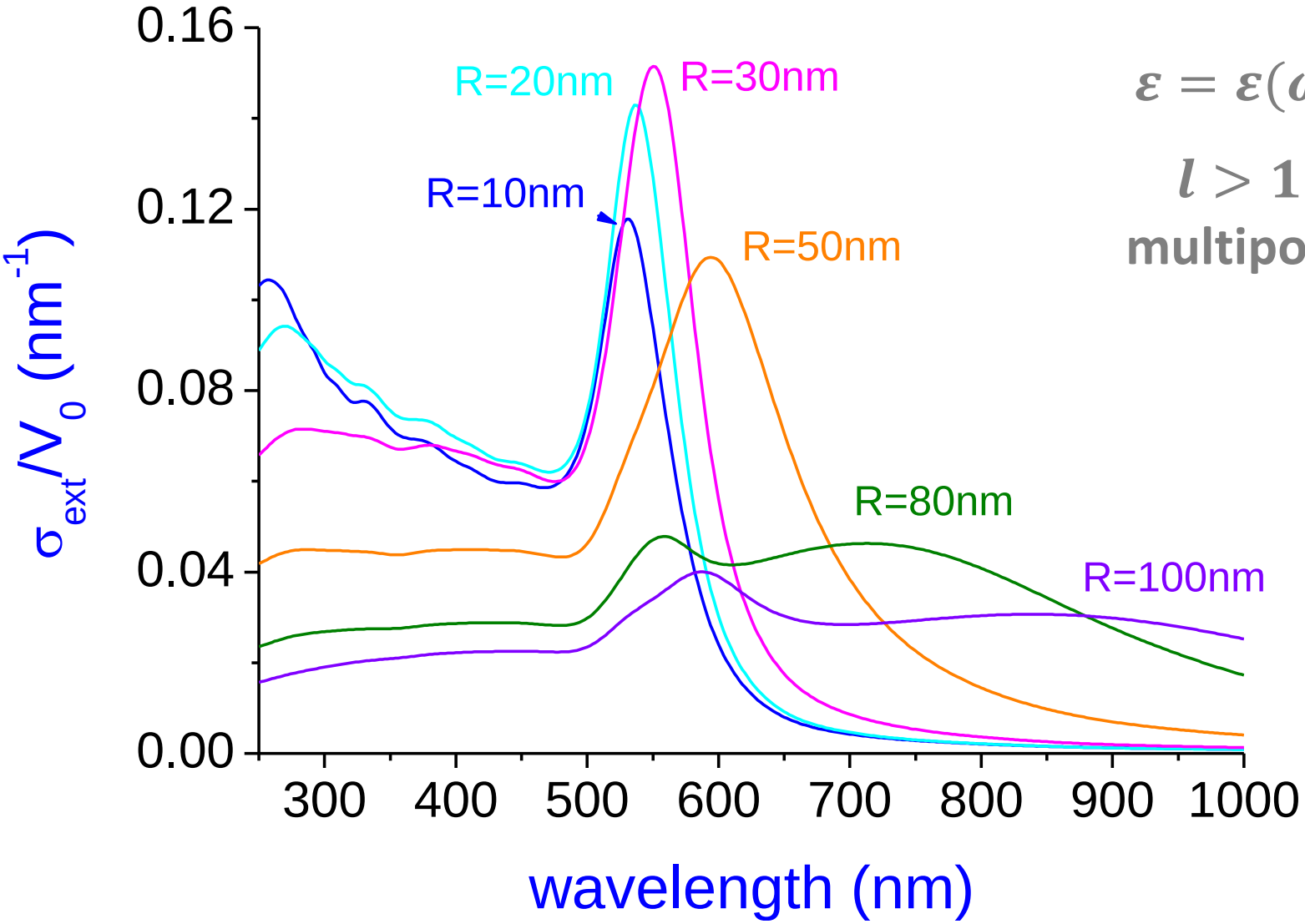


$$\varepsilon = \varepsilon(\omega, R)$$

$$l = 1$$

(dipole)

Au NP in SiO_2

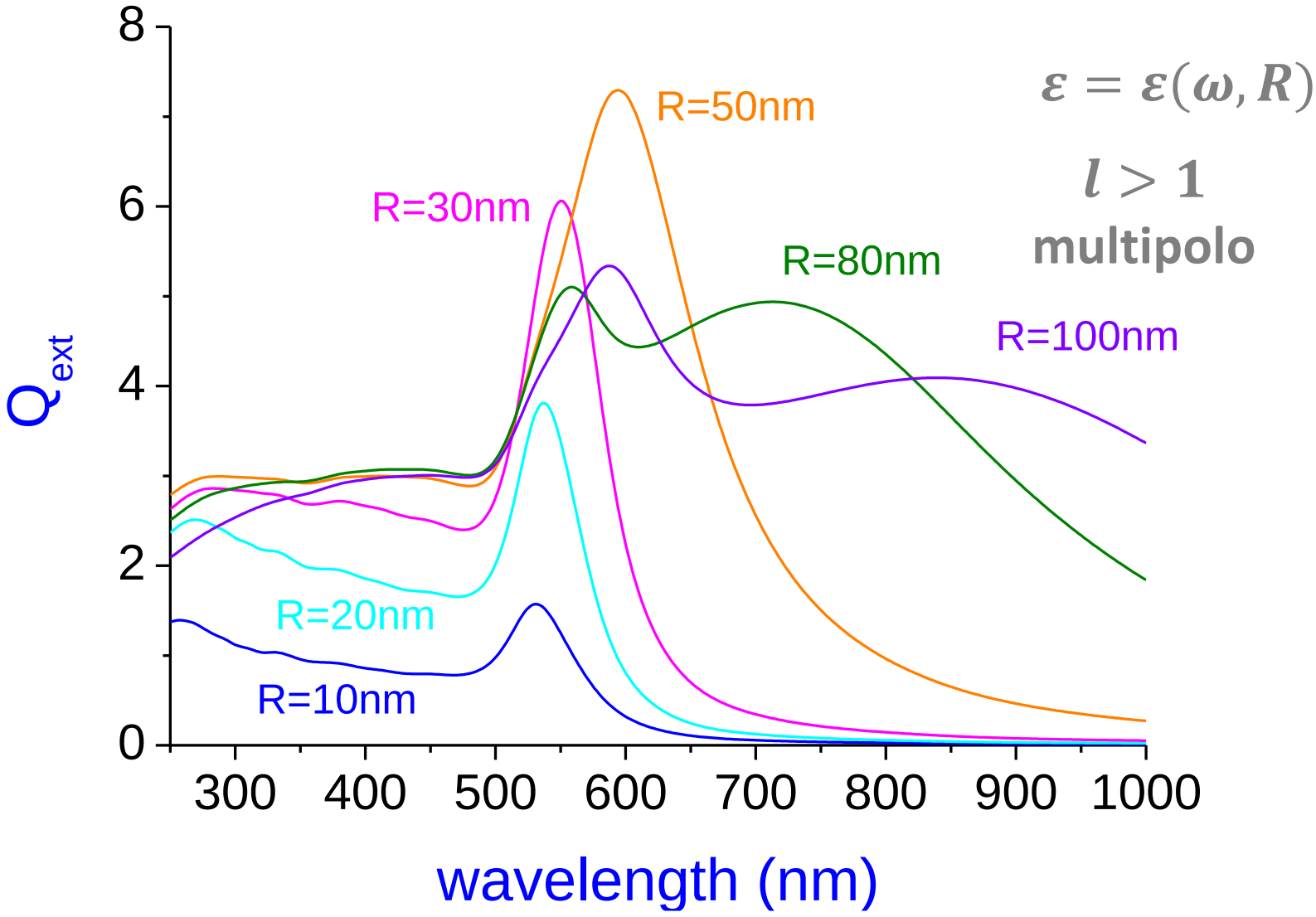


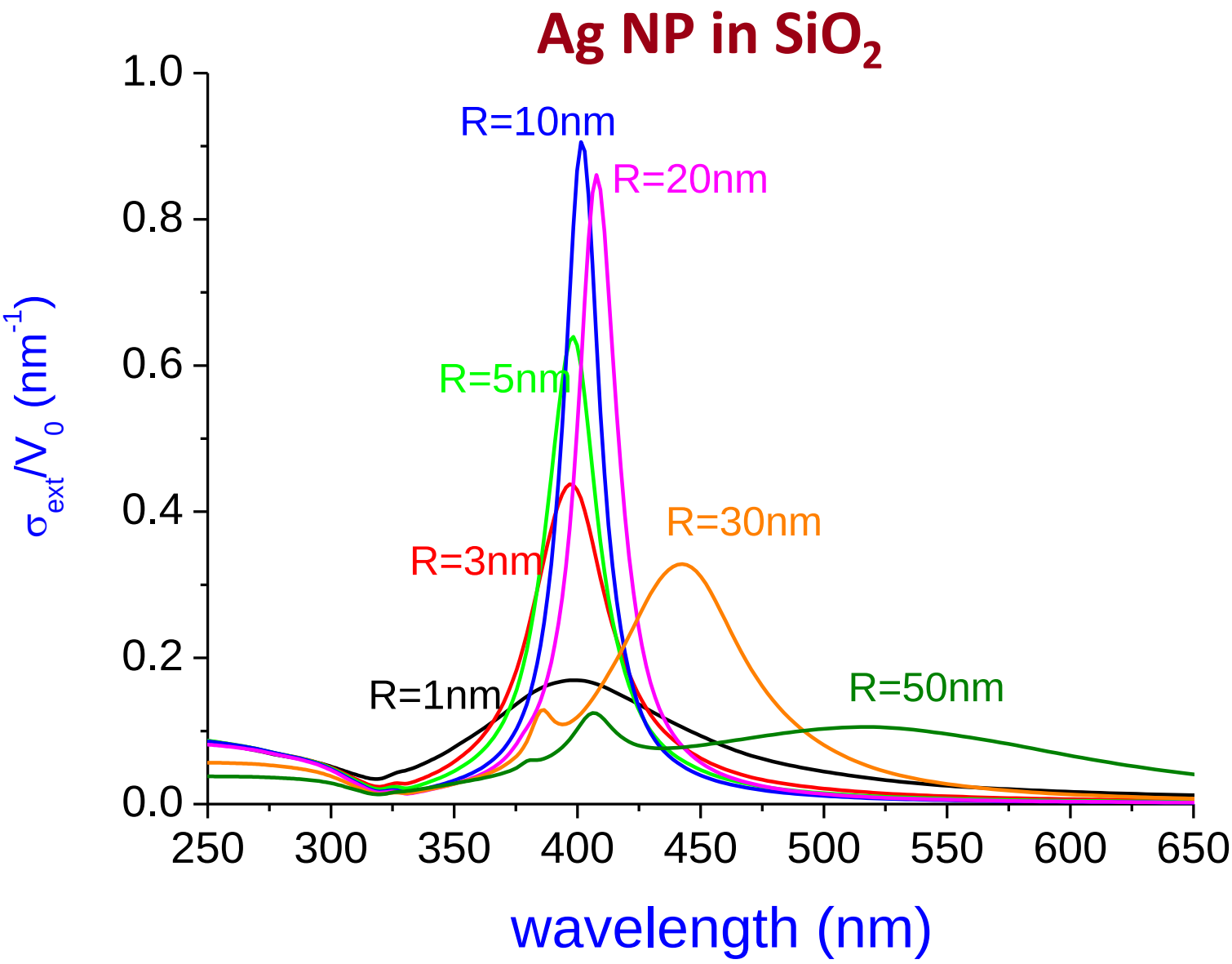
$$\varepsilon = \varepsilon(\omega, R)$$

