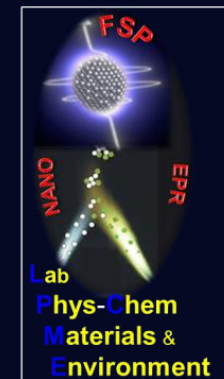




# Engineering of Flame-made Plasmonic-Semiconducting Nanocatalysts: A Study of the Photo-induced Carrier Dynamics and Interfacial Electron Transfer



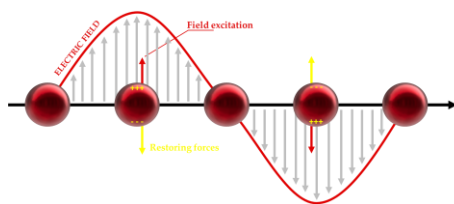
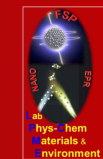
Constantinos Moularas, Christos Dimitriou, Areti Zindrou, Yiannis Deligiannakis



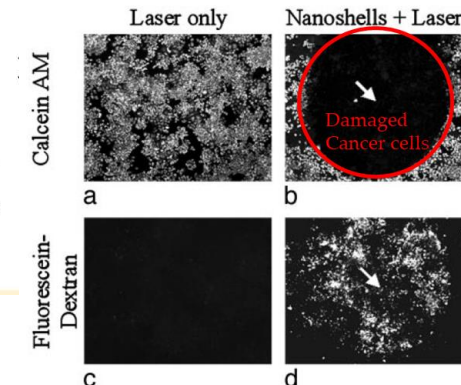
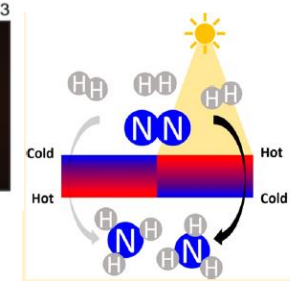
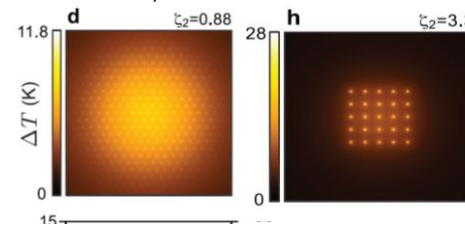
Lab of Physical Chemistry of Materials &  
Environment,  
Physics Department,  
University of Ioannina

<http://nanomaterials.physics.uoi.gr/>

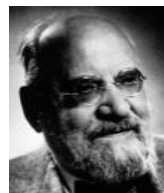
# Nanoplasmonics



G. Baffou et al., *ACS Nano* 2013



J. L. West et al., *Proc Natl Acad Sci U S A*. 2003

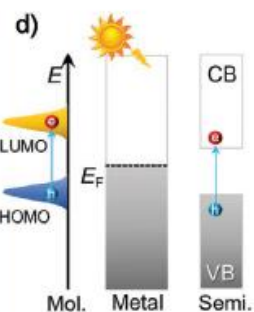


## Local Surface Plasmon Resonance

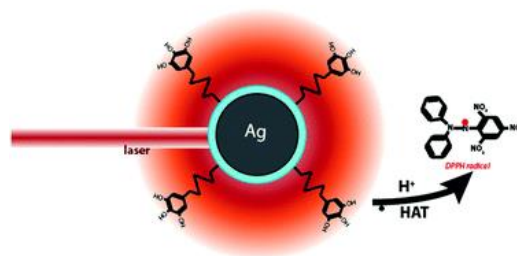
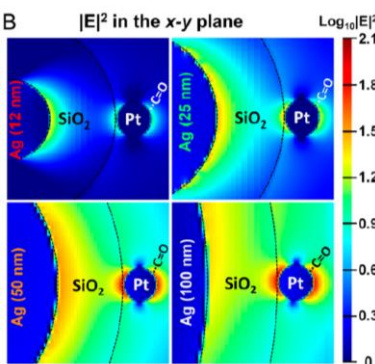
## Photothermal Effects

## Near-field enhancement

## Hot Carriers

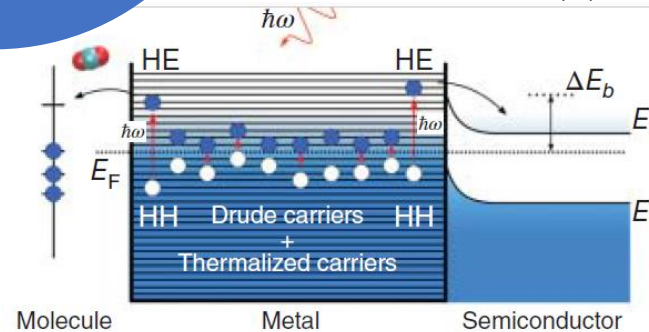


K. Li et al., *Nano Lett.* 2017

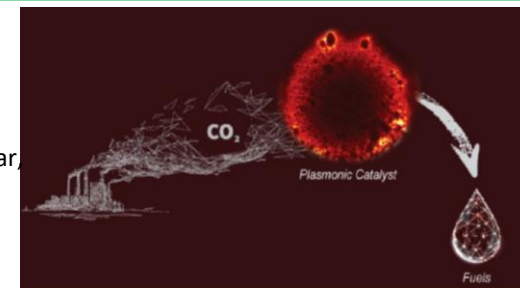


G. A. Sotiriou, C. O. Blattmann, Y. Deligiannakis, *Nanoscale* 2016

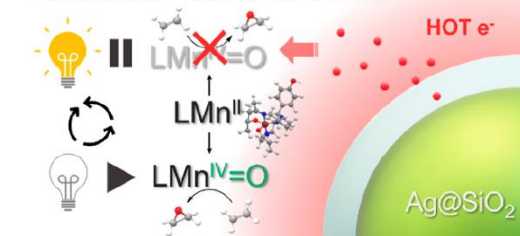
R. Verma, R. Belgamwar, V. Polshettiwar, *ACS Materials Lett.* 2021, 3, 574–598.



