Atelier "Plasmonique, des nouveaux concepts aux applications pratiques"

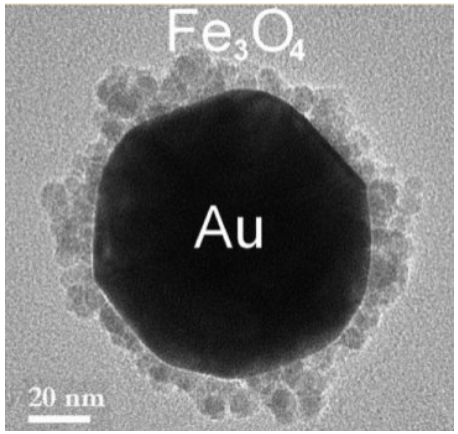
Hybrid Plasmonics

Adnen Mlayah

5 Février 2015

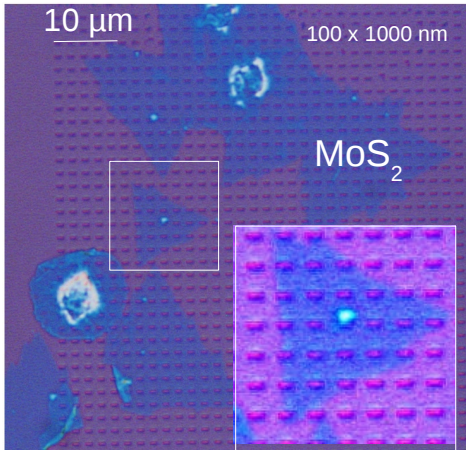
Hybrid Plasmonics

Hybrid Plasmonic/magnetic



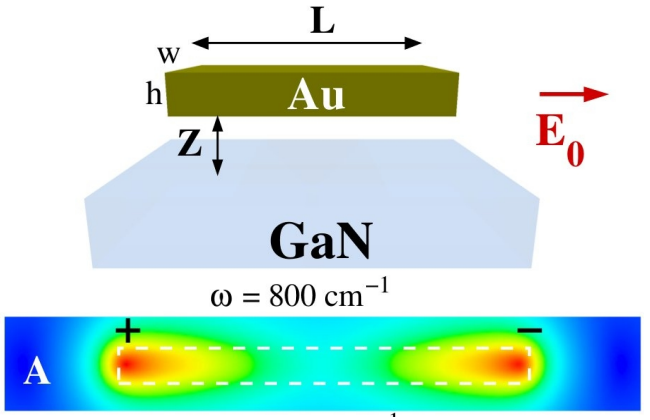
Collaboration with Prof. Smiri, FSB Bizerte
J. Phys. Chem. C 117, 16166 (2013)

Hybrid Plasmonic/excitonic



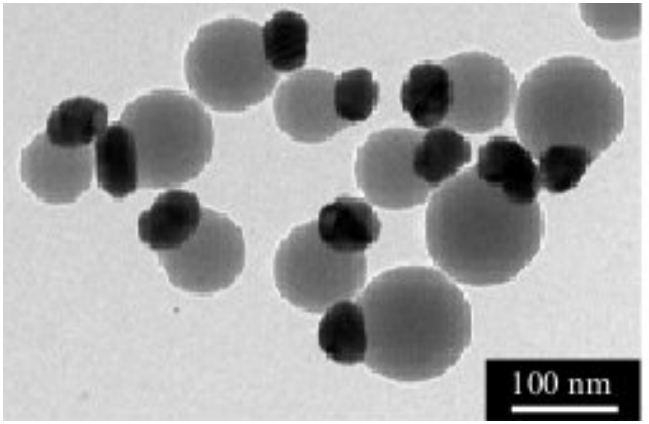
ACS Nano 8, 12682 (2014)
Collaboration with Prof.Lu, Rice University Houston

Hybrid Plasmonic/Phononic



Optics Express 4, 4558 (2013)

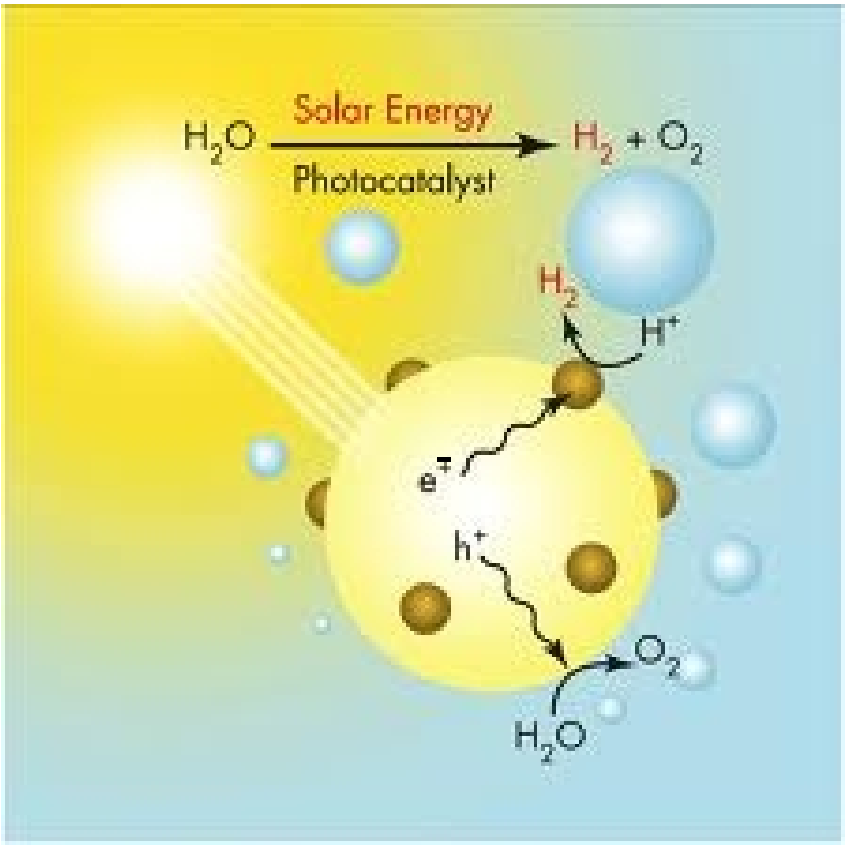
Hybrid Plasmonic/dielectric



Collaboration with Prof. Han, IMRE Singapore
Advanced Materials 24, 2310 (2012)