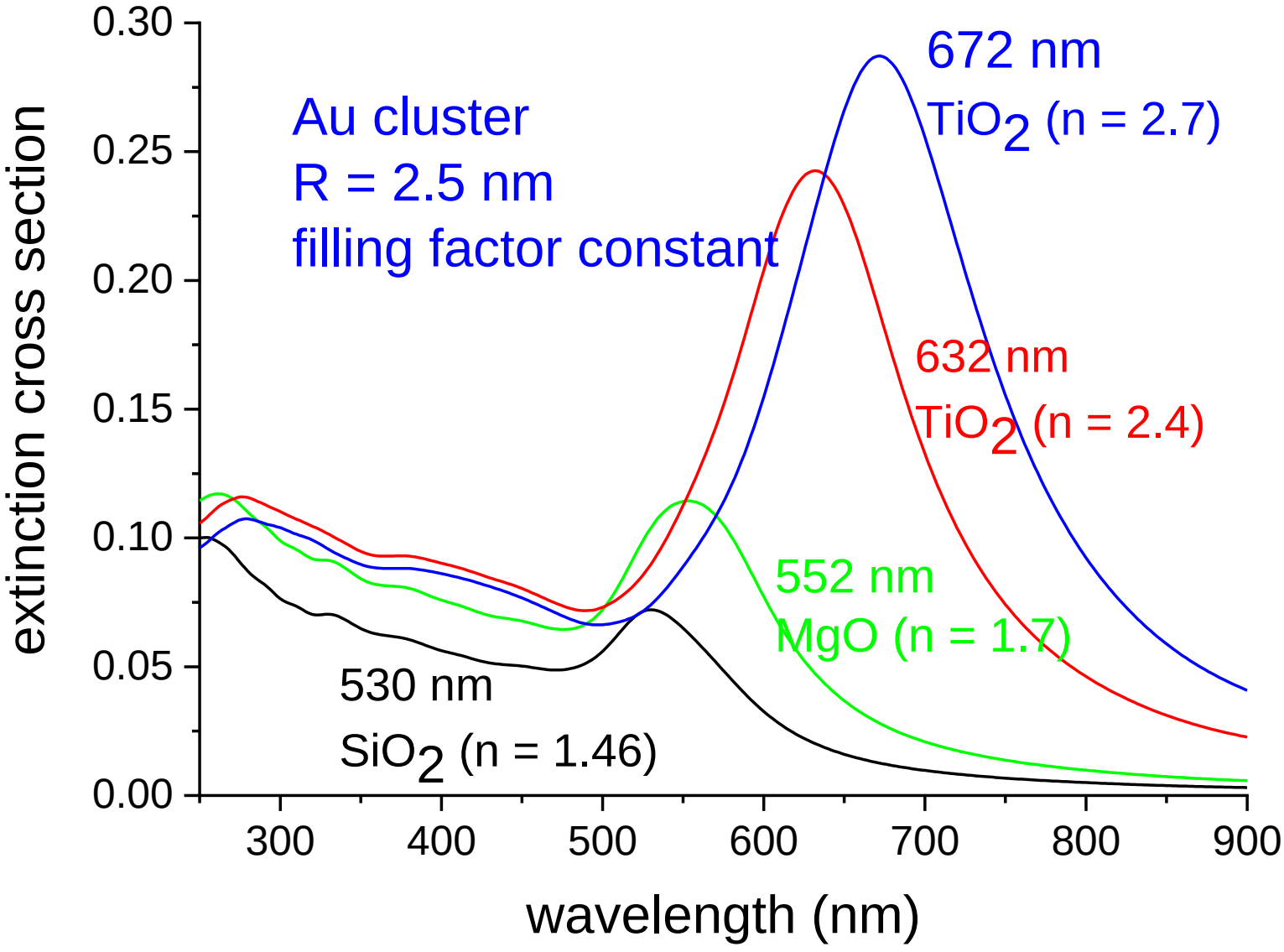
$$l > 1$$

multipolo

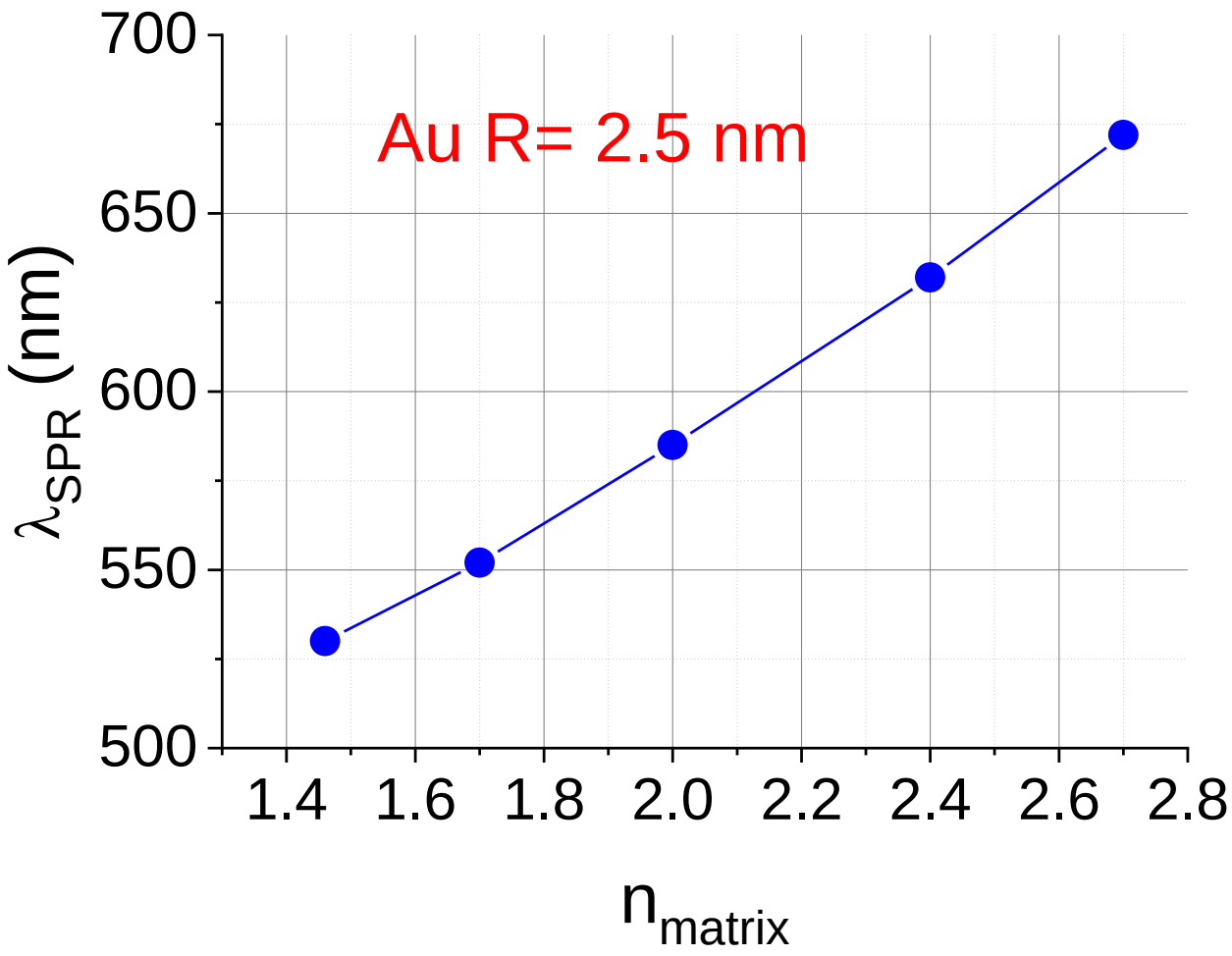
Au NP in SiO_2(eff.)