A. Gemenetzi, C. Moularas, L. Belles, Y. Deligiannakis, M. Louludi, *ACS Catal.* 2022.

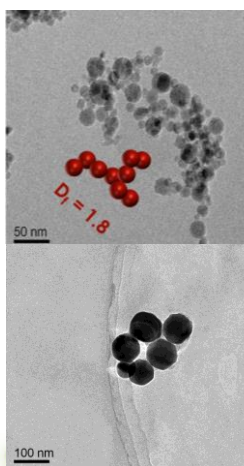
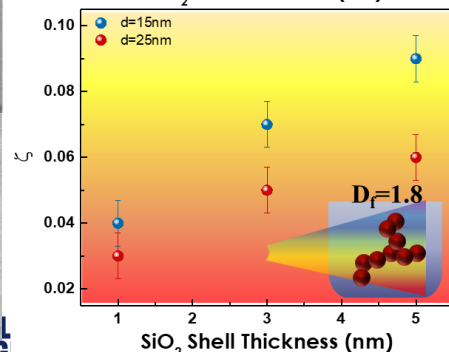
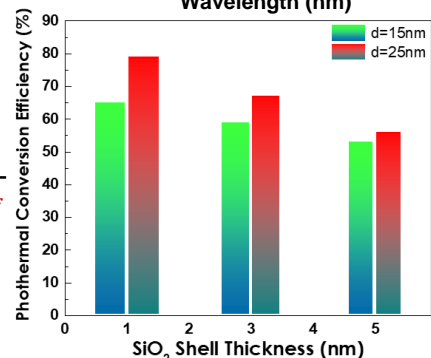
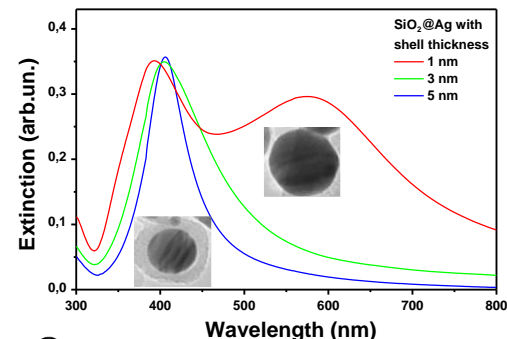
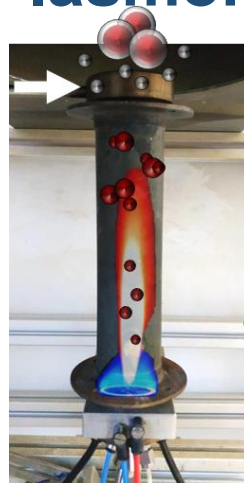


## Reversible Plasmonic Switch

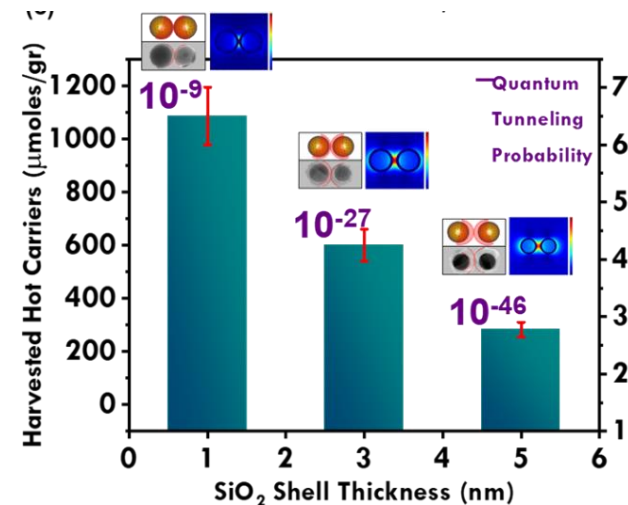
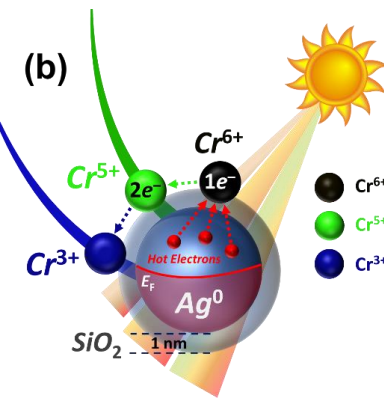
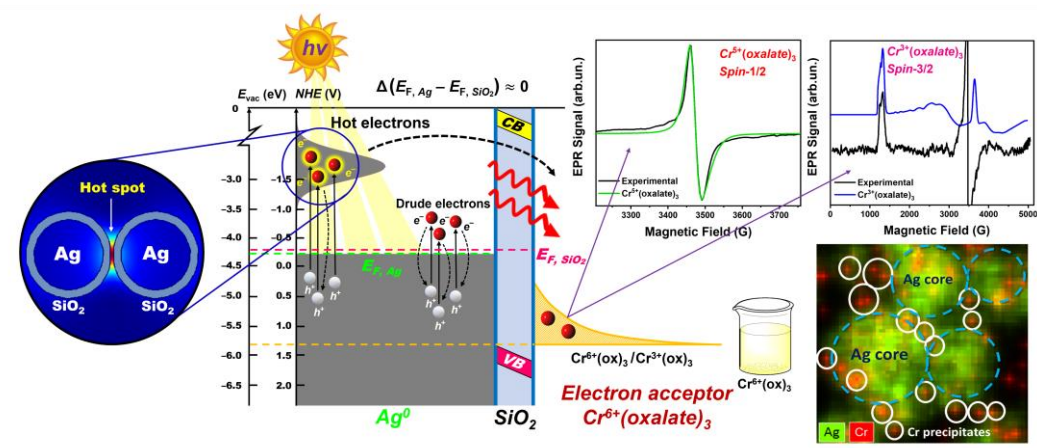