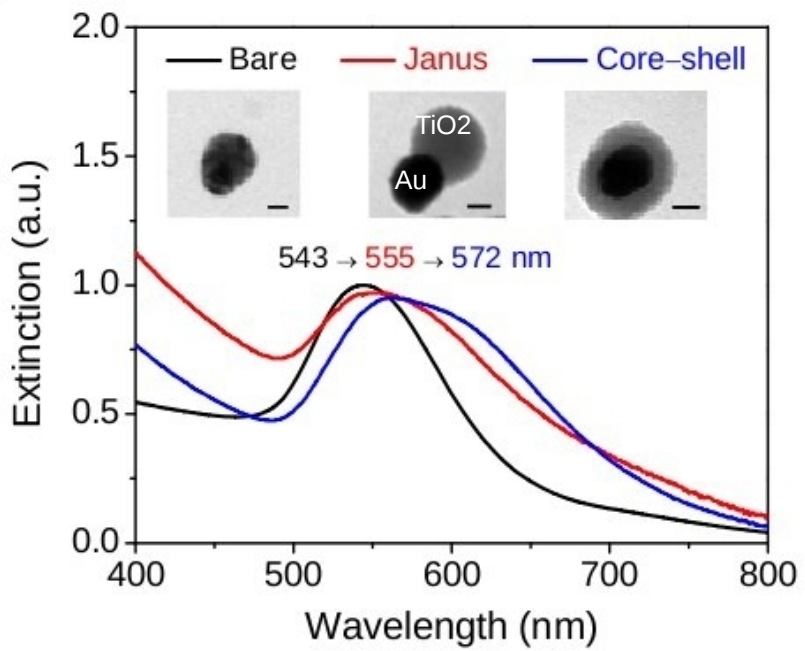
Water splitting

Sun light + NPs +Water = Energy

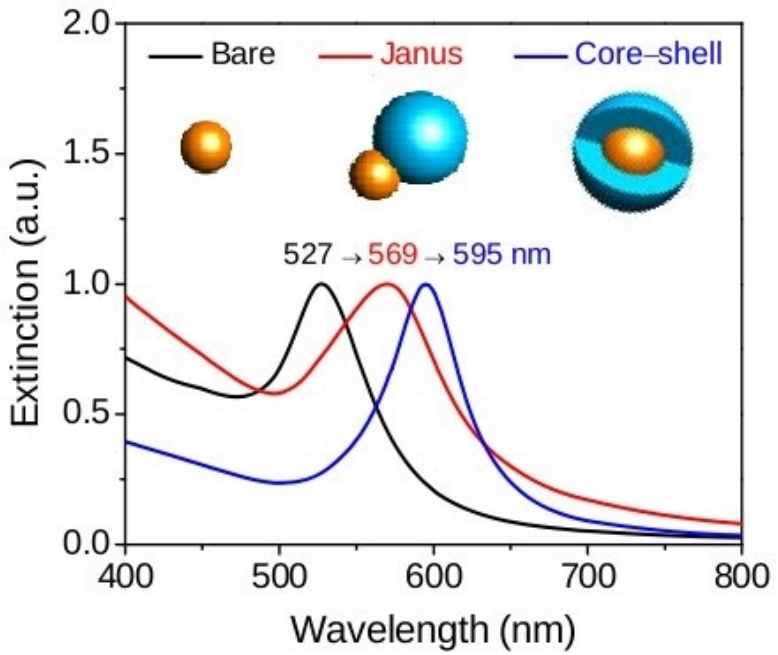


Hybrid nanostructure engineering

Measured spectra

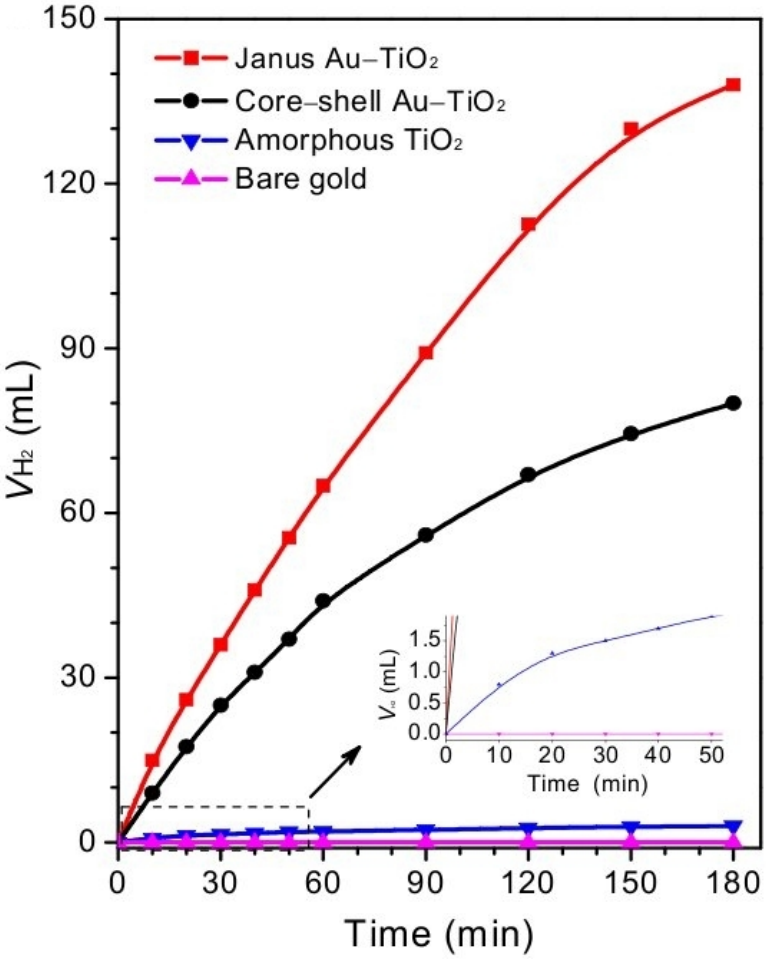


DDA simulations



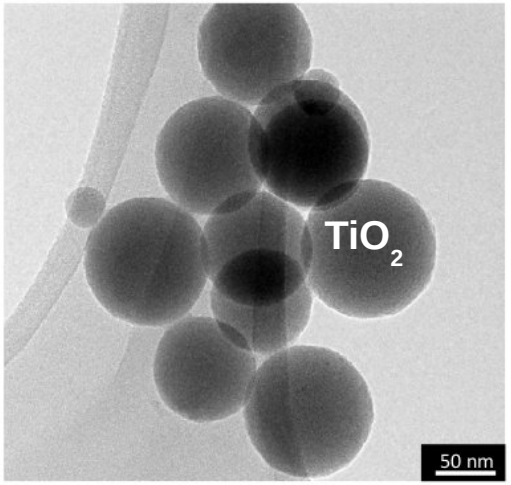
Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

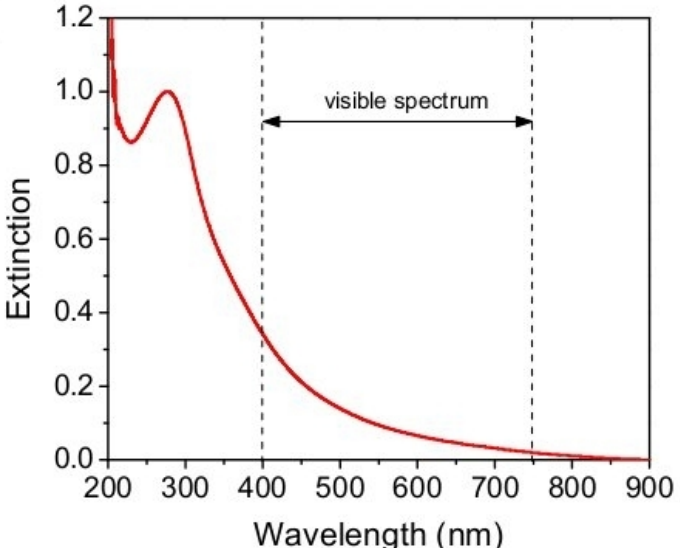
H_2 production

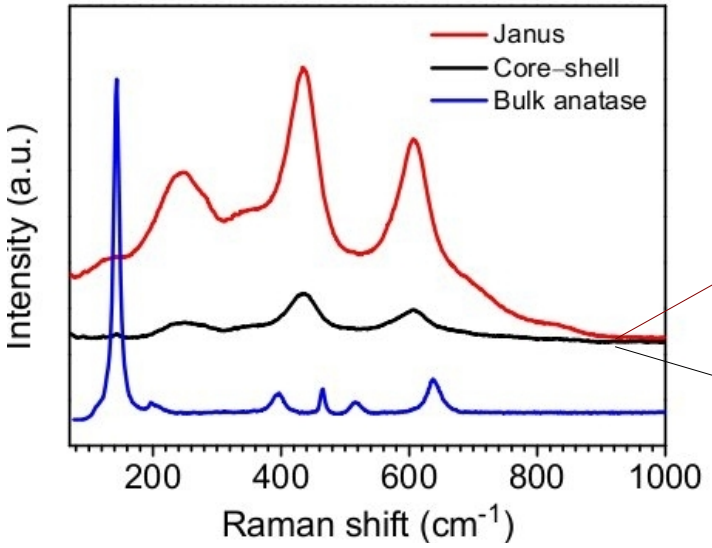


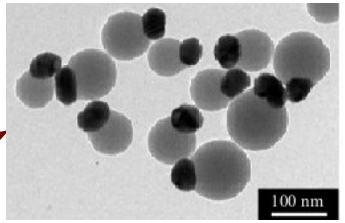
Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