Ag NP in SiO2
R=10nm
R=20nm
R=5nm
R=30nm
R=3nm
R=1nm
R=50nm
σext/V0 (nm-1)
1.0
0.8
0.6
0.4
0.2
0.0
250
300
350
400
450
500
550
600
650
wavelength (nm)

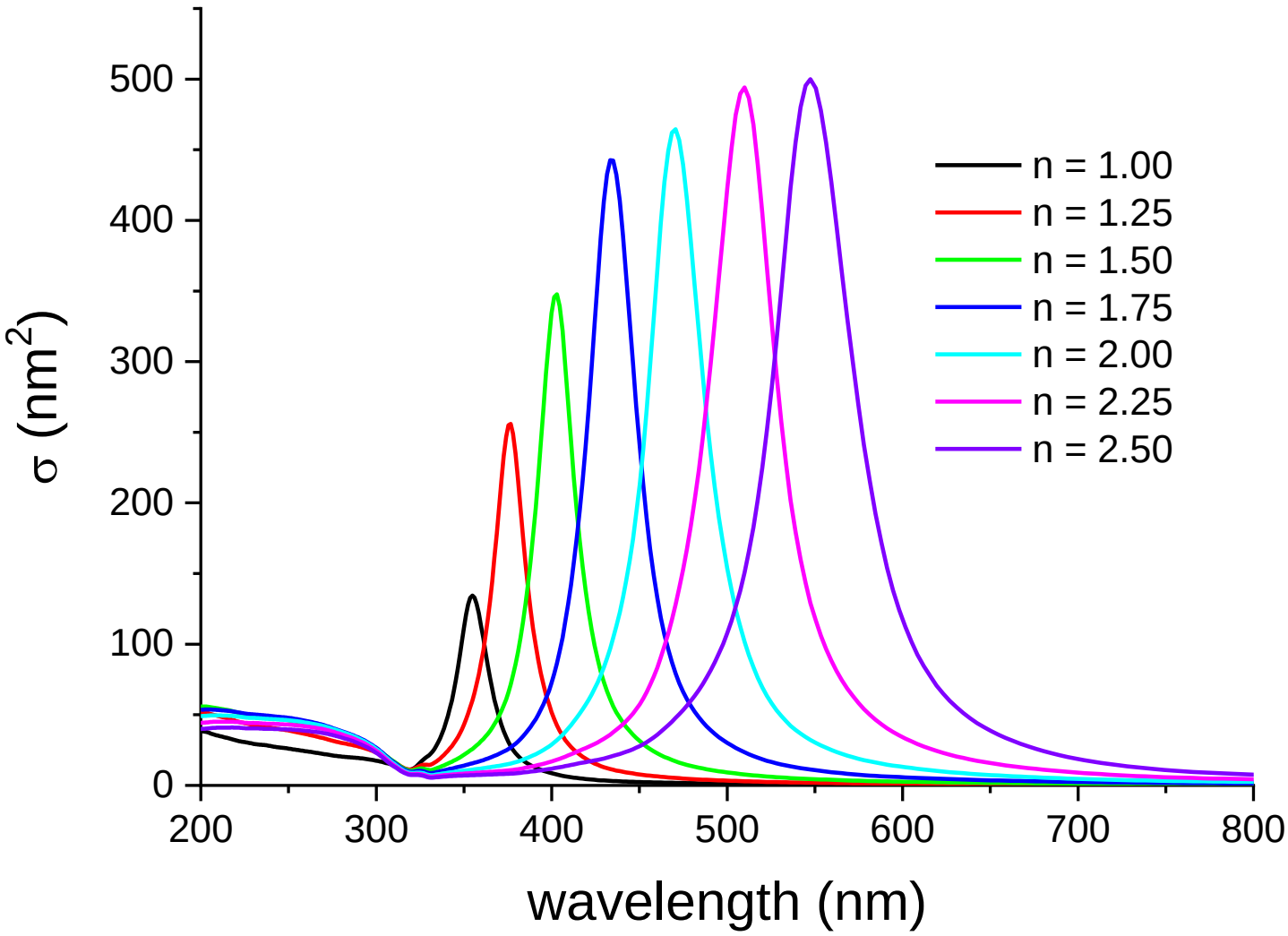

Au cluster
R = 2.5 nm
filling factor constant
672 nm
TiO2 (n = 2.7)
632 nm
TiO2 (n = 2.4)
552 nm
MgO (n = 1.7)
530 nm
SiO2 (n = 1.46)
extinction cross section
wavelength (nm)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
300
400
500
600
700
800
900

Matrix


Au R= 2.5 nm
700
650
600
550
500
λ_{SPR} (nm)
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
n_{matrix}

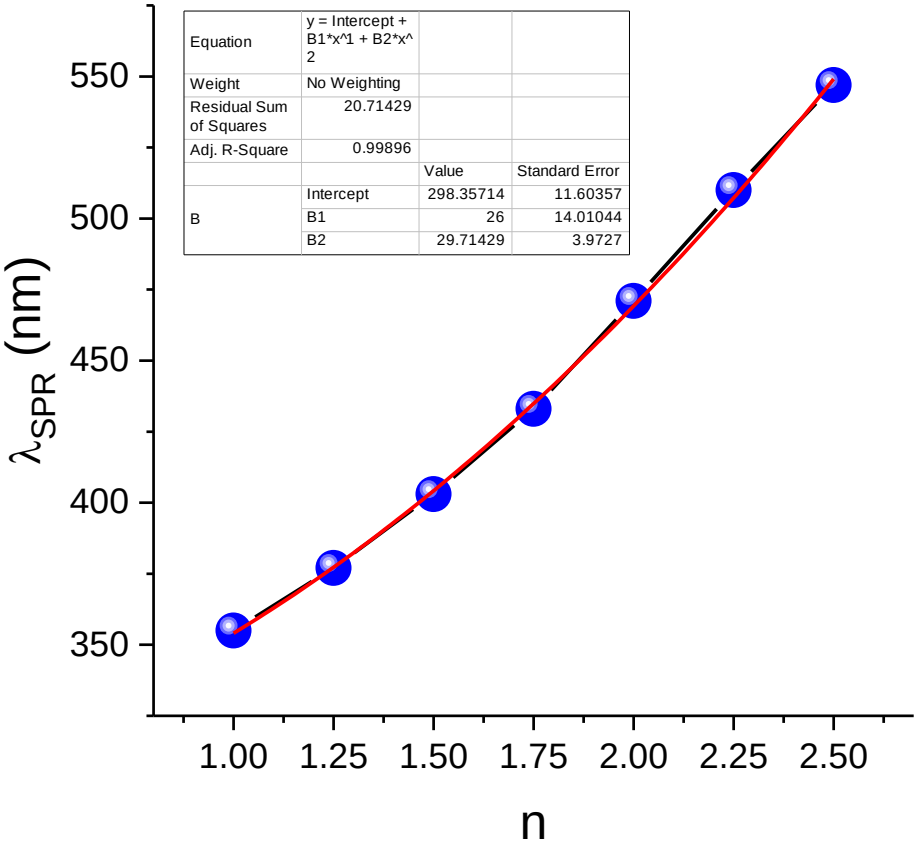
Matrix – SPR Sensor

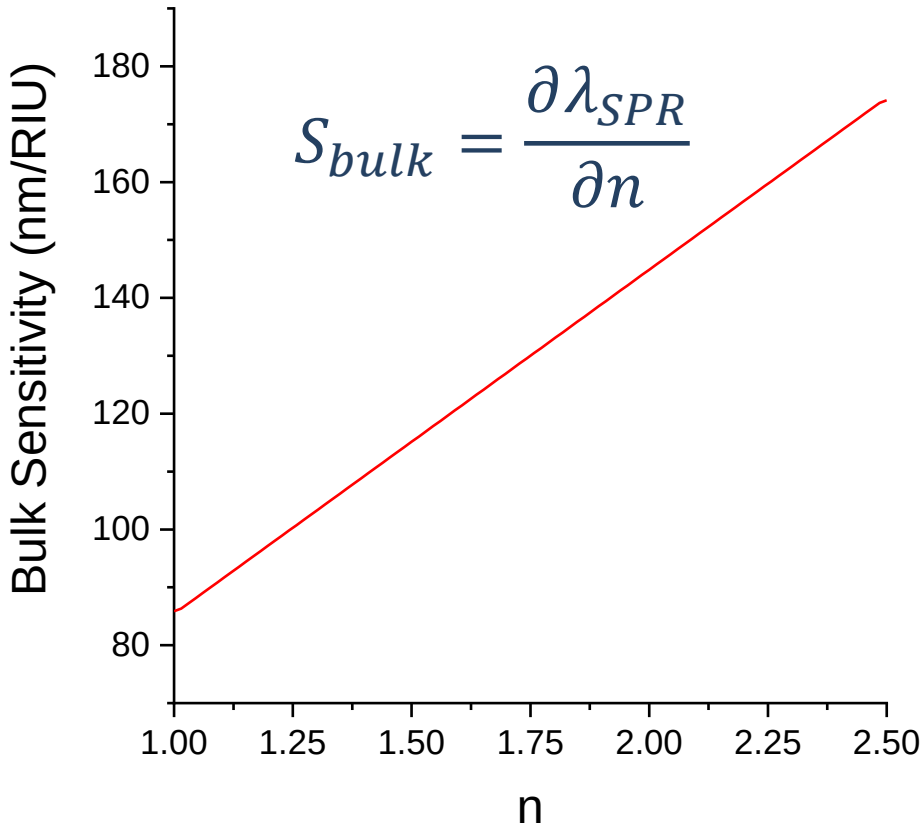
Ag (R=5 nm)



Sensibility to refractive index

Ag (R=5 nm)



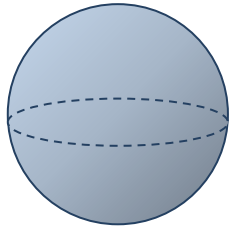


$$S_{bulk} = \frac{\partial \lambda_{SPR}}{\partial n}$$

$$\lambda_{SPR} = b_2 n^2 + b_1 n + b_0$$

$$S_{bulk} = 2b_2 n \quad + b_1$$

Mie Theory (dipolar approx): shape effect

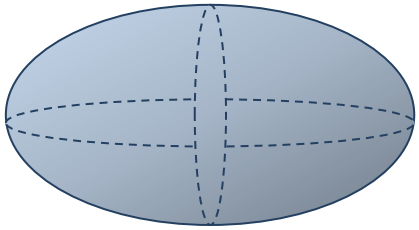
1.  Spherical Cluster

$$\sigma_{ext} = 9\frac{\omega}{c}\varepsilon_m^{3/2}V_0\frac{\varepsilon_2}{(\varepsilon_1+2\varepsilon_m)^2+\varepsilon_2^2}$$