# FSP-made Plasmonic Nanoaggregates

## Plasmonic Heating



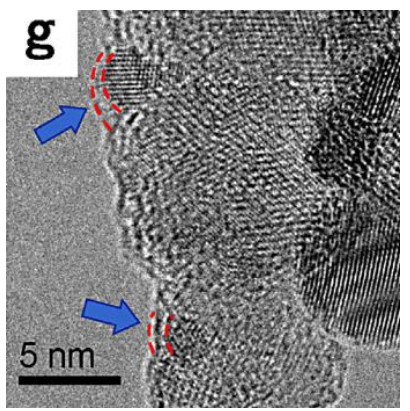
## Hot Electron Harvesting



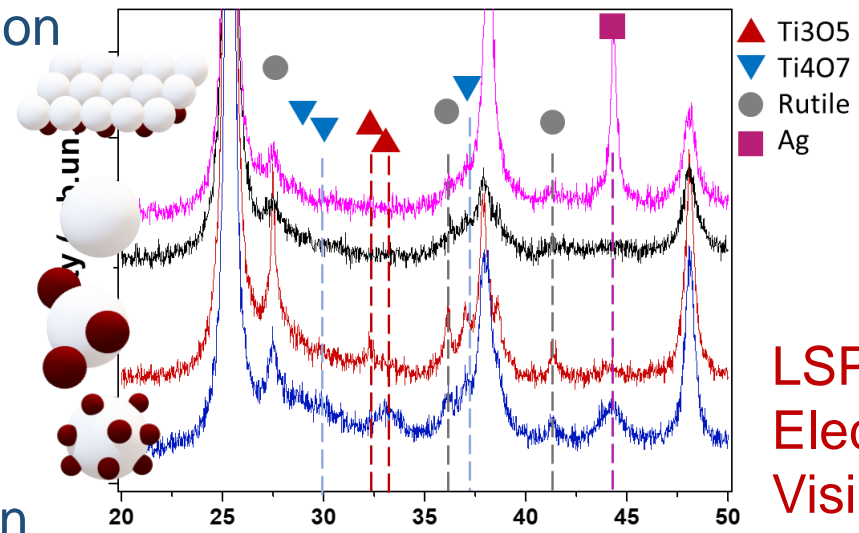
C. Moularas, Y. Georgiou, K. Adamska, Y. Deligiannakis, *Journal of Physical Chemistry C* 2019

C. Moularas, C. Dimitriou, Y. Georgiou, Y. Deligiannakis, *Applied Catalysis B: Environmental* 2022

# Ag / TiO<sub>2</sub> Plasmon-driven Interfacial Distortion



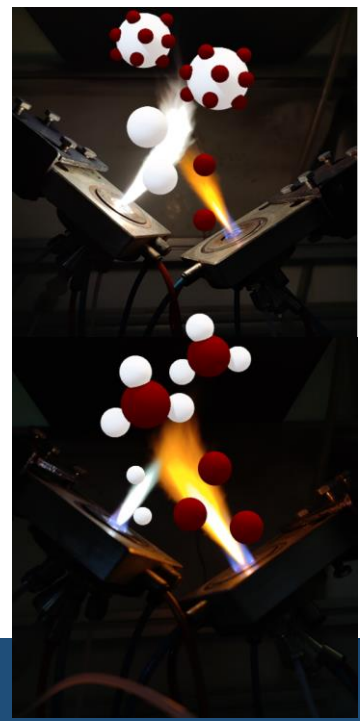
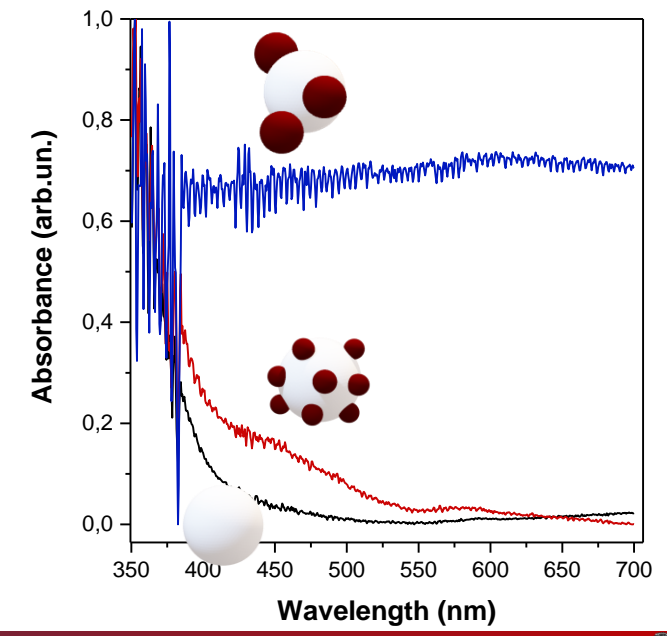
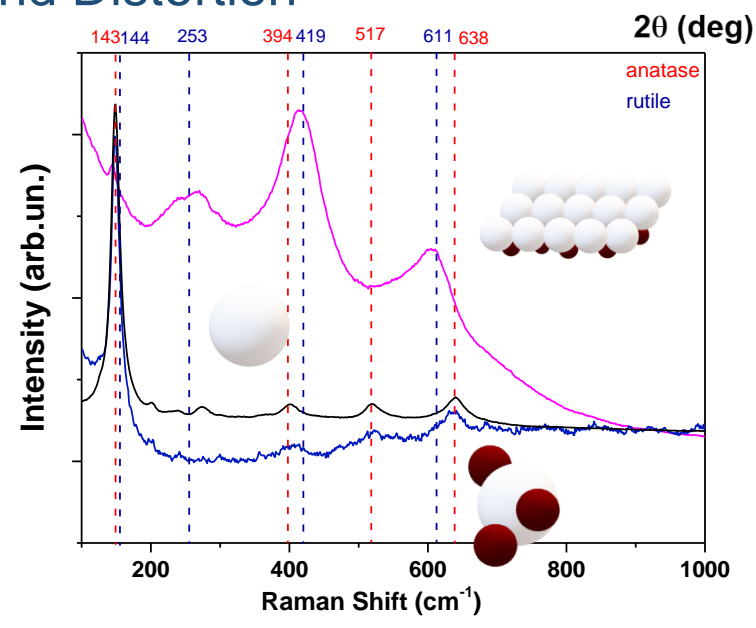
## Magneli Formation