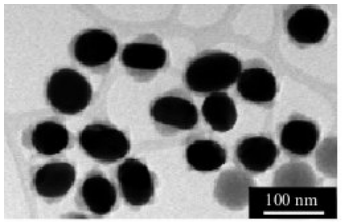
Au@TiO2 : $Ti0_2$ is amorphous





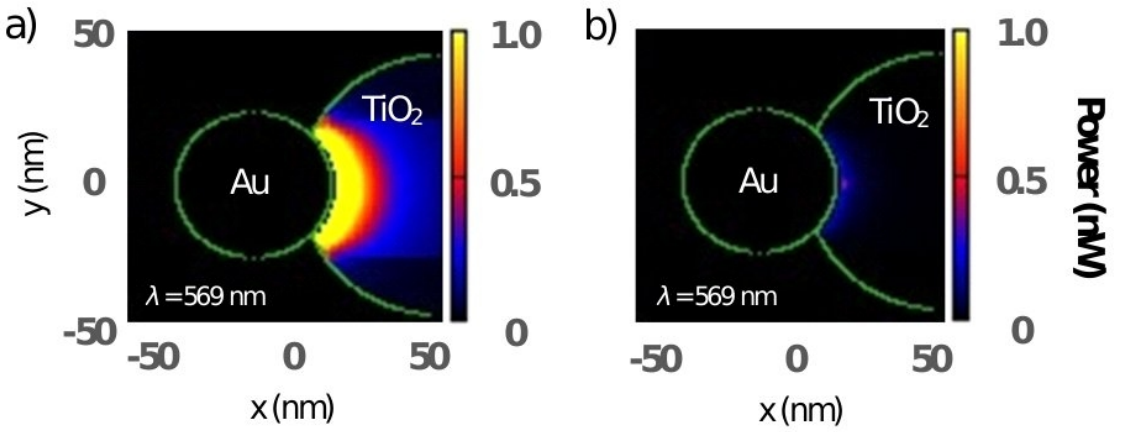


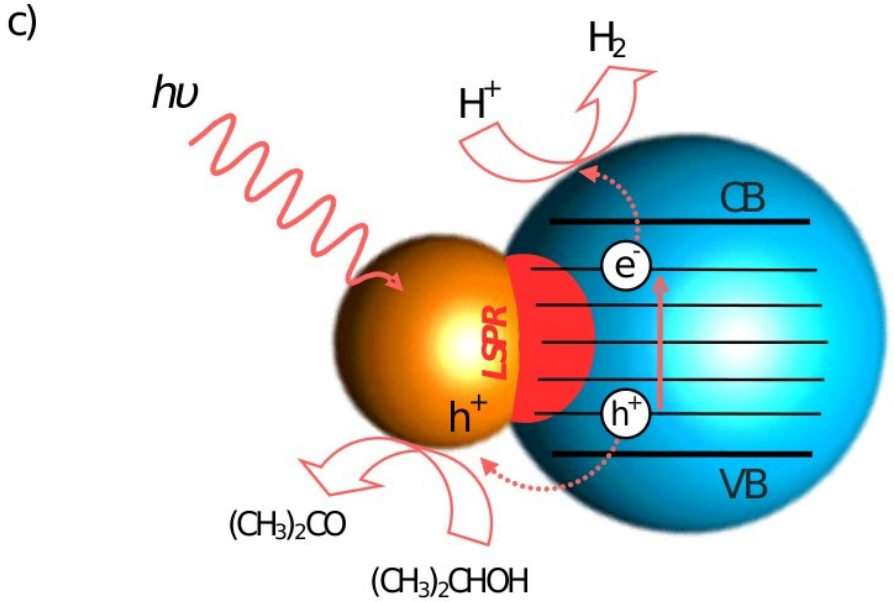




Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

Au@TiO2 : light harvesting

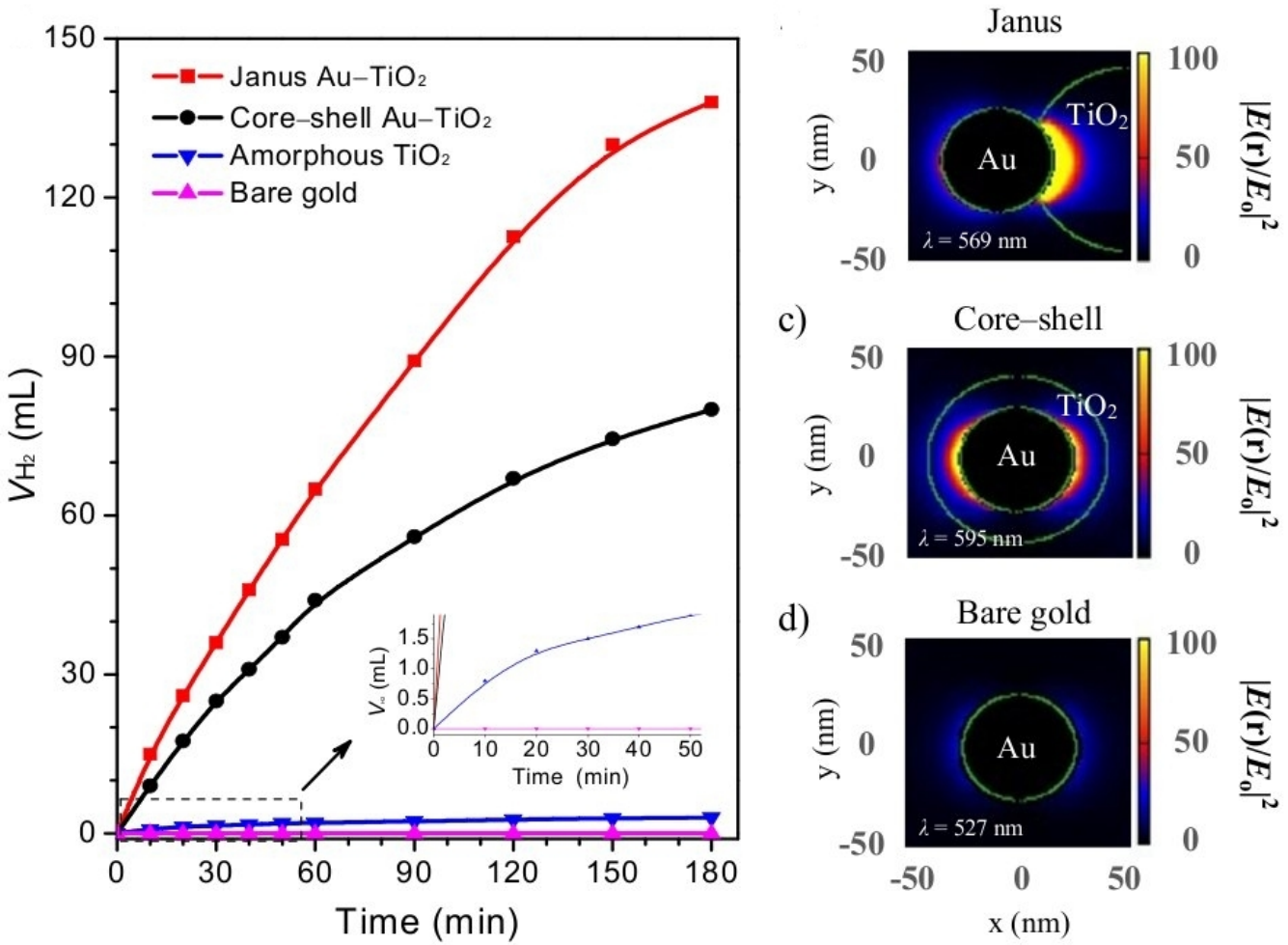




$$(CH_3)_2CHOH + 2h^+ \longrightarrow (CH_3)_2CO + 2H^+ + 2e^- \longrightarrow (CH_3)_2CO + H_2$$

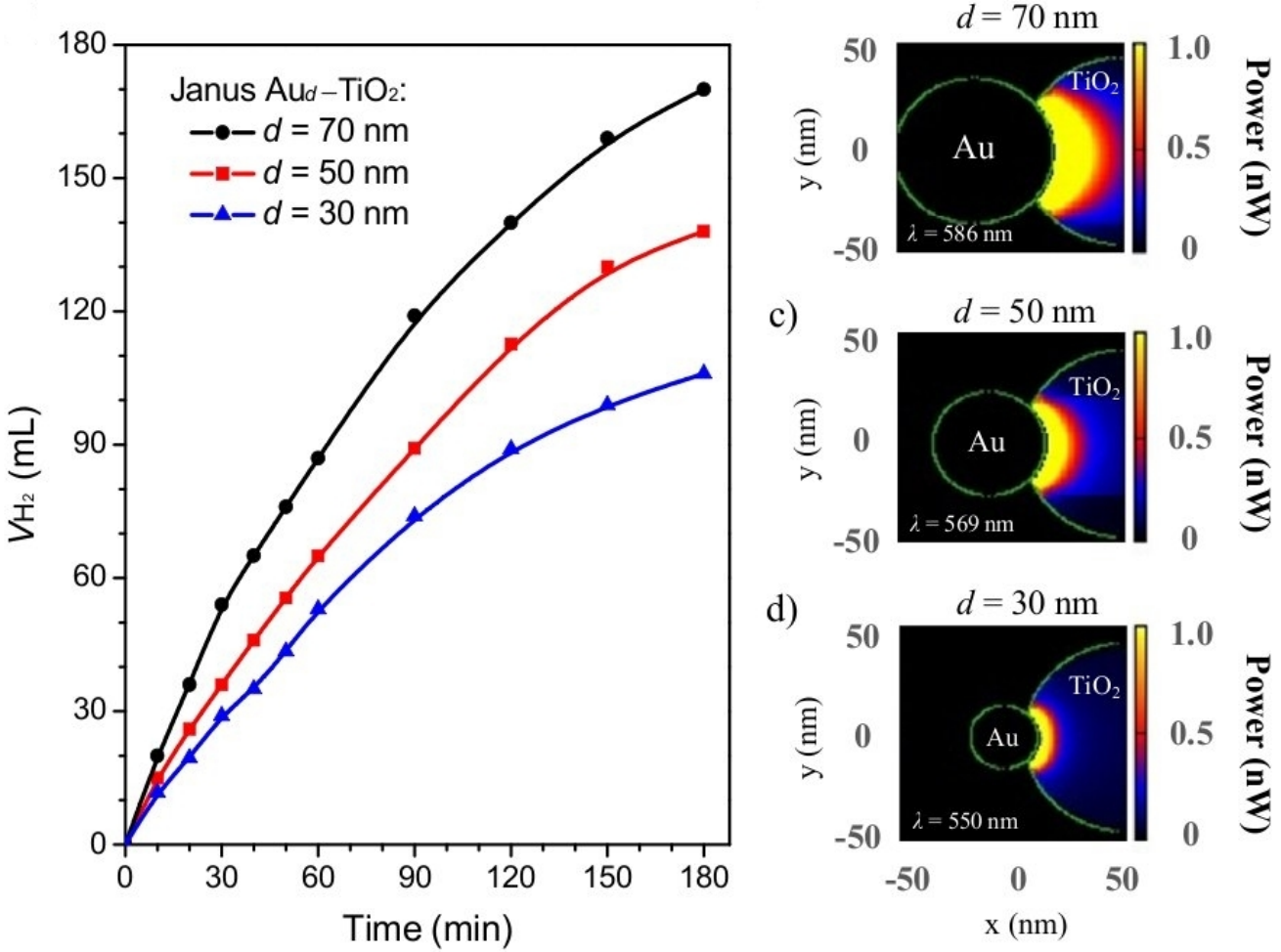
Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

Au@TiO2 : janus vs core-shell



Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

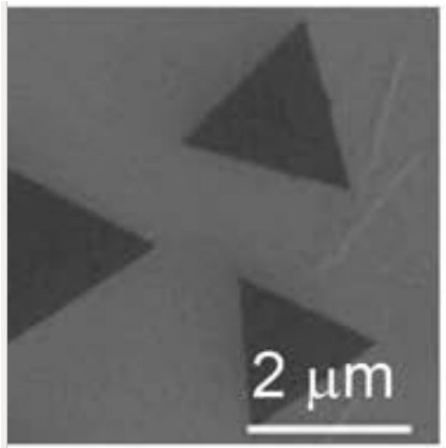
Water splitting : size effect

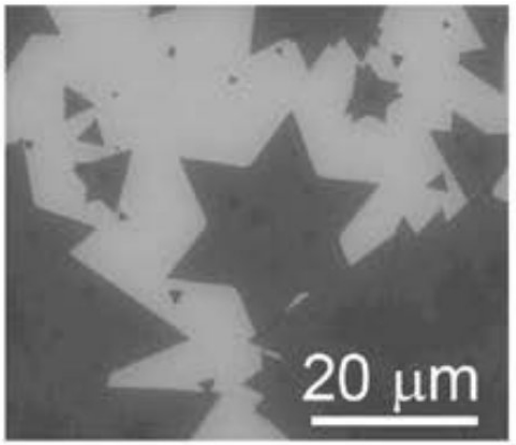


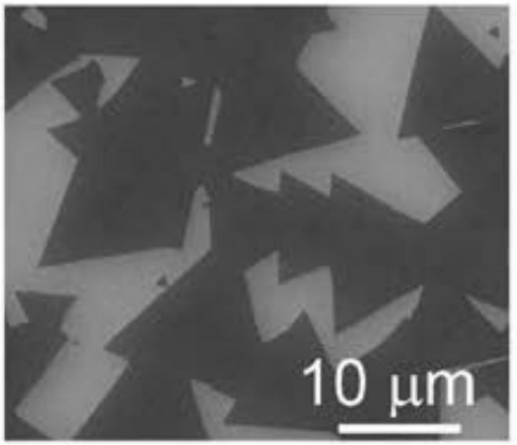
Zhi Wei Seh et al. Advanced Materials 24, 2310 (2012)

Hybrid Plasmonic/TMD

Reliability, large scale production, thickness control, transfer and Manipulation, Si-technology compatible





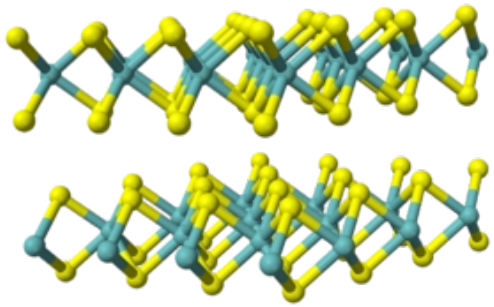


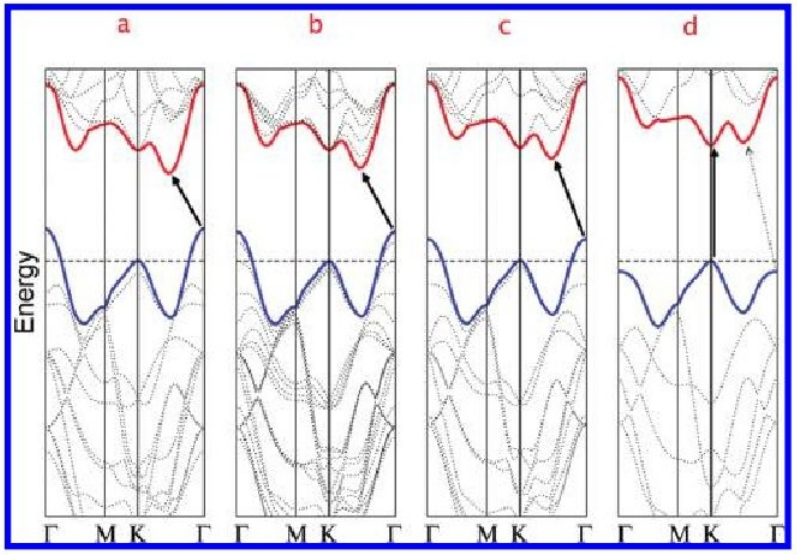
Chemical and thermal sensing, Photo-catalysis, Photo-transistors and Photo-detectors