Mie Theory hypotheses:

1. Isolated clusters (non interacting)
2. ε(ω,R) as input
3. Spherical Clusters
4. Non-absorbing medium

2. Ellipsoidal Cluster (Gans Theory)



Dipolar scattering from small, non-interacting volumes

$$\sigma_{ext} = \frac{1}{3}\frac{\omega}{c}\varepsilon_m^{3/2} V_0 \sum_{j=1}^{3} \frac{\varepsilon_2 / L_j^2}{\left[\varepsilon_1 + \varepsilon_m (1 - L_j)/L_j\right]^2 + \varepsilon_2^2}$$

Random distribution

$$L_1 = \frac{1 - e^2}{e^2}\left[\frac{1}{2e}\ln\left(\frac{1+e}{1-e}\right) - 1\right]$$

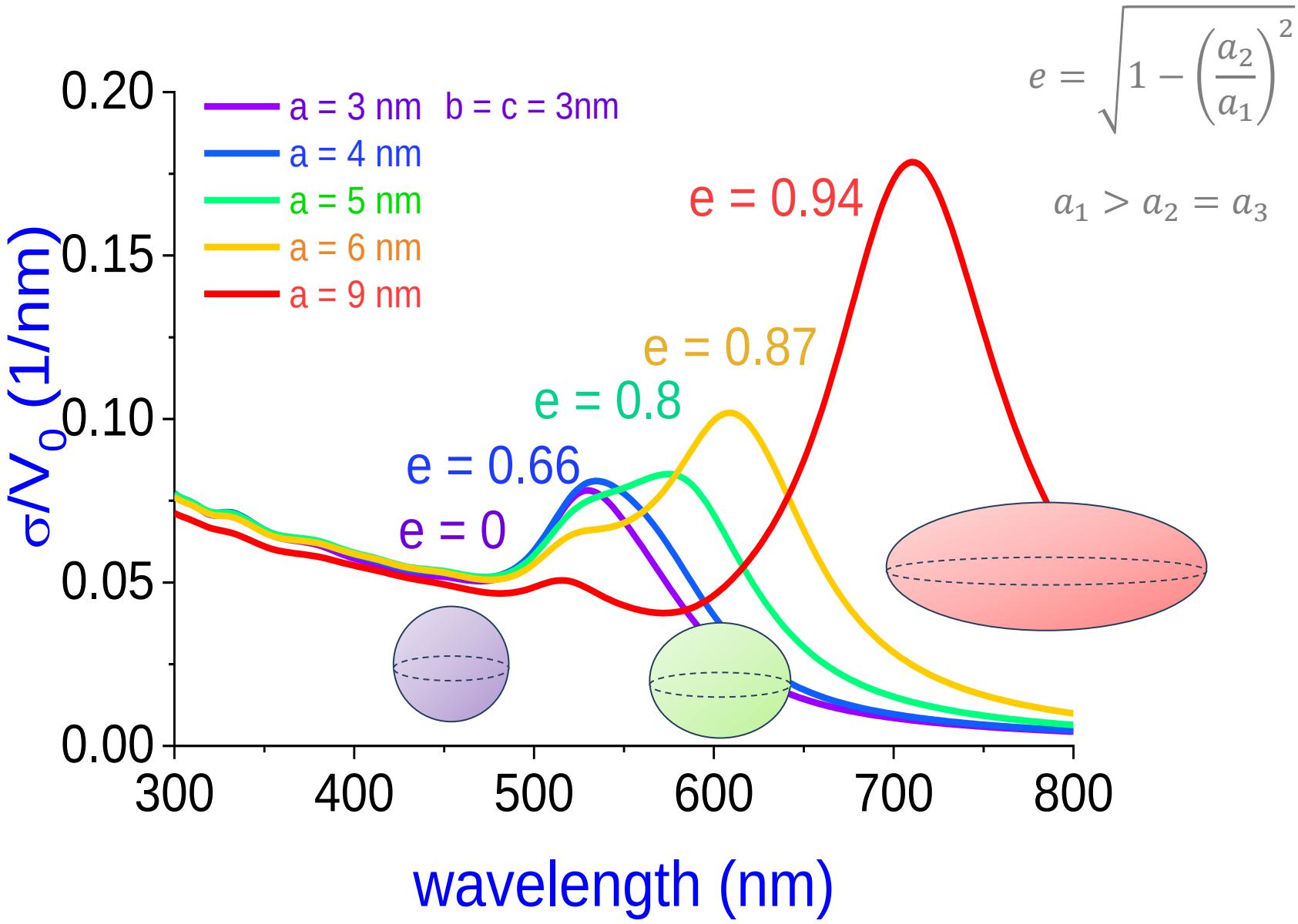
$$L_2 = L_3 = \frac{1 - L_1}{2} \qquad L_1 + L_2 + L_3 = 1 \qquad L_j = \frac{1}{3}$$

Sphere

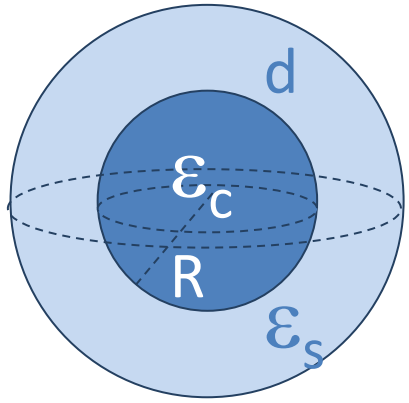
$$e = \sqrt{1 - \left(\frac{a_2}{a_1}\right)^2} \qquad a_1 > a_2 = a_3$$

R. Gans, 'Uber die Form ultramikroskopischer Goldteilchen', Ann. Phys. 1912, 342, 881

Rod-like NP


$e = \sqrt{1 - \left(\frac{a_2}{a_1}\right)^2}$
$a_1 > a_2 = a_3$
a = 3 nm b = c = 3nm
a = 4 nm
a = 5 nm
a = 6 nm
a = 9 nm
e = 0.94
e = 0.87
e = 0.8
e = 0.66
e = 0
σ/V0 (1/nm)
0.20
0.15
0.10
0.05
0.00
300
400
500
600
700
800
wavelength (nm)

3. Core-shell cluster



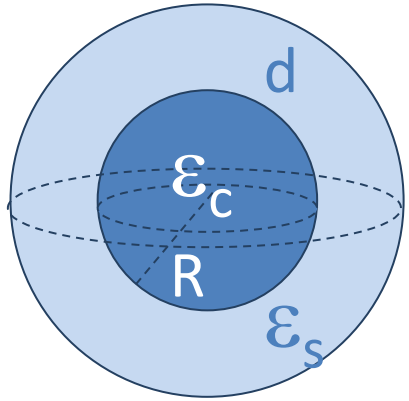
$$\sigma_{ext} = 4\pi \frac{\omega}{c} \varepsilon_m^{1/2} \, \mathrm{Im}(\alpha)$$

$$\alpha = 4\pi (R+d)^3 \frac{(\varepsilon_s - \varepsilon_m)(\varepsilon_c + 2\varepsilon_s) + \left(\frac{R}{R+d}\right)^3 (\varepsilon_c - \varepsilon_s)(\varepsilon_m + 2\varepsilon_s)}{(\varepsilon_s + 2\varepsilon_m)(\varepsilon_c + 2\varepsilon_s) + \left(\frac{R}{R+d}\right)^3 (\varepsilon_c - \varepsilon_s)(2\varepsilon_s - \varepsilon_m)}$$

Single core:

$$\begin{cases} \varepsilon_s = \varepsilon_c \\ R' = R + d \end{cases}$$

3.