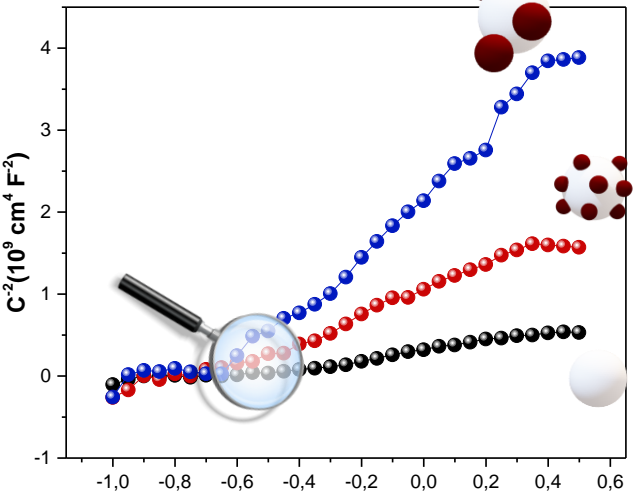
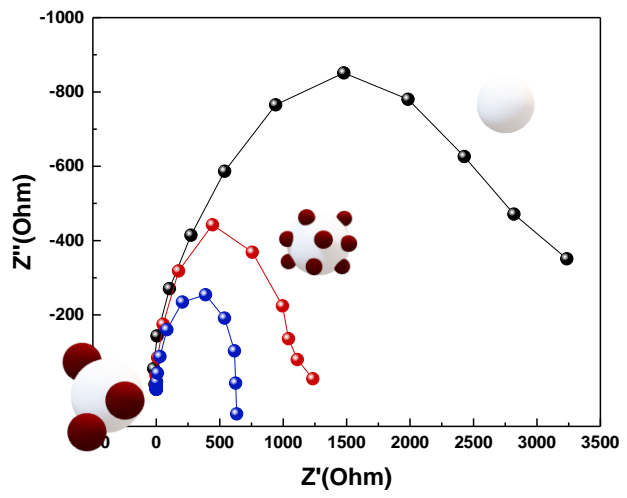
K. Fujiwara, Y. Deligiannakis, C. G. Skoutelis, S. E. Pratsinis, *Applied Catalysis B: Environmental* 2014.