Jun Lou and Sina Najmaei @ RICE, Houston

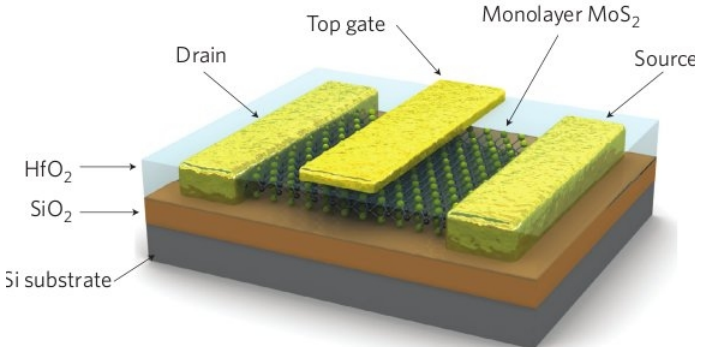
Transition Metal Dichalcogenides

MoS_2

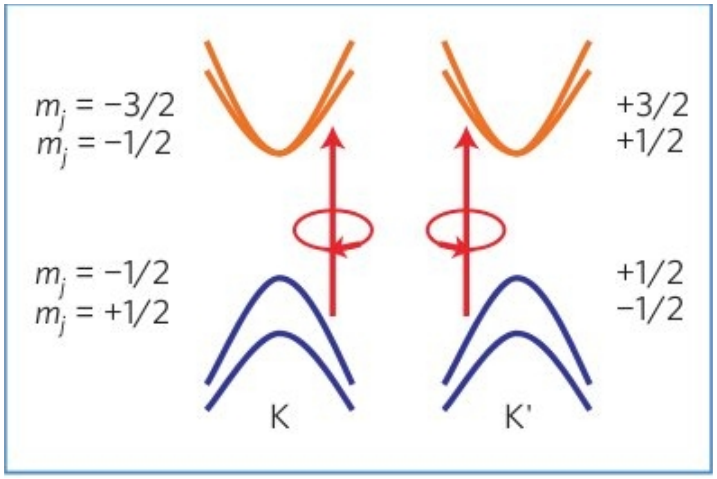




Indirect to direct band gap transition

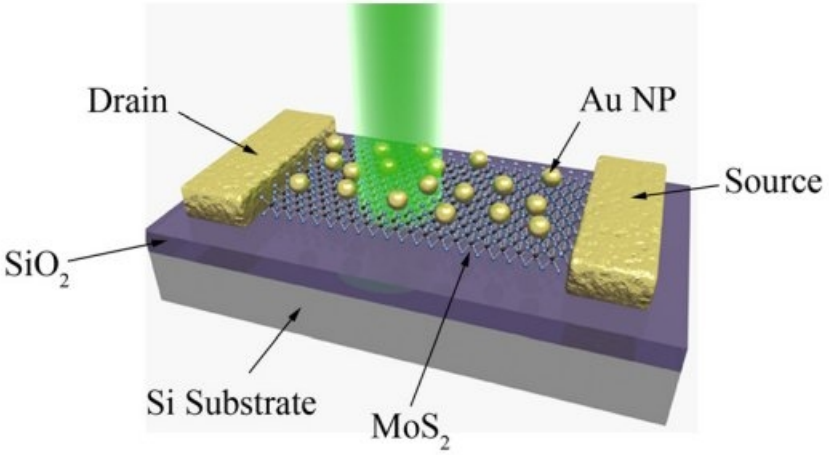


Single-layer MoS2 FET,
Radisavljevic et al. Nature Nanotech, 6, (2011)

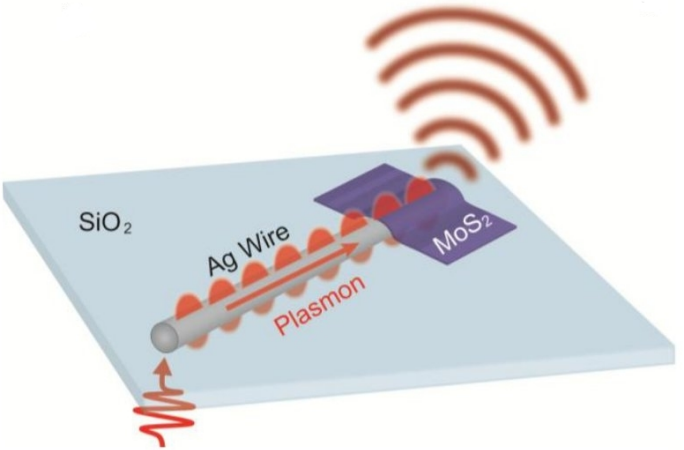


Valleytronics,
Mak et al. Nature Materials, 12 (2013)

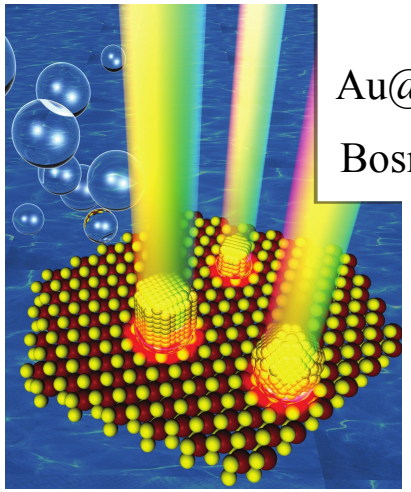
Plasmonics and 2D dichalcogenides



J. Lin et al., Appl. Phys. Lett. 102, (2013)

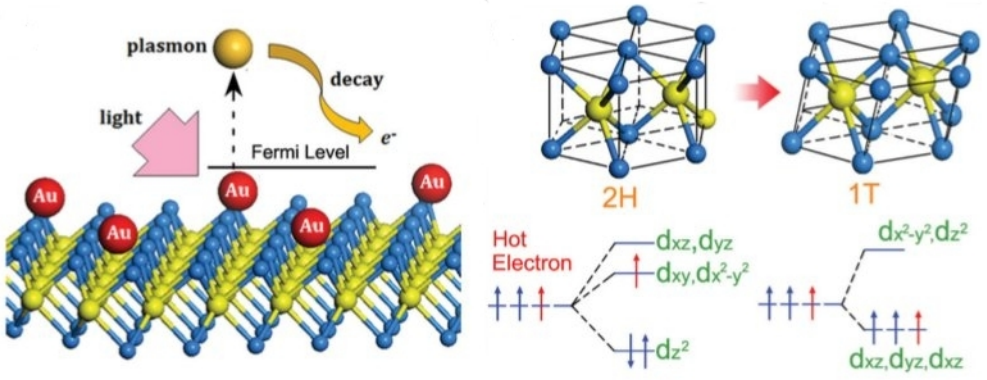


Novotny arXiv:14014.1853v1 (2014)



Au@MoS2 Water splitting

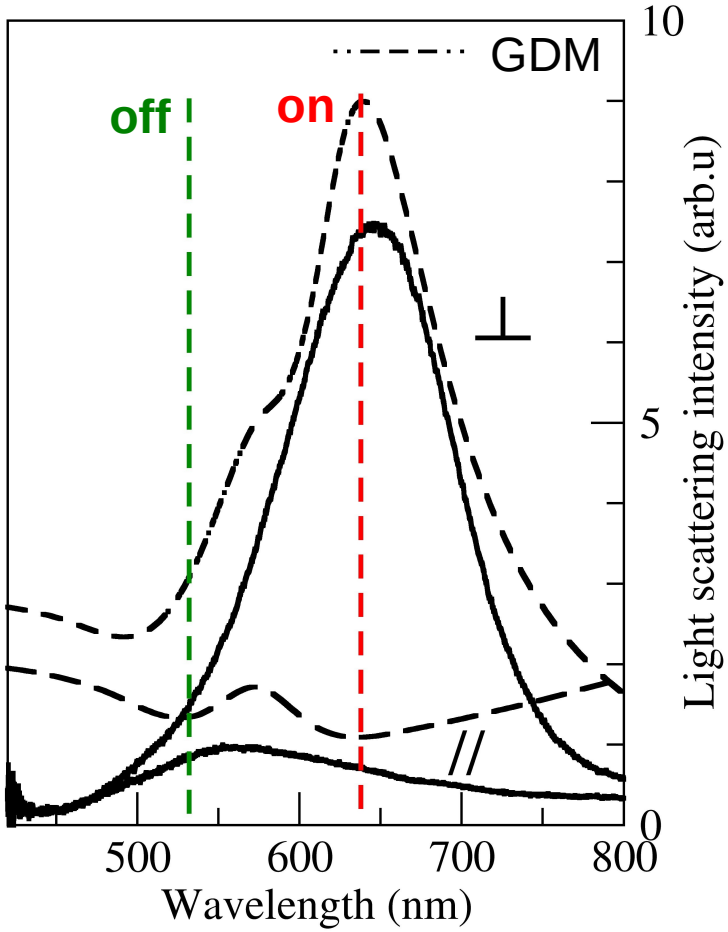
Bosman. Small 17, (2014)

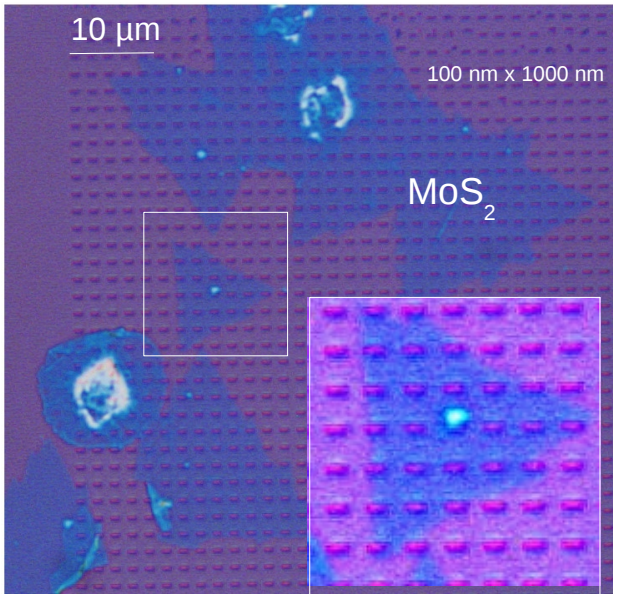


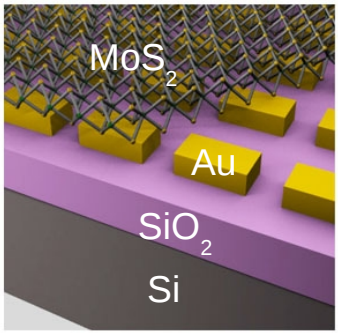
Najmaei, Halas Adv. Mat. 26, (2014)