Core-shell cluster

$$\alpha = 0$$
$$\sigma_{ext} = 0$$

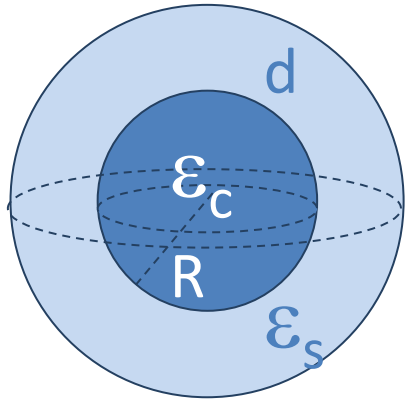
invisibility

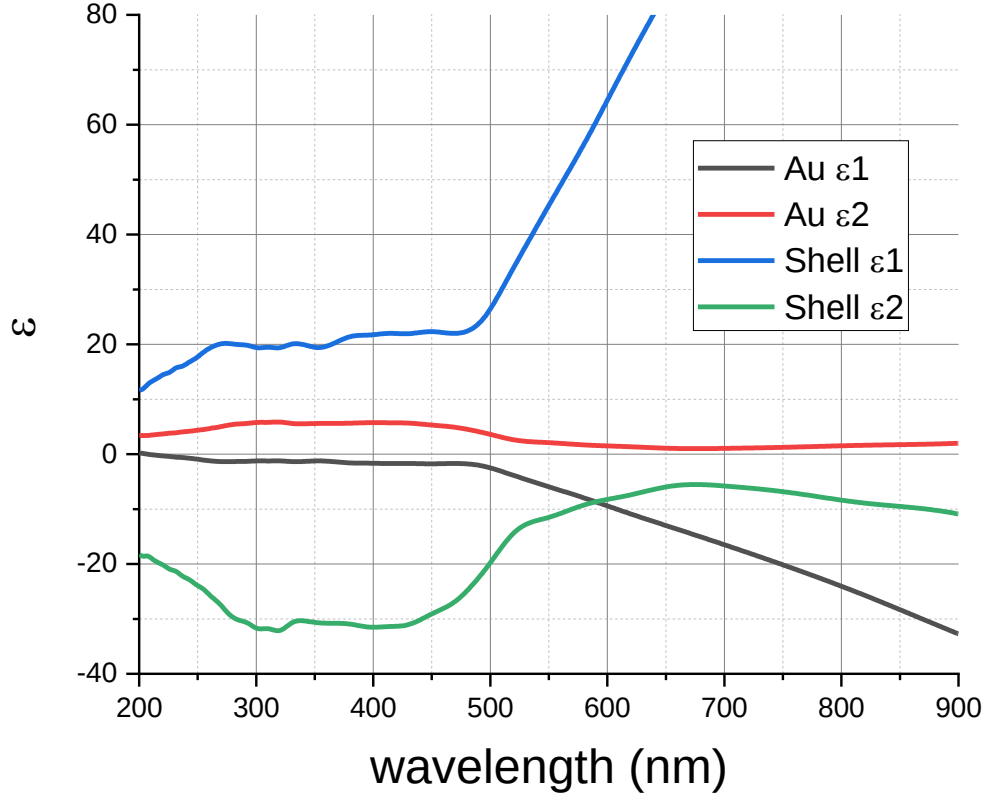
$$f \equiv \frac{R}{R+d}$$

$$(\varepsilon_s - \varepsilon_m)(\varepsilon_c + 2\varepsilon_s) + (f)^3(\varepsilon_c - \varepsilon_s)(\varepsilon_m + 2\varepsilon_s) = 0$$

$$\left(\frac{R}{R+d}\right)^3 \frac{(\varepsilon_c - \varepsilon_s)}{(\varepsilon_c + 2\varepsilon_s)} = -\frac{(\varepsilon_s - \varepsilon_m)}{(\varepsilon_m + 2\varepsilon_s)}$$

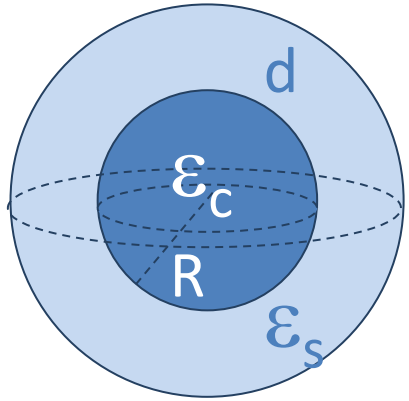
3. Core-shell cluster

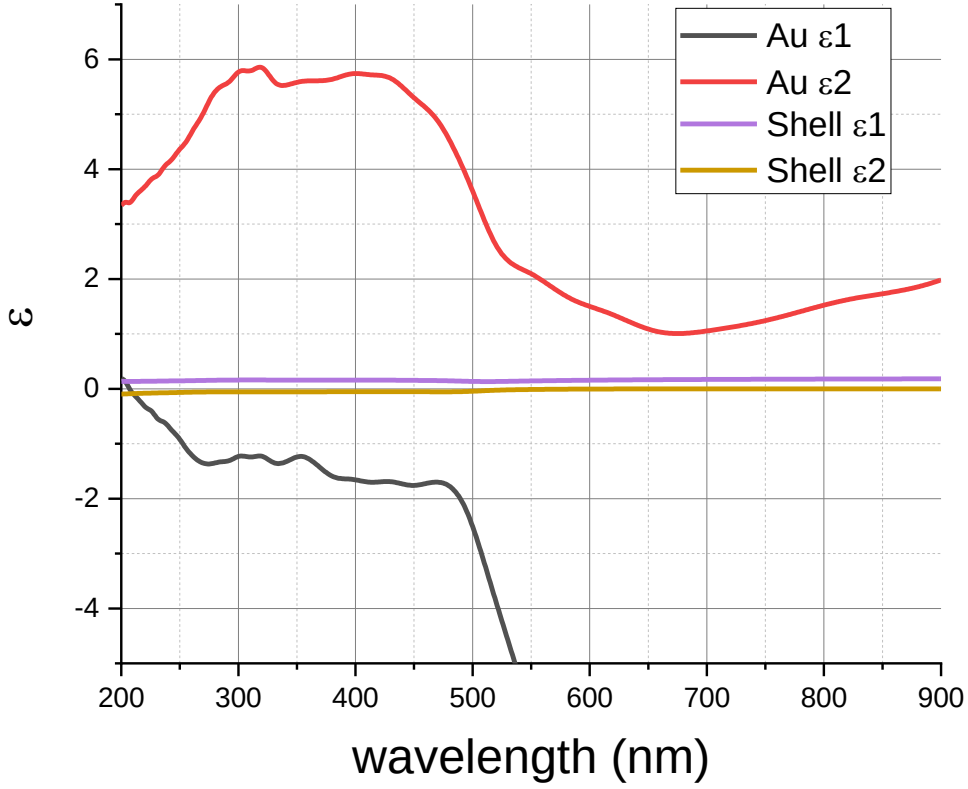




$$f \equiv \frac{R}{R+d} = 0.77$$

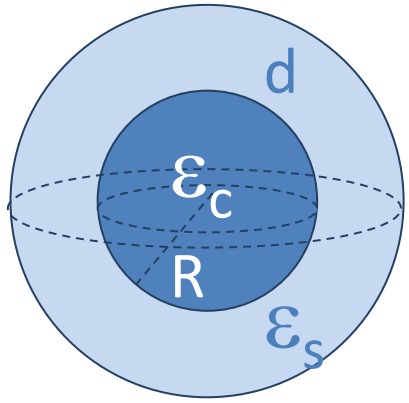
3. Core-shell cluster

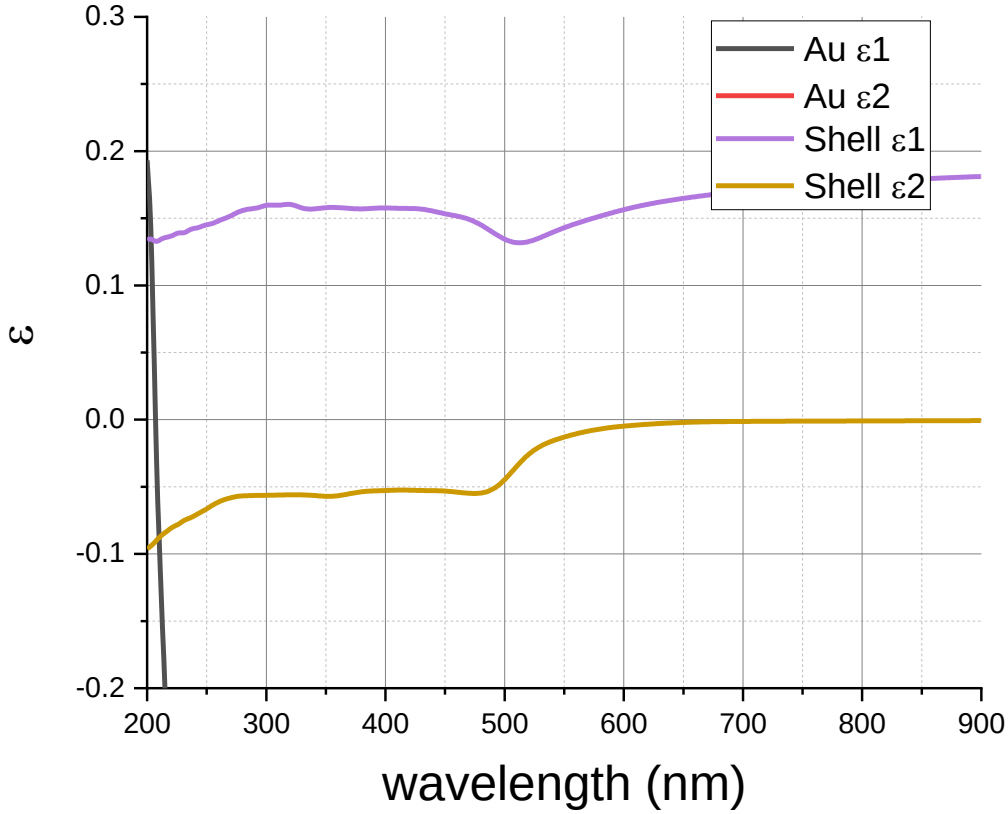




$$f \equiv \frac{R}{R+d} = 0.77$$

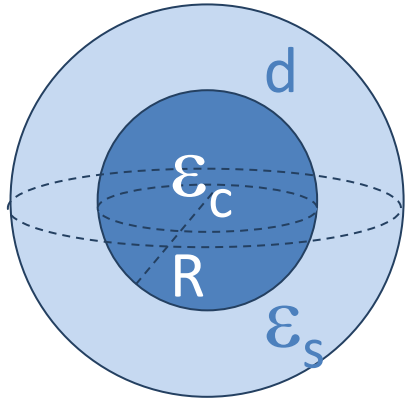
3. Core-shell cluster





$$f \equiv \frac{R}{R+d} = 0.77$$

3.