LSPR Damping  
Electron transfer channels  
Visible-light Absorption

## Bond Distortion

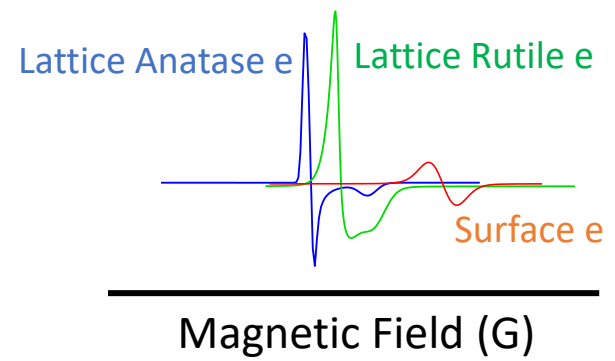
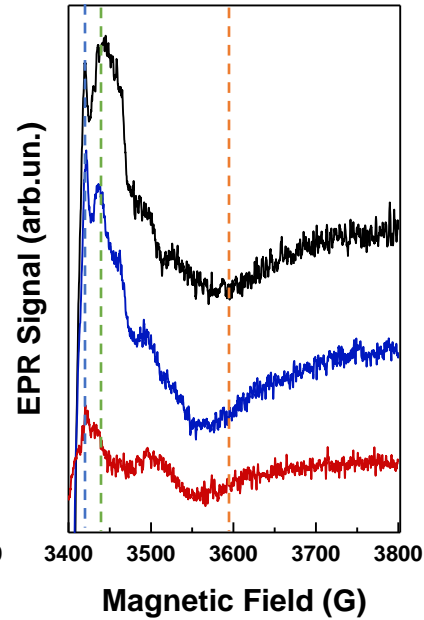
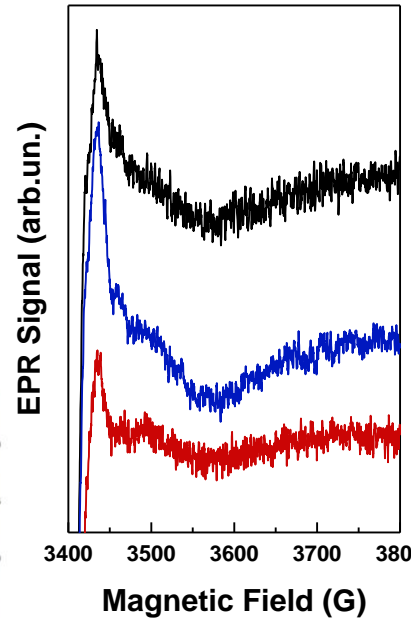
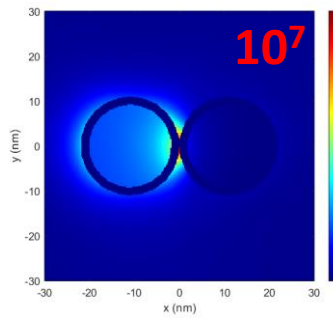
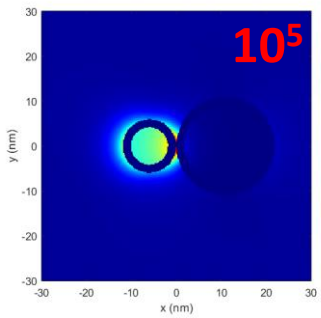
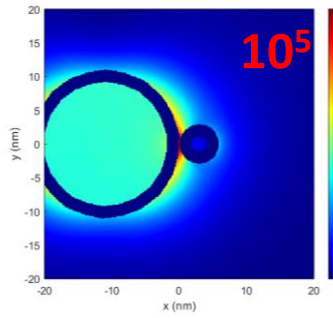
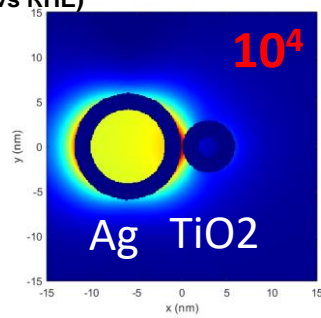
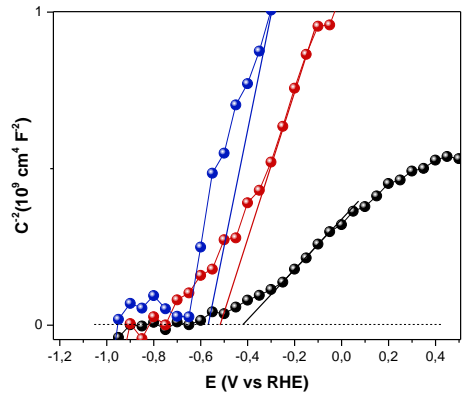


# Photo-induced Carrier Dynamics



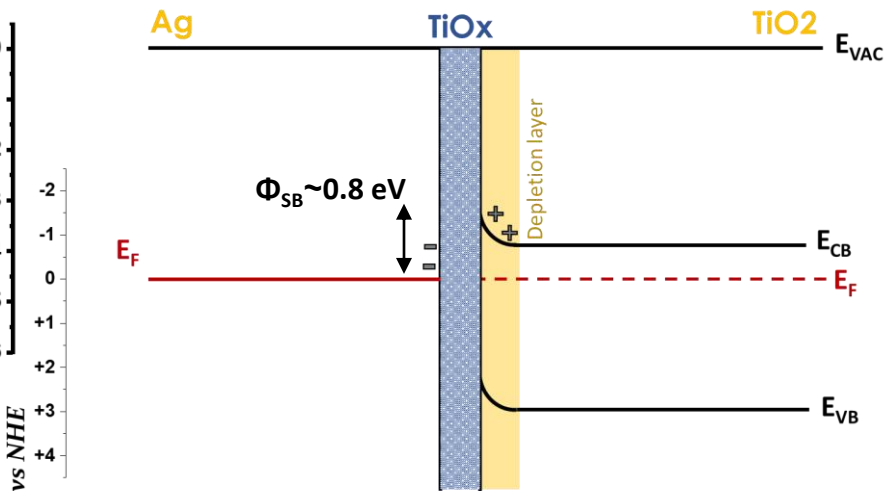
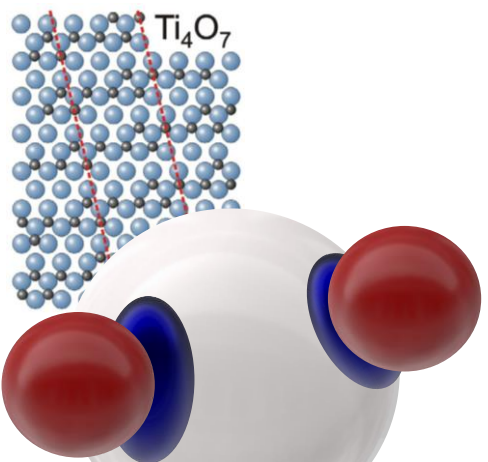
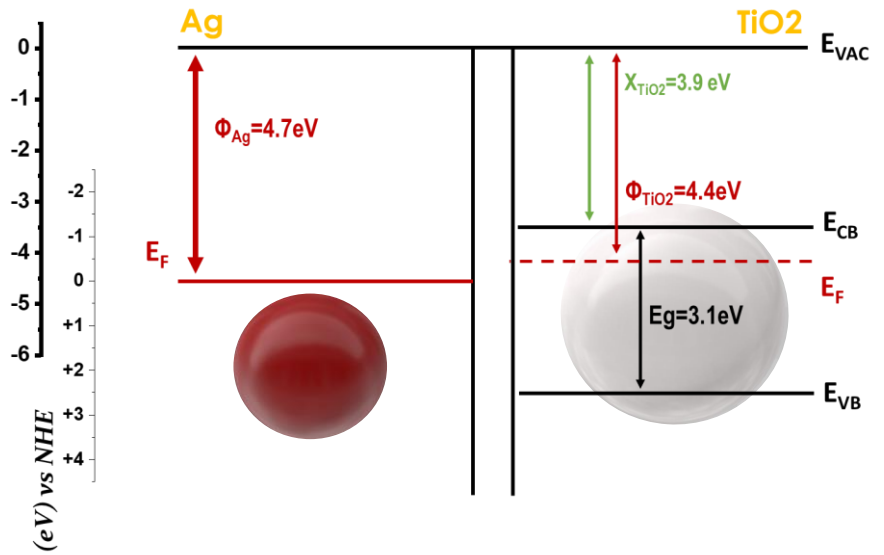
## Hot Electron Transfer from Ag to TiO<sub>2</sub> & Trapping at Magneli sites