MoS_2 growth and transfer to gold nano-antennas

Light scattering from a single antenna

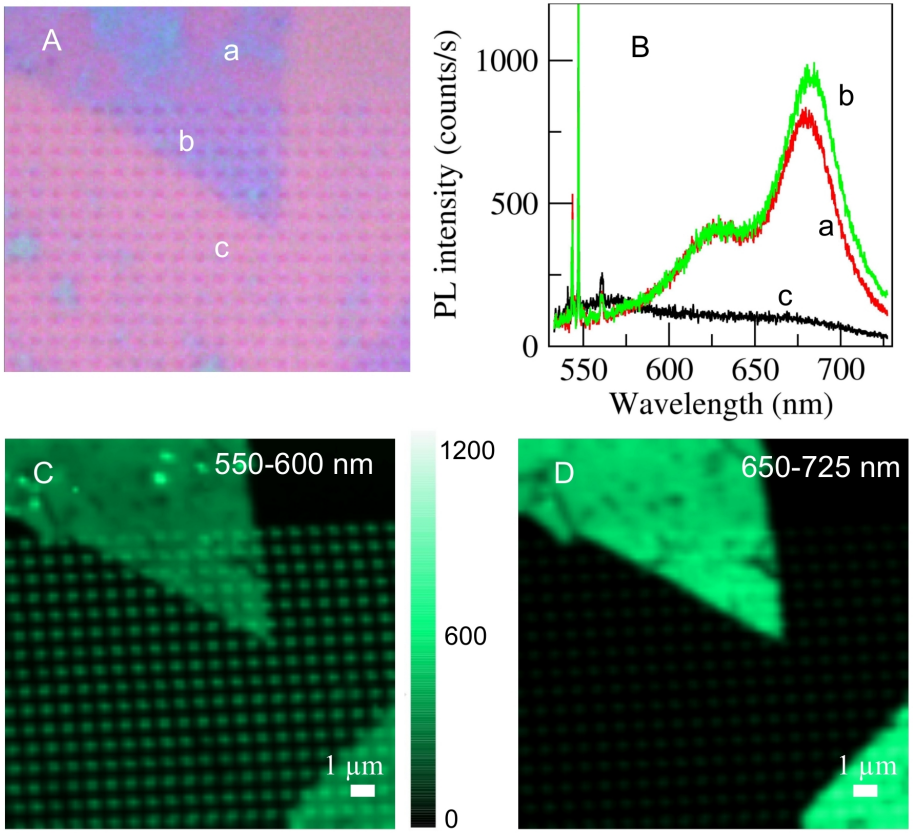






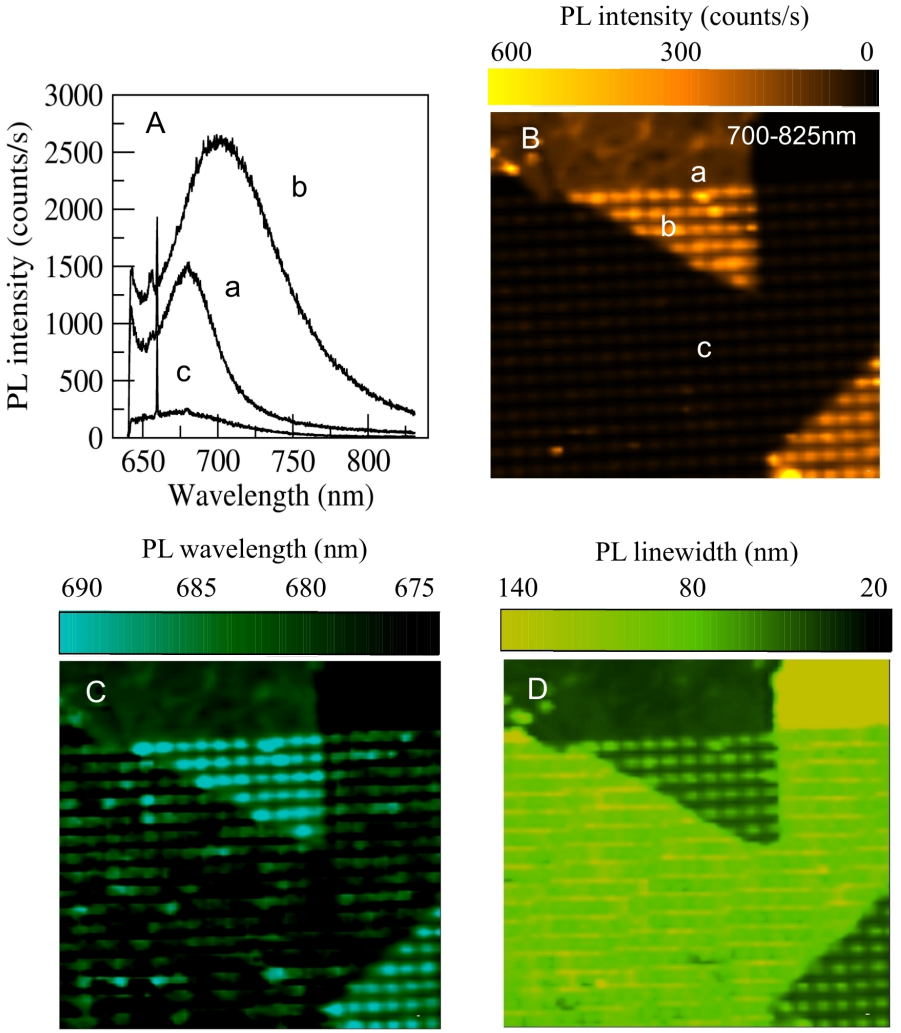
ACS Nano 8, 12682 (2014)

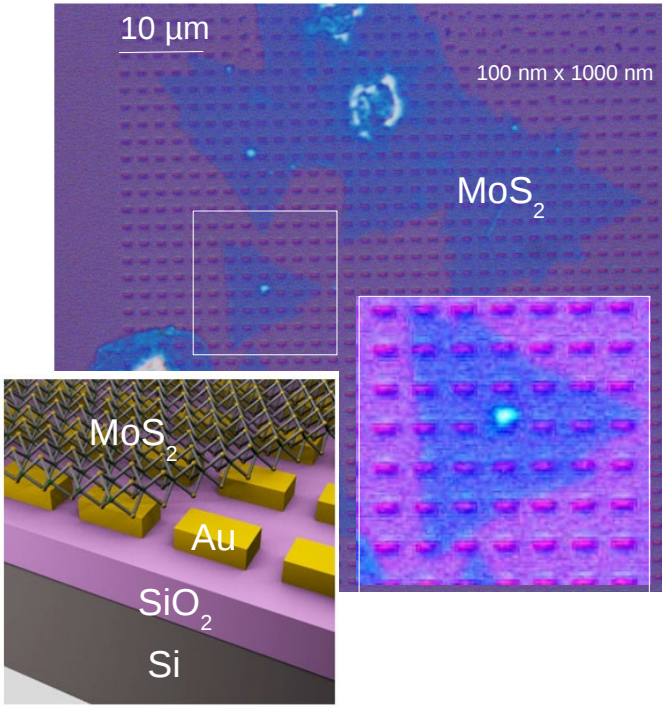
Off-Plasmonic resonance excitation



ACS Nano 8, 12682 (2014)

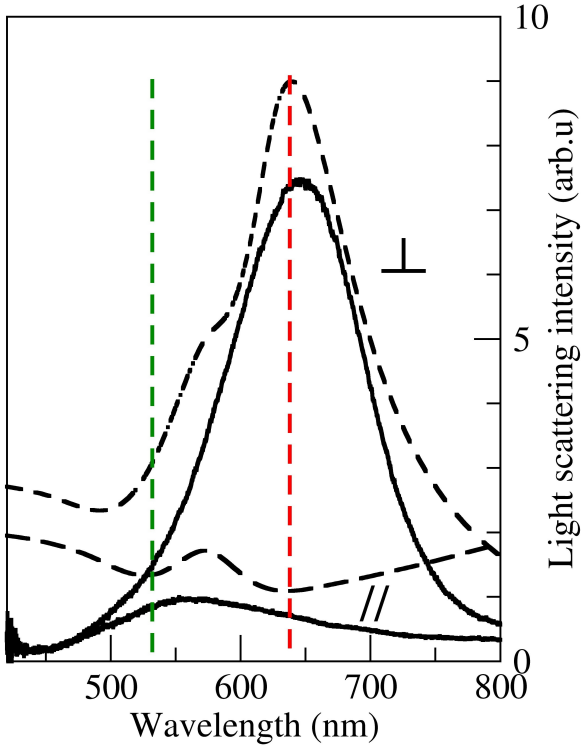
Plasmonic pumping of PL emission

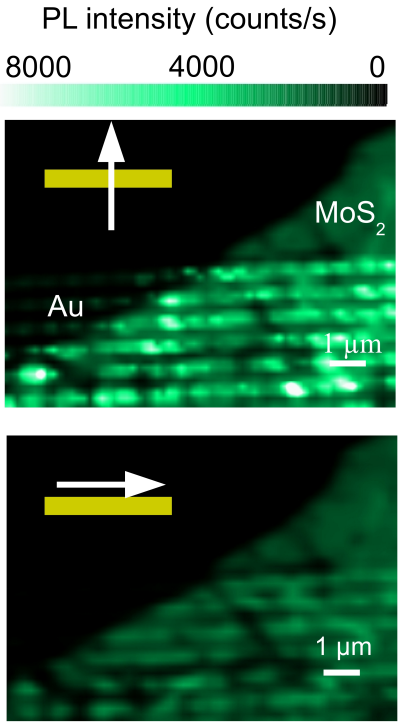




ACS Nano 8, 12682 (2014)