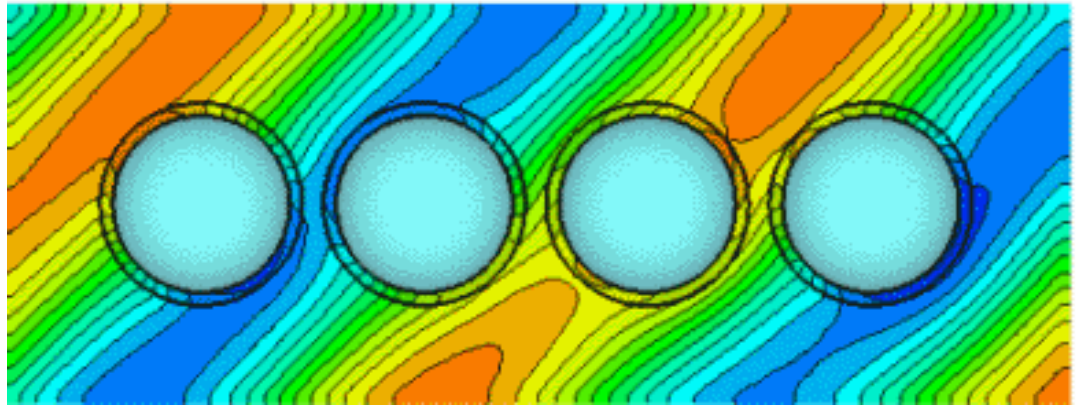
Core-shell cluster

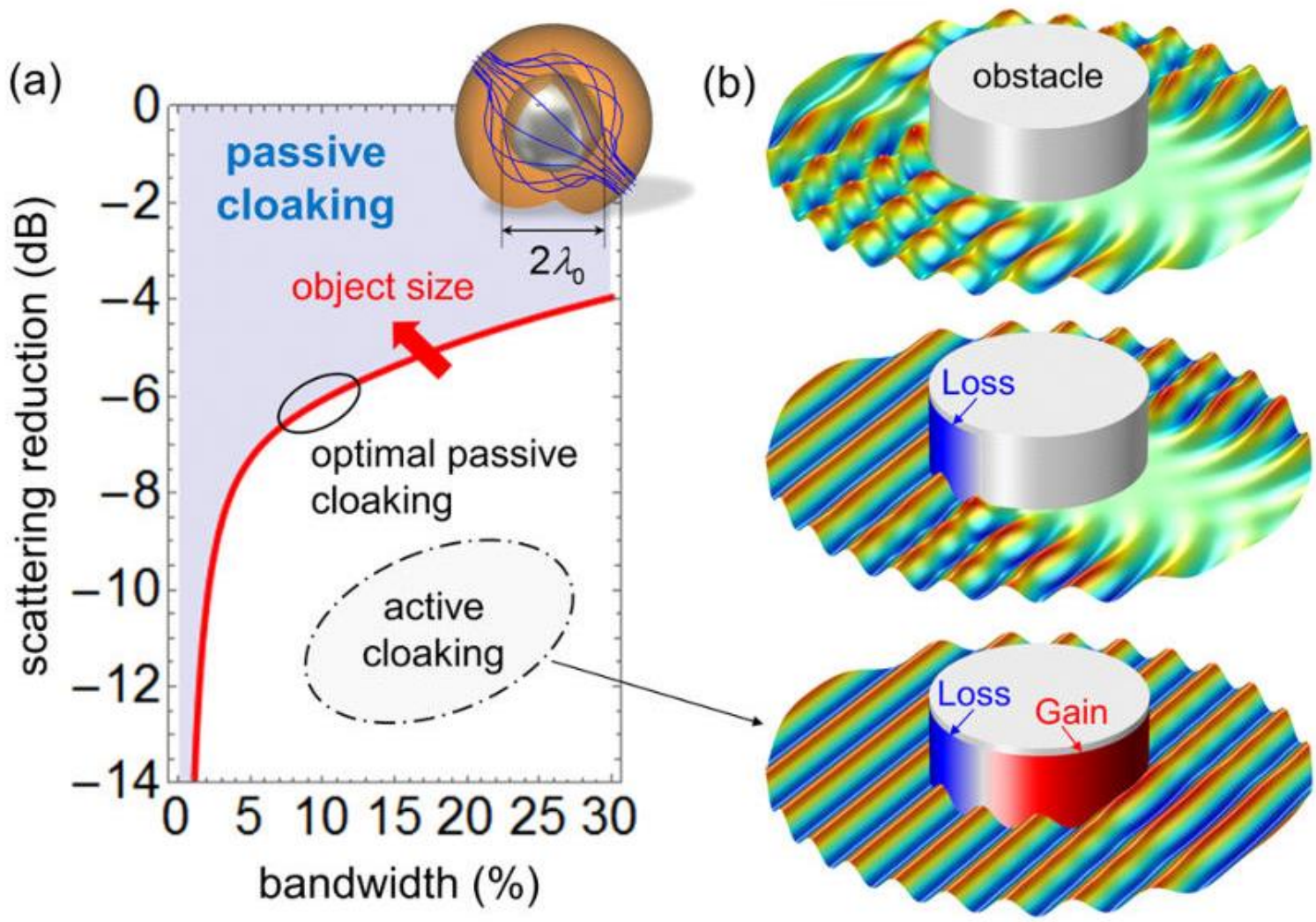
$\alpha = 0$

$\sigma_{ext} = 0$

invisibility

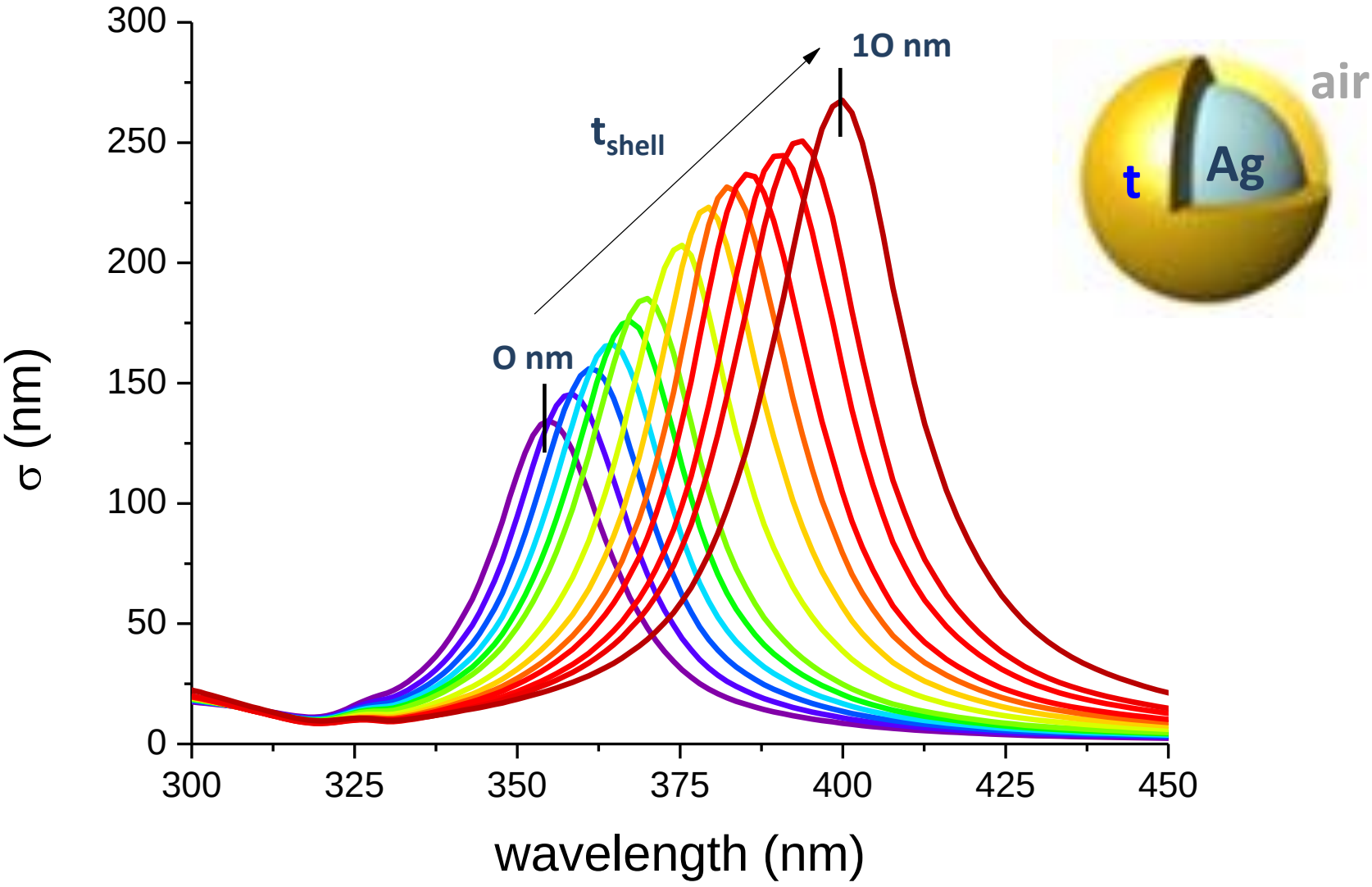
metamaterials





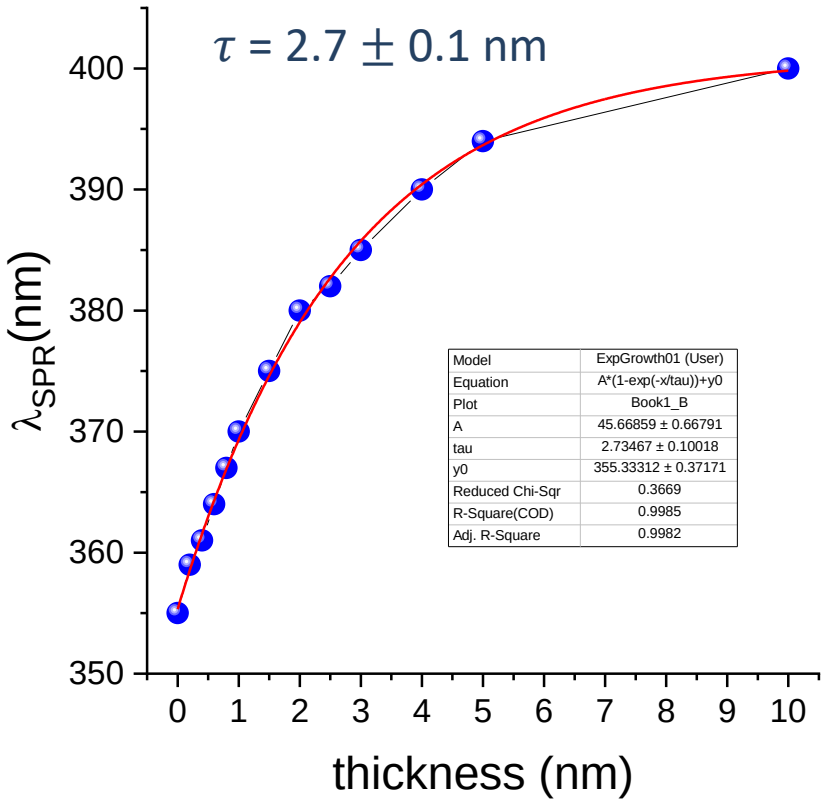
1. Monticone, F. & Alù, A. Invisibility exposed: physical bounds on passive cloaking. *Optica* **3**, 718–724 (2016).