Enhanced Carrier Mobility  
Conduction Band Shift  
(~0.14 V)

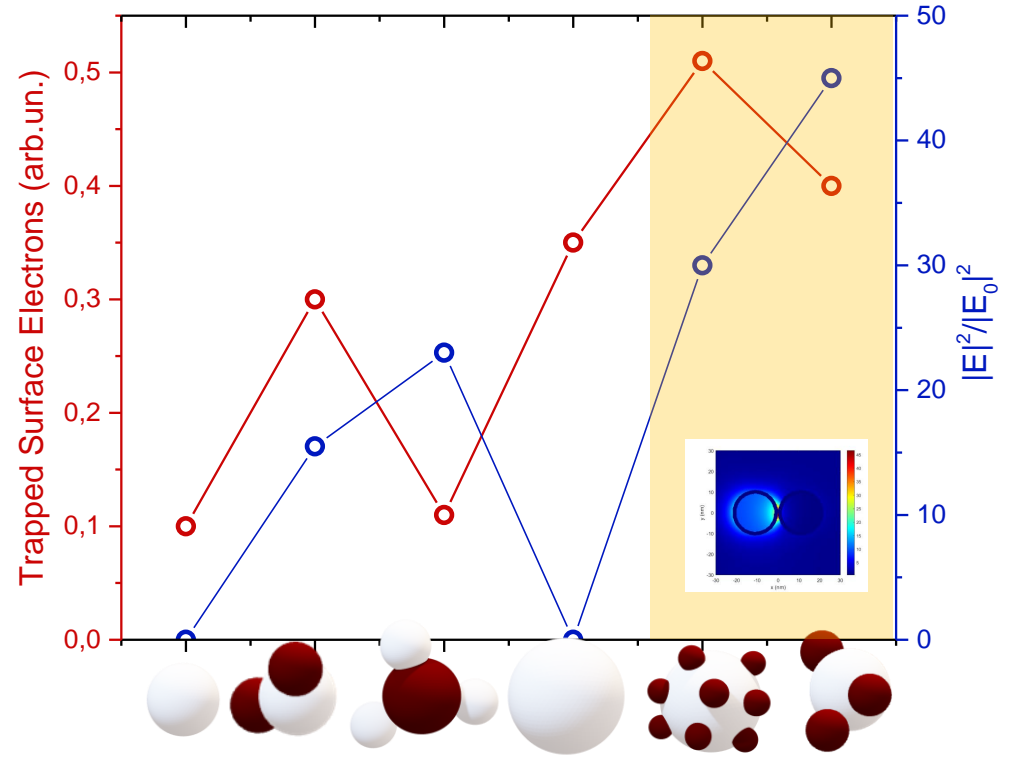


# Conclusions

- Controlled Hot-spot-driven formation of Magneli nanoislands
- Successful hot-electron injection under visible light (455nm)



Magneli Interface



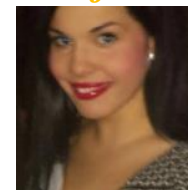
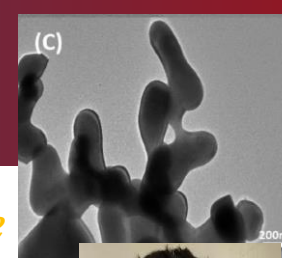
# THANK YOU

Dr. Panagiota Stathi - FSP-made Catalysts, CO<sub>2</sub>RR  
Dr. Maria Solakidou - FSP-made Catalysts, H<sub>2</sub>O Splitting  
PhD Students

Constantinos Moularas - Plasmonics, Photo-induced carrier dynamics  
Pavlos Psathas - FSP perovskites & doping engineering  
Areti Zindrou - FSP tailoring of flame-made suboxides  
Christos Dimitriou - Gas-phase engineering of quantum dots  
Loukas Belles – FSP-made electrocatalysts engineering, ORR



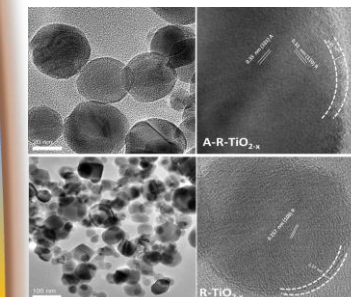
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Modification