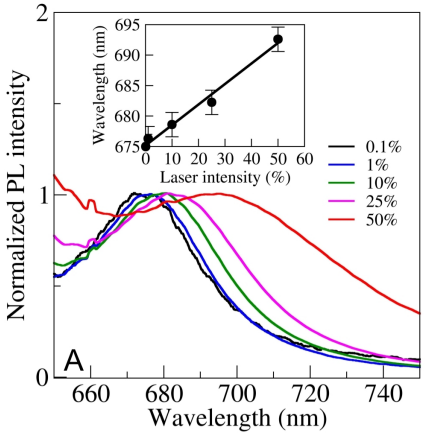
Plasmonic pumping of PL emission : polarisation effect

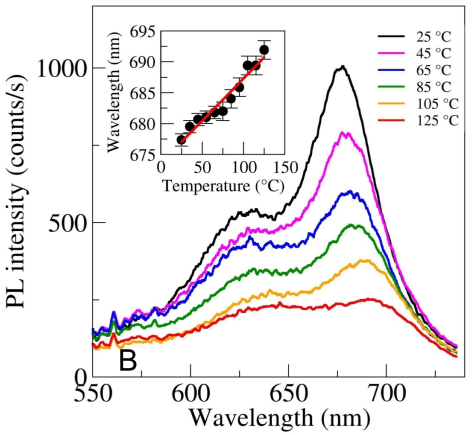


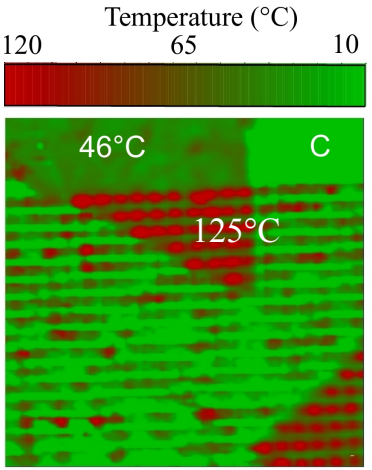


ACS Nano 8, 12682 (2014)

Plasmonic induced Photothermal Effect



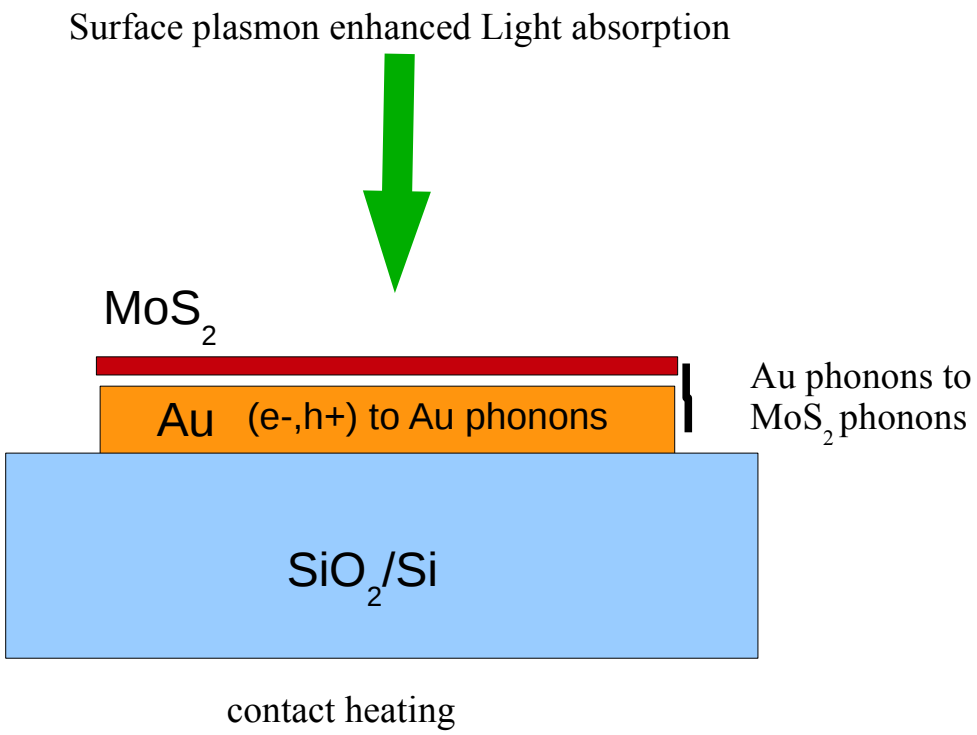




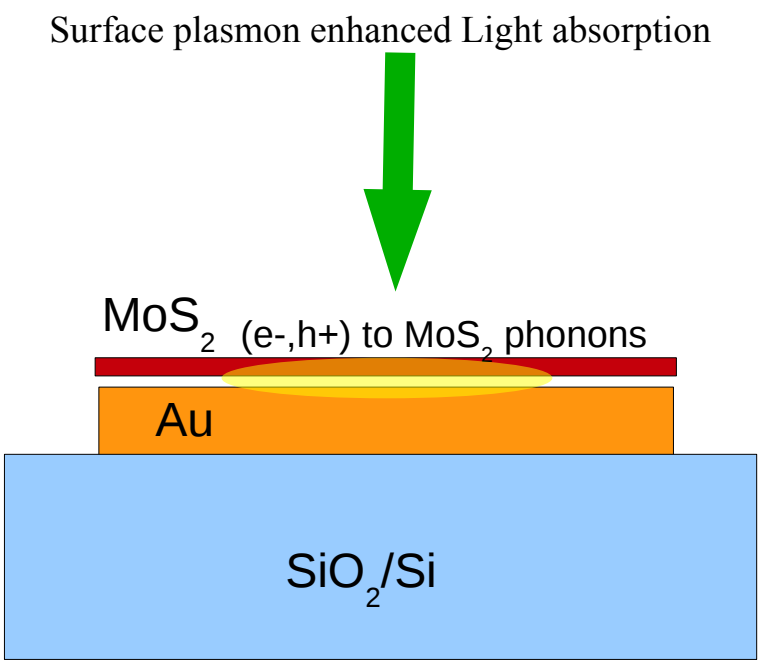
$\Delta T = 23°C$ MoS_2

$\Delta T = 97°C$ MoS_2@Au

Mechanisms of Plasmonic induced Photo-thermal effect



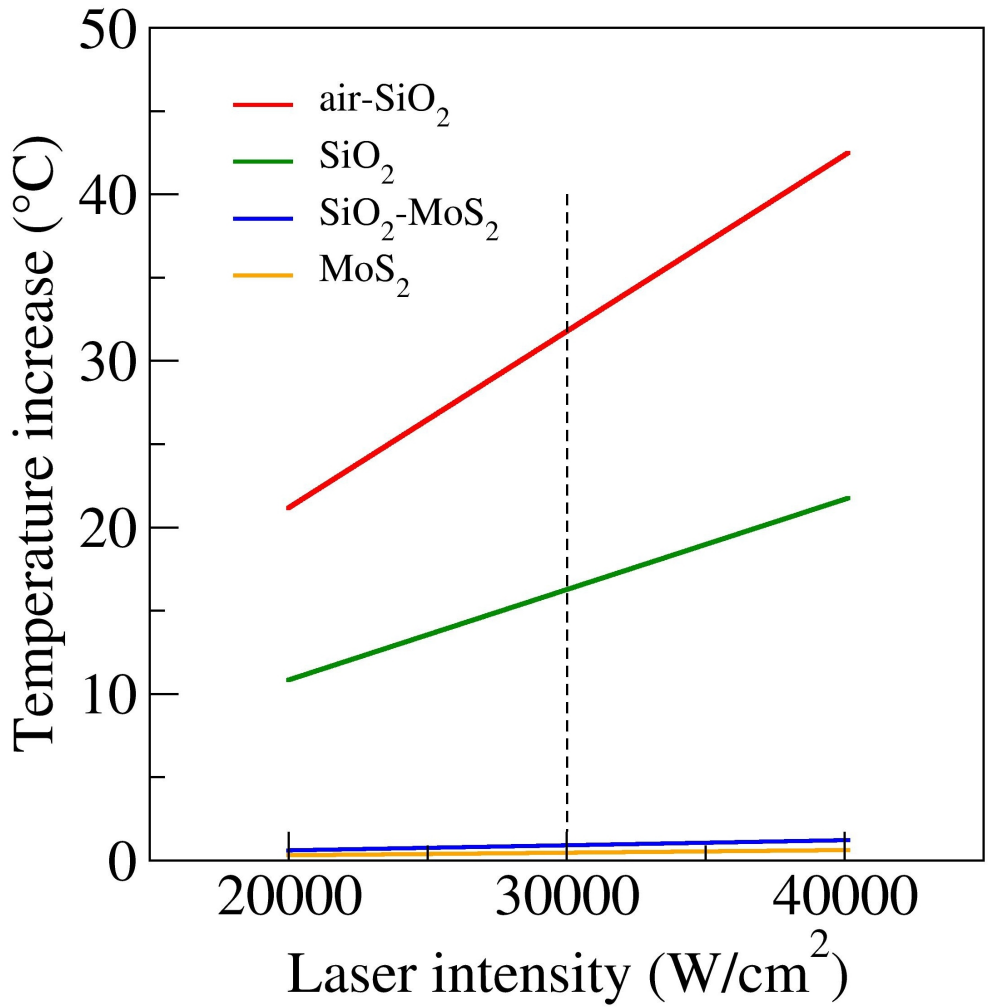
contact heating



Near-field heating

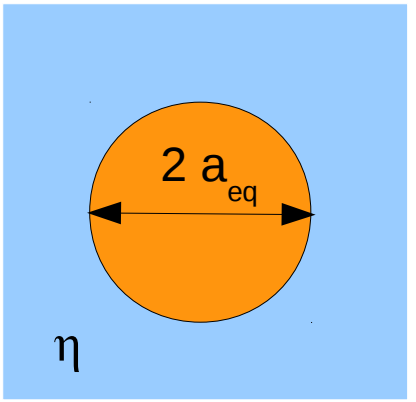
ACS Nano 8, 12682 (2014)

Modeling the Plasmonic heating of the gold nano-antenna



$$Q(\omega) = \frac{\omega}{8\pi} Im(\varepsilon_m(\omega)) \int_V |\mathbf{E}(\mathbf{r},\omega)|^2 d\mathbf{r}$$