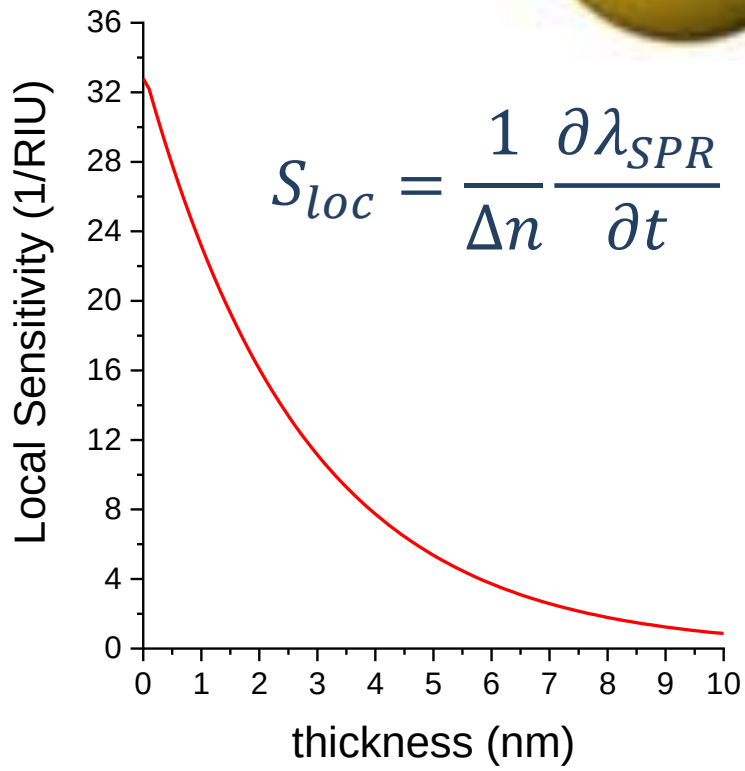
Ag (R=5 nm) @ shell (n=1.5)



Sensitivity to the shell thickness t

Ag (R=5 nm) @ shell (n=1.5)





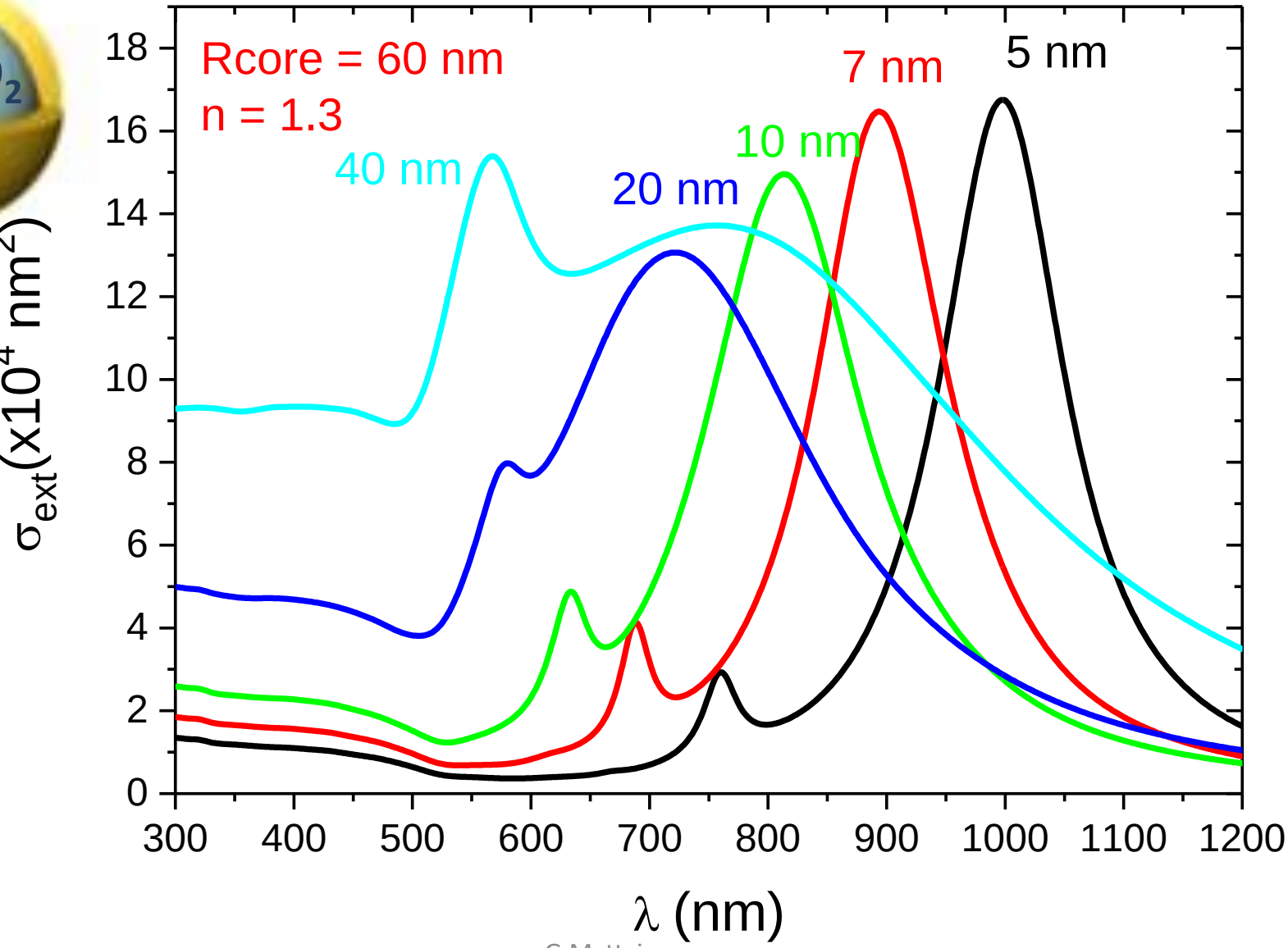
$$S_{loc} = \frac{1}{\Delta n}\frac{\partial \lambda_{SPR}}{\partial t}$$

$$\lambda_{SPR} = \lambda_0 + A\left(1 - e^{-t/\tau}\right)$$

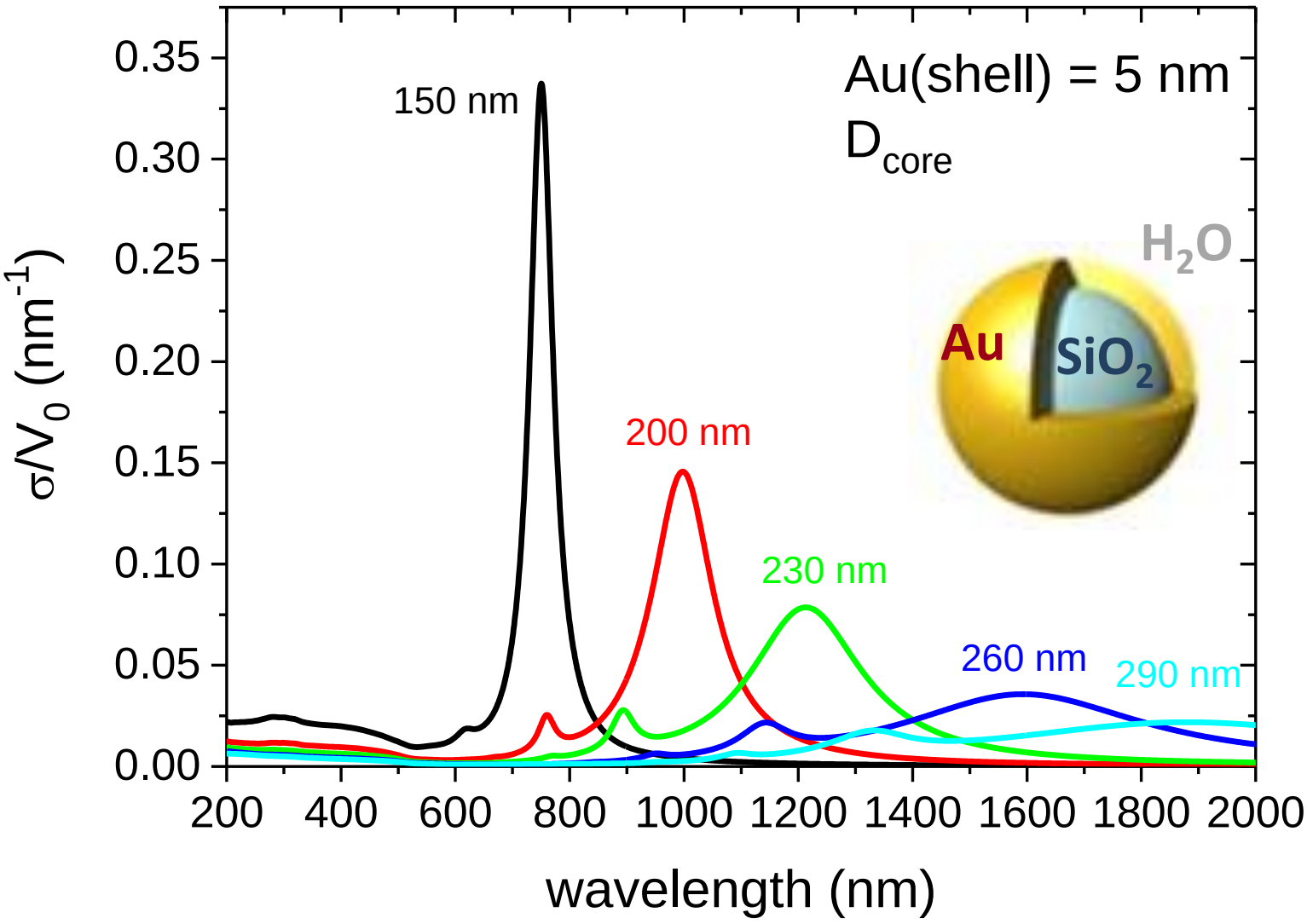
$$S_{loc} = \frac{1}{\Delta n}\frac{A}{\tau}e^{-t/\tau}$$