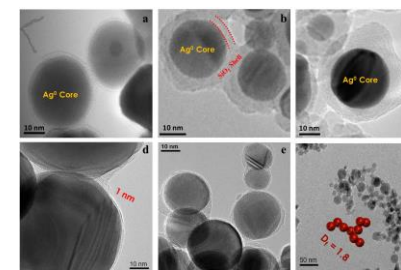
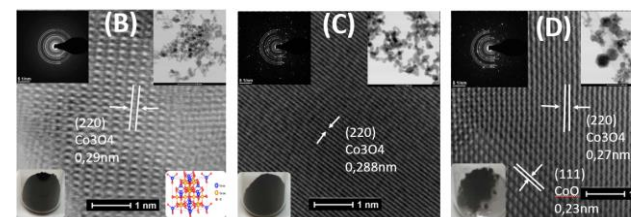
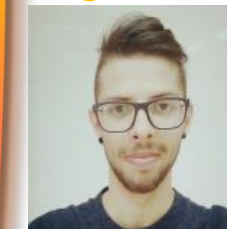
Perovskites



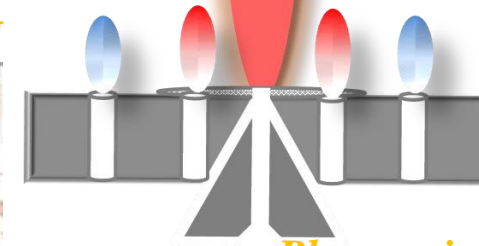
Quantum Dots



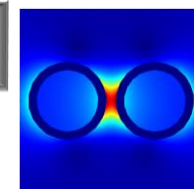
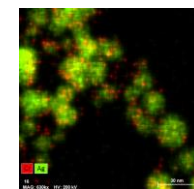
Interface  
Engineering