E(**r**, ω) from GDM

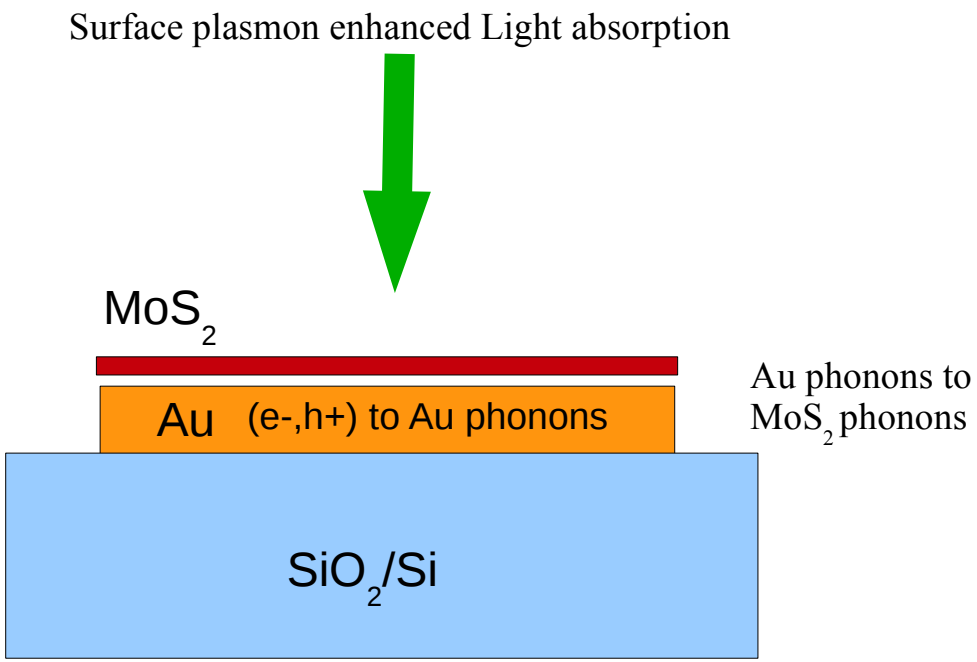


$\Delta T = Q/4\pi a_{eq}\eta$

Measured ΔT = 97°C Calculated ΔT = 1°C

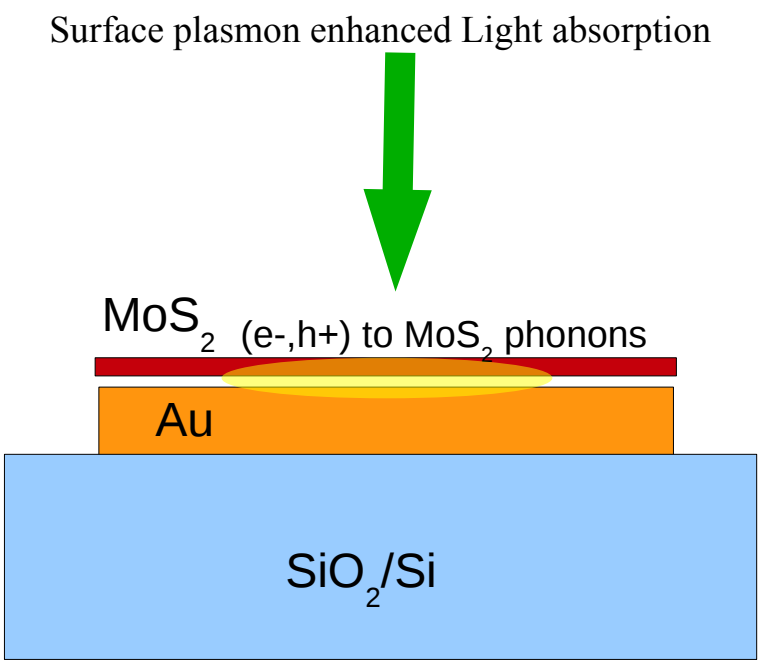
ACS Nano 8, 12682 (2014)

Mechanisms of Plasmonic induced Photo-thermal effect



contact heating

Weak

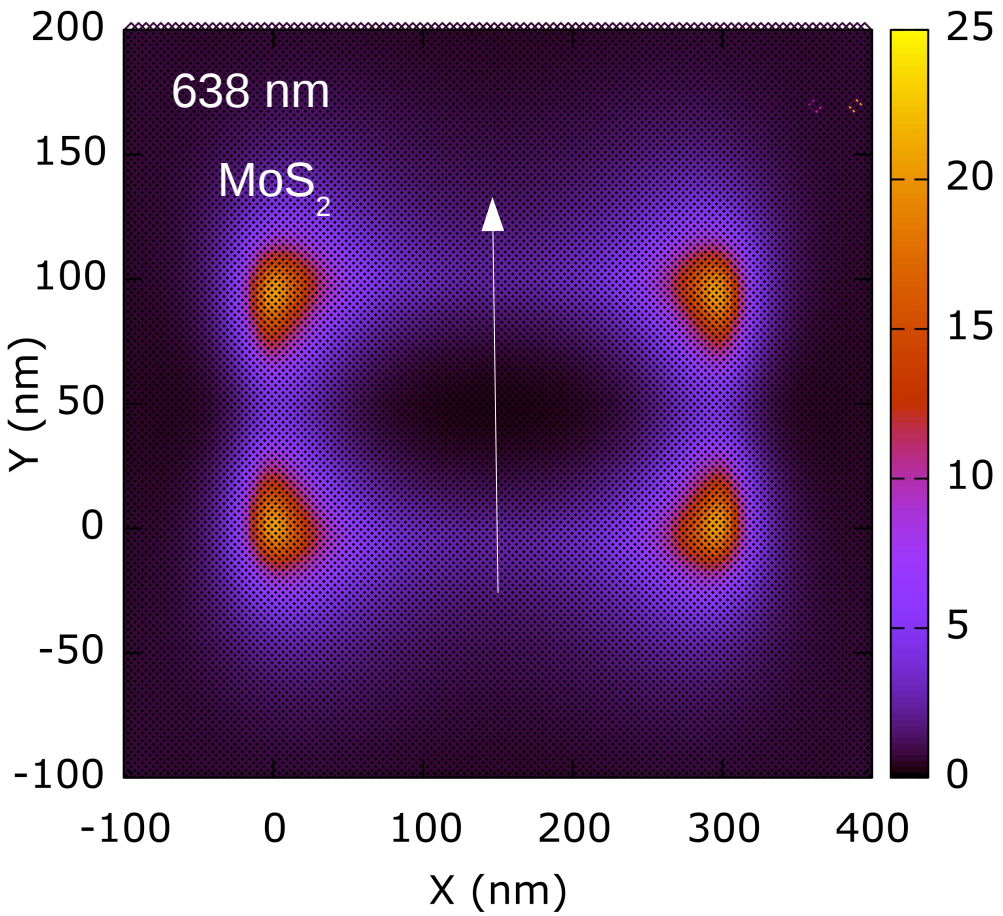


Near-field heating

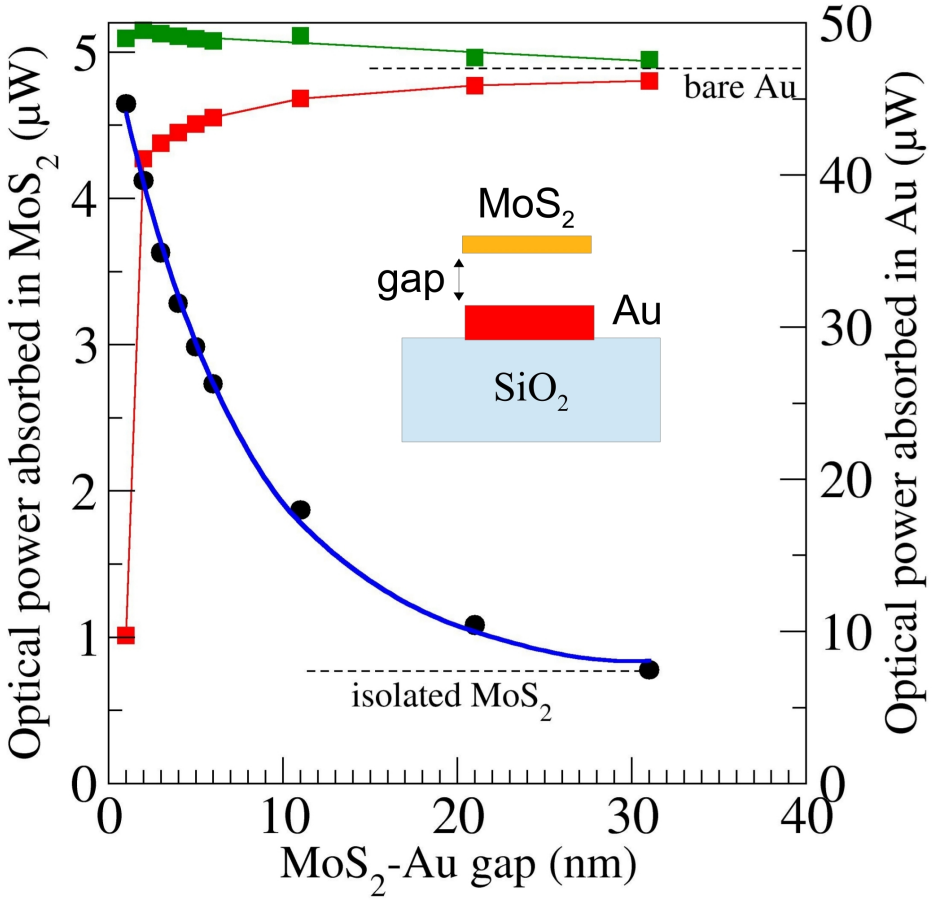
ACS Nano 8, 12682 (2014)

Au-MoS2 near-field interaction

GDM Simulations



DDA Simulations

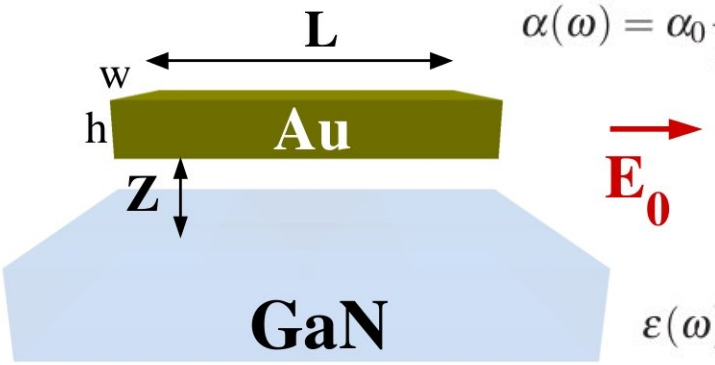


ΔT = 23°C MoS_2

ΔT = 97°C MoS_2@Au

ACS Nano 8, 12682 (2014)