Nano-shell


H_2O
Au
SiO_2


Rcore = 60 nm
n = 1.3
40 nm
20 nm
10 nm
7 nm
5 nm
σ_{ext}(x10^4 nm^2)
λ (nm)
0
2
4
6
8
10
12
14
16
18
300
400
500
600
700
800
900
1000
1100
1200

Nano-shell


Au(shell) = 5 nm
D core
150 nm
200 nm
230 nm
260 nm
290 nm
H2O
Au
SiO2
σ/V0 (nm-1)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
200
400
600
800
1000
1200
1400
1600
1800
2000
wavelength (nm)

Size distributed systems

Size distributed systems

$$I(x) = I_0 e^{-\gamma x}$$

$$\gamma(\omega) = n\sigma_{ext}(\omega)$$

$$\gamma(\omega) = n \int_0^\infty \sigma_{ext}(\omega, R) f(R) dR$$

Size-distribution function

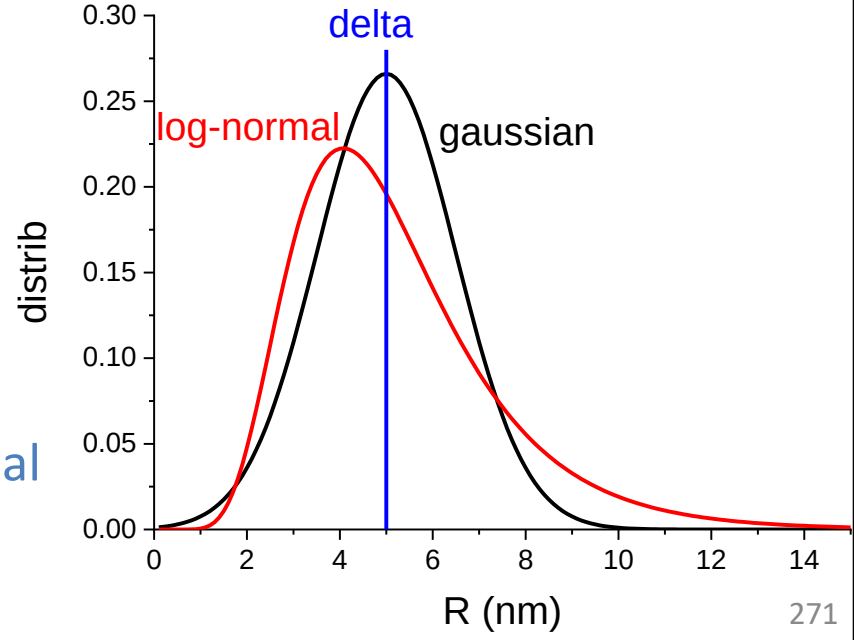
$$\int_0^\infty f(R) dR = 1$$

Monodispersed

$$f(R) = \delta(R - R_0)$$

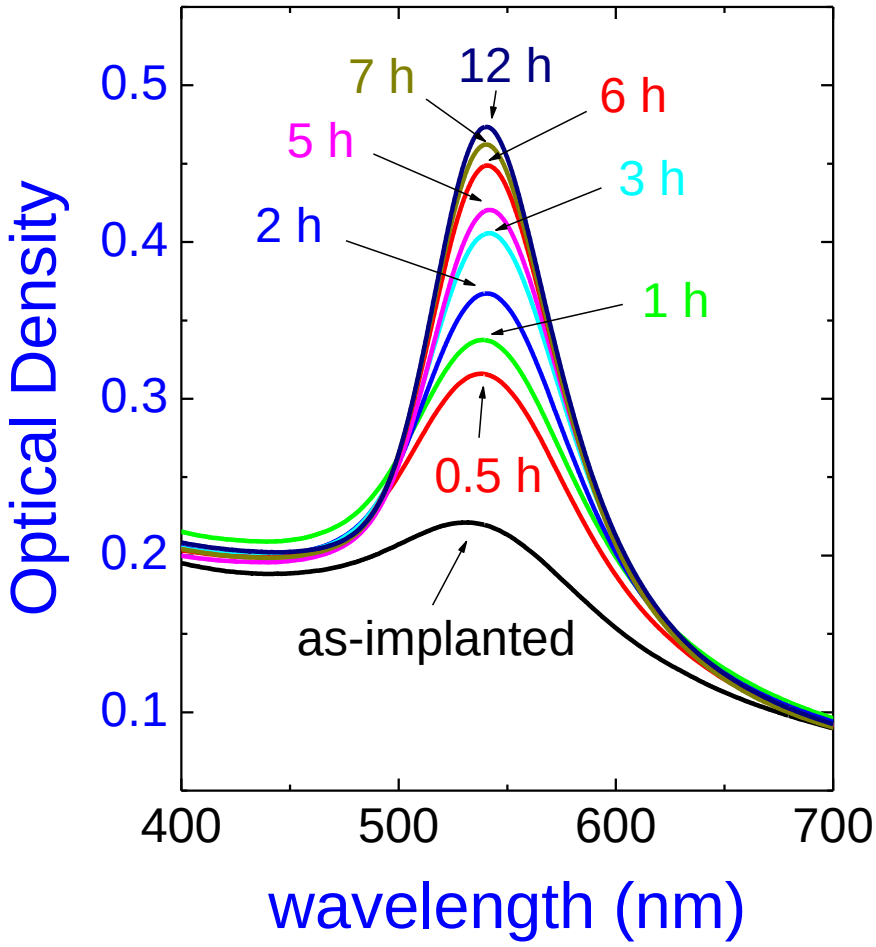
$$f(R) = A \exp\left[-\frac{1}{2}\left(\frac{R - R^*}{\sigma}\right)^2\right]$$ Gaussian

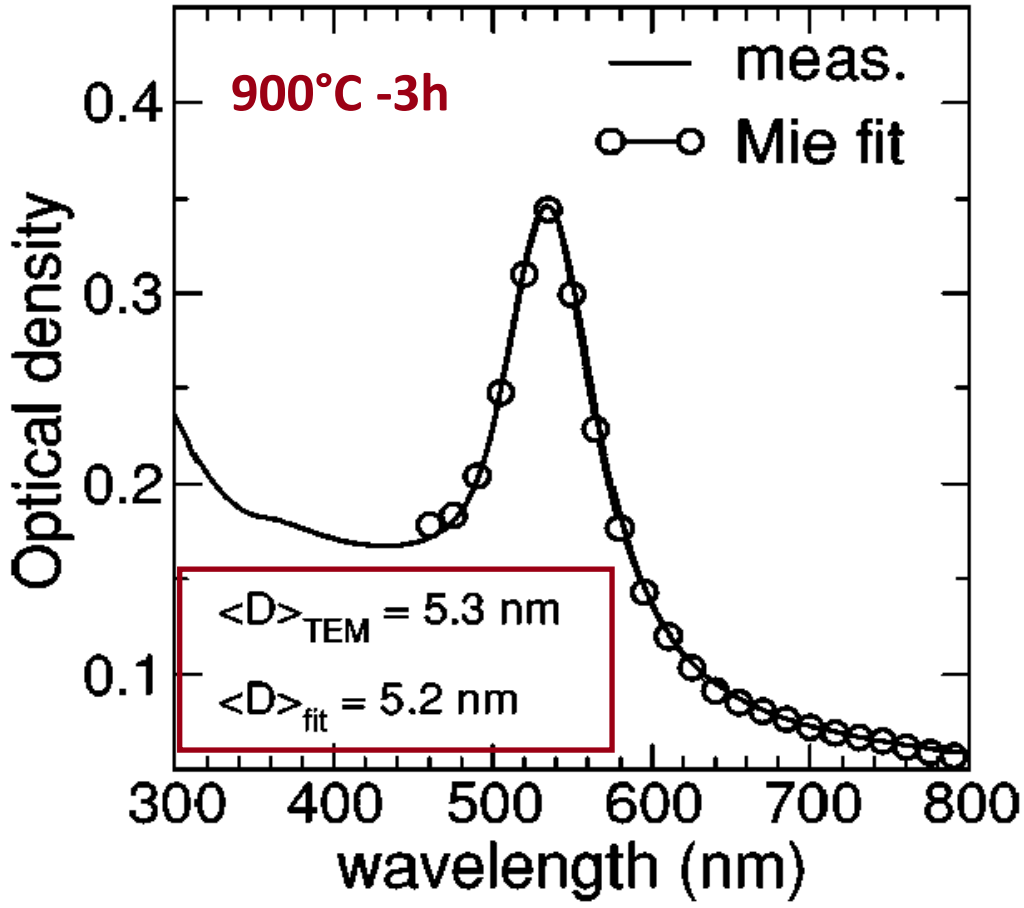
$$f(R) = \frac{A}{R} \exp\left[-\frac{1}{2}\left(\frac{\ln R - \ln R^*}{\ln \sigma}\right)^2\right]$$ LogNormal



Linear optical properties

Au 190 keV, 3×10^{16} ioni/cm^2 in SiO_2





Comparison optical fit - TEM

Comparison monodisp. – size-distrib.