Plasphonics : when phonons meet plasmons



$$\alpha(\omega) = \alpha_0 \frac{\omega_1^2}{\omega_1^2 - \omega^2 + i\omega\gamma_1} \qquad \omega_1 = c\,\pi/L$$

$$\varepsilon(\omega) = \varepsilon_\infty \frac{\omega_L^2 - \omega^2 + i\omega\gamma_L}{\omega_T^2 - \omega^2 + i\omega\gamma_T}$$

$$\mathbf{p}(\mathbf{R},\omega) = \frac{\alpha(\omega)}{1 - \frac{1}{(2R)^3}\frac{\varepsilon(\omega)-1}{\varepsilon(\omega)+1}\alpha(\omega)} \cdot \mathbf{E}_0(\mathbf{R},\omega)$$

$$0 = (\omega^2 - \omega_{SP}^2(Z))(\omega^2 - \omega_{sph}^2) - \delta^2 \frac{\omega_1^2 \varepsilon_\infty^2}{(\varepsilon_\infty + 1)^2} \frac{\alpha_0}{4(Z + h/2)^3}$$

$$\delta^2 = \omega_L^2 - \omega_T^2, \text{ and } \omega_{SP}^2(Z) = \omega_1^2\left(1 + \frac{\alpha_0}{8(Z+h/2)^3}\frac{\varepsilon_\infty - 1}{\varepsilon_\infty + 1}\right) \text{ and } \omega_{sph}^2 = \frac{\omega_T^2 + \varepsilon_\infty \omega_L^2}{1 + \varepsilon_\infty}$$

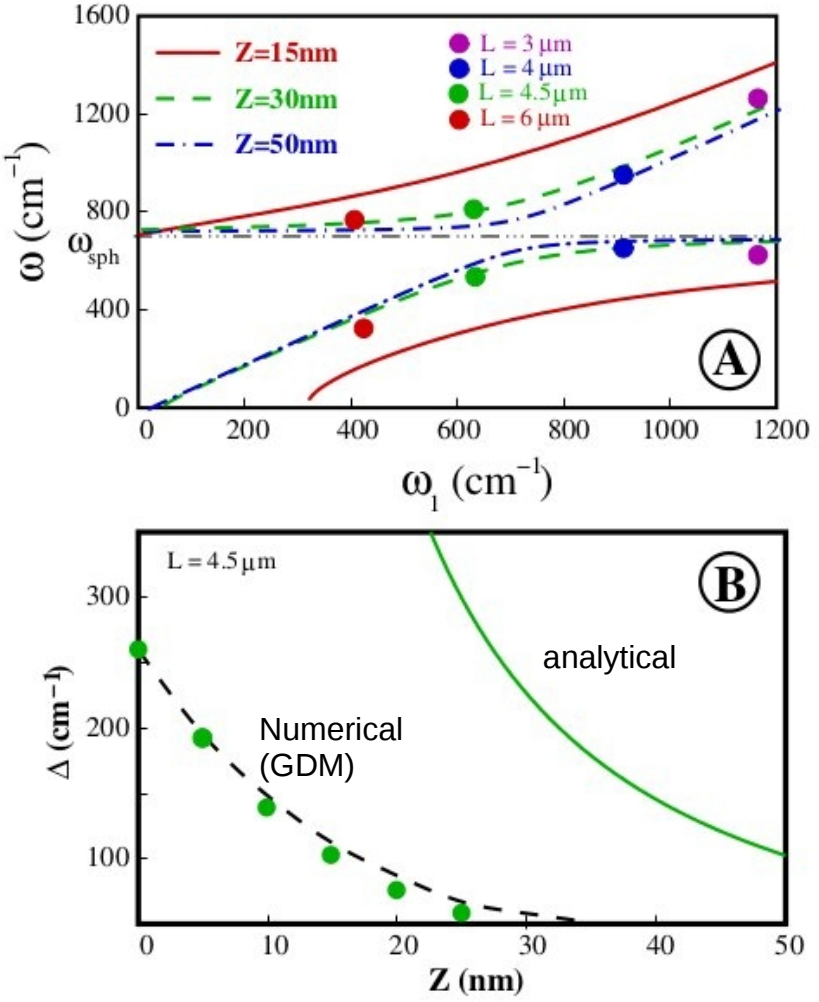
$$\Delta = \omega_+ - \omega_- = \delta \cdot \frac{\omega_1}{\omega_{sph}} \cdot \frac{\varepsilon_\infty}{\varepsilon_\infty + 1} \cdot \frac{\alpha_0^{1/2}}{2(Z + h/2)^{3/2}} \text{ Rabi splitting}$$

Marty et al. Optics Express 21, 2013

Plasphonics : when phonons meet plasmons

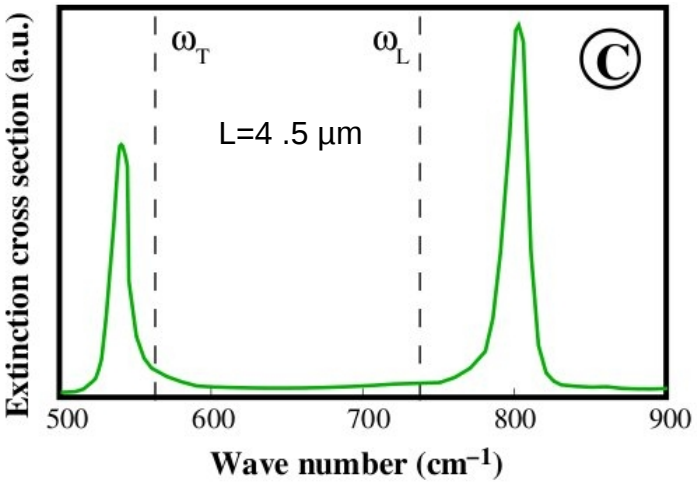
Rabi splitting

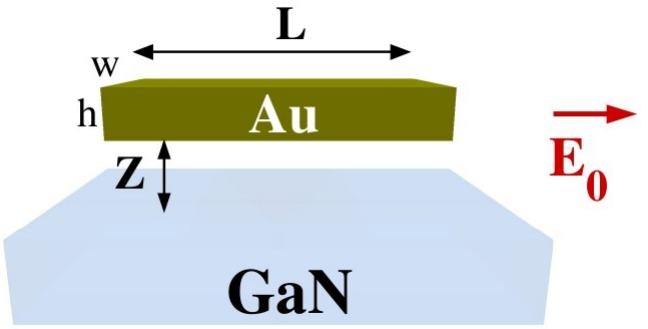
$$\Delta = \omega_+ - \omega_- = \delta \cdot \frac{\omega_1}{\omega_{sph}} \cdot \frac{\varepsilon_\infty}{\varepsilon_\infty + 1} \cdot \frac{\alpha_0^{1/2}}{2(Z + h/2)^{3/2}}$$

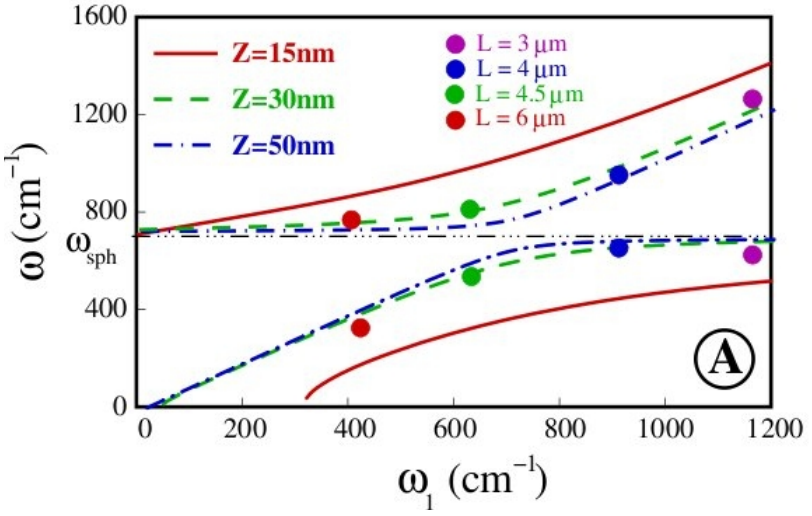


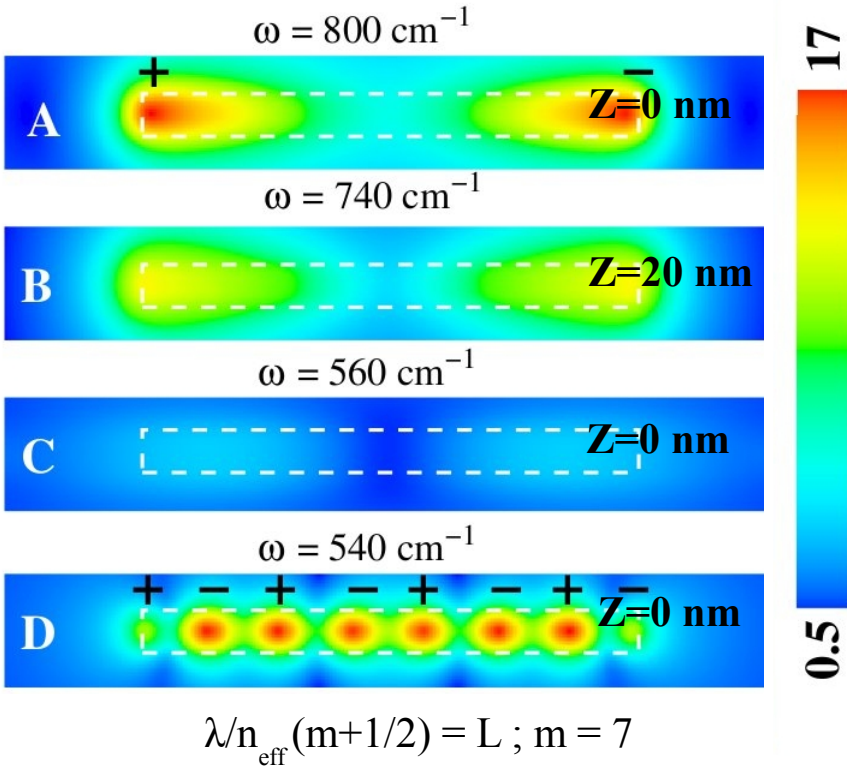
Marty et al. Optics Express 21, 2013

Plasphonics : when phonons meet plasmons









$\lambda/n_{eff}(m+1/2) = L$; $m = 7$

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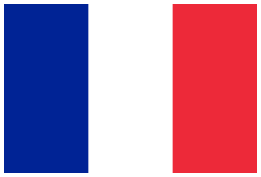

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