Defect Engineering



Plasmonics



Co-financed by Greece and the European Union

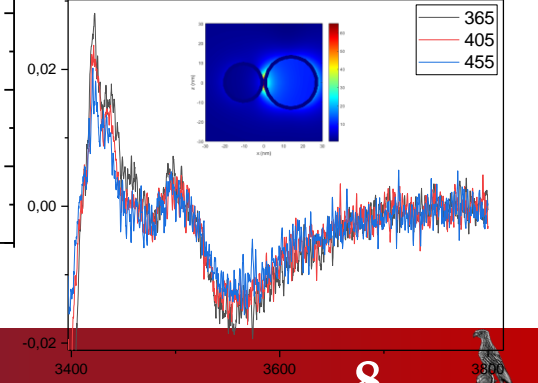
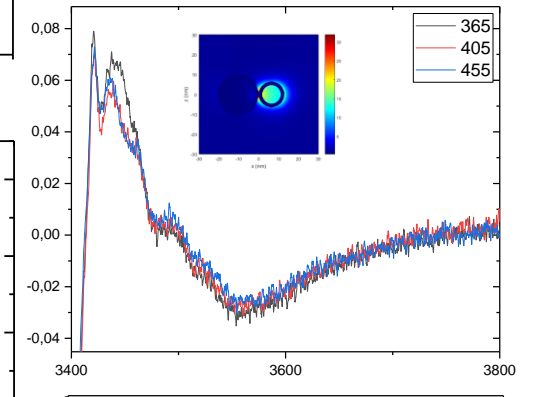
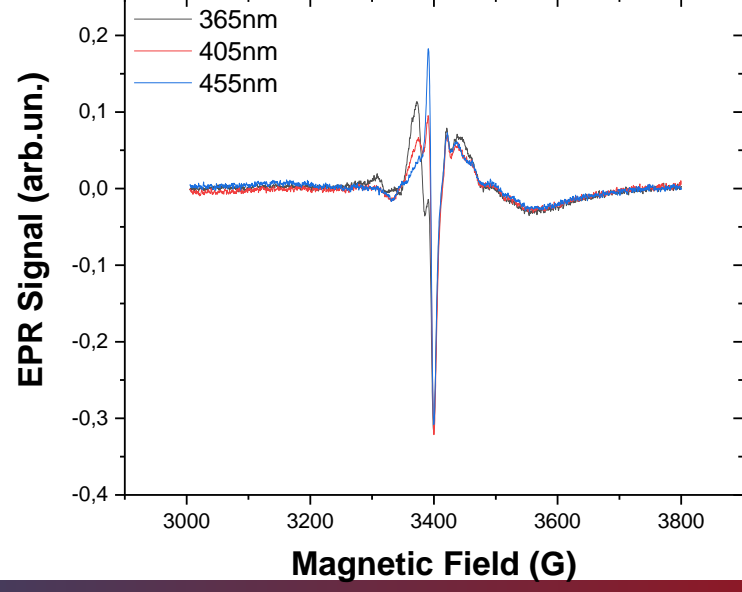
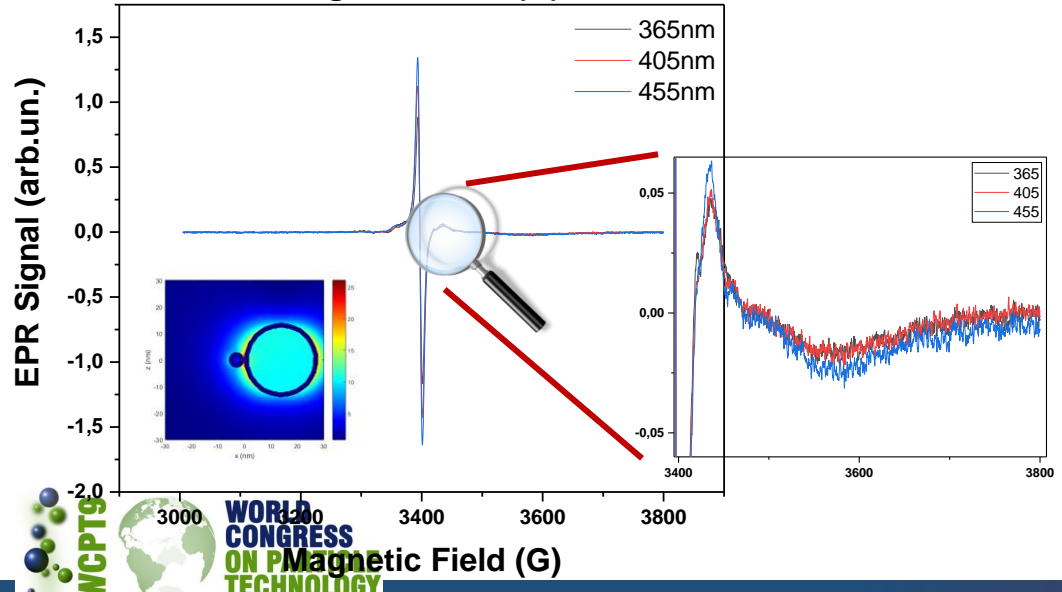
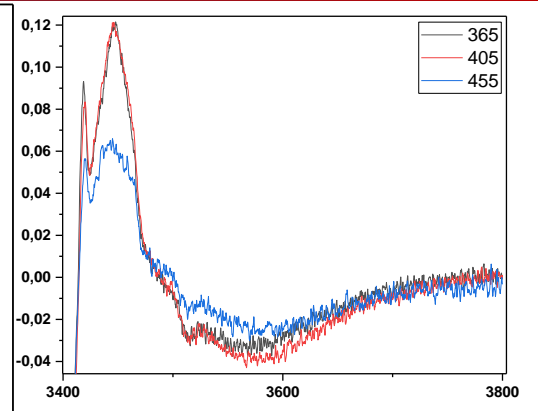
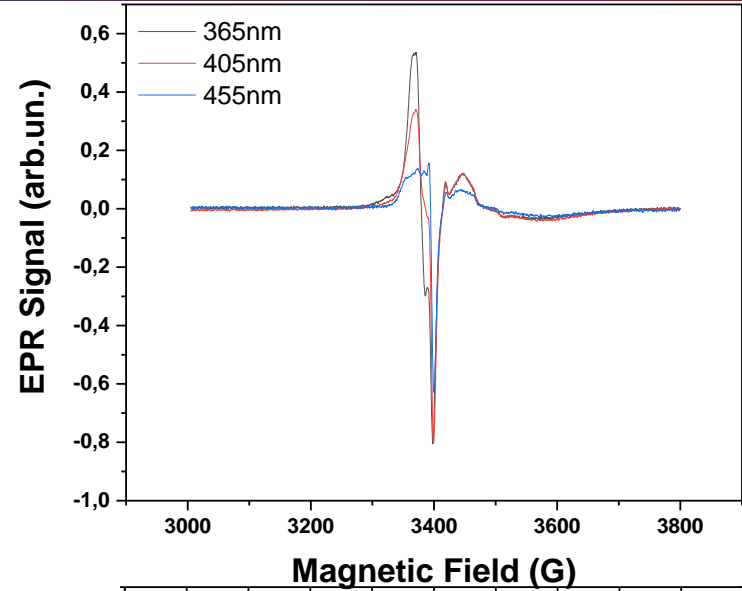
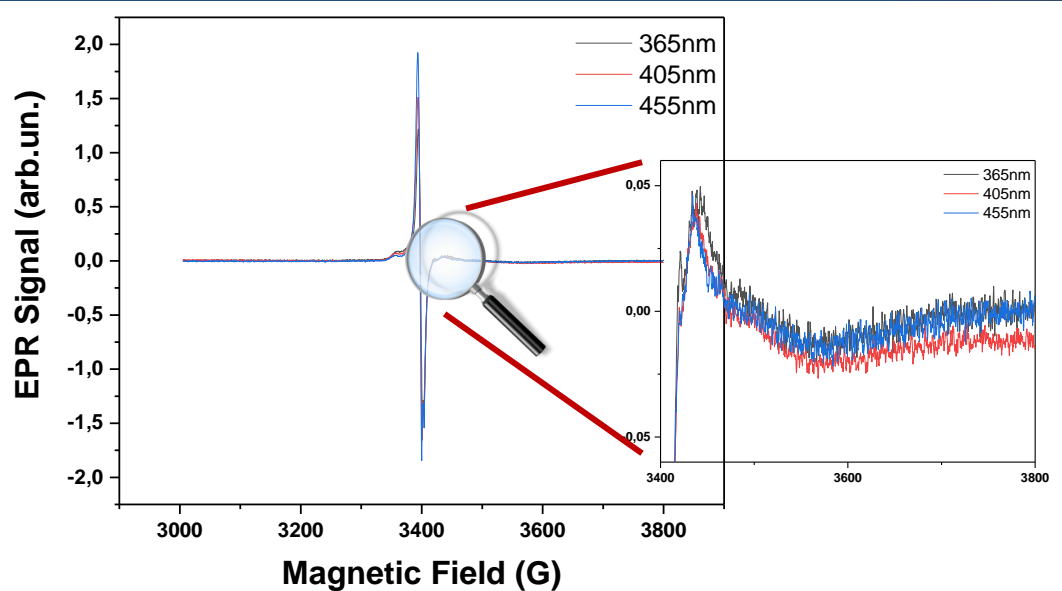


We acknowledge support of this work by the project "Center For Research, Quality Analysis Of Cultural Heritage Materials And Communication Of Science" (MIS 5047233) which is implemented under the Action "[Reinforcement of the Research and Innovation Infrastructure](#)", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

<http://nanomaterials.physics.uoi.gr/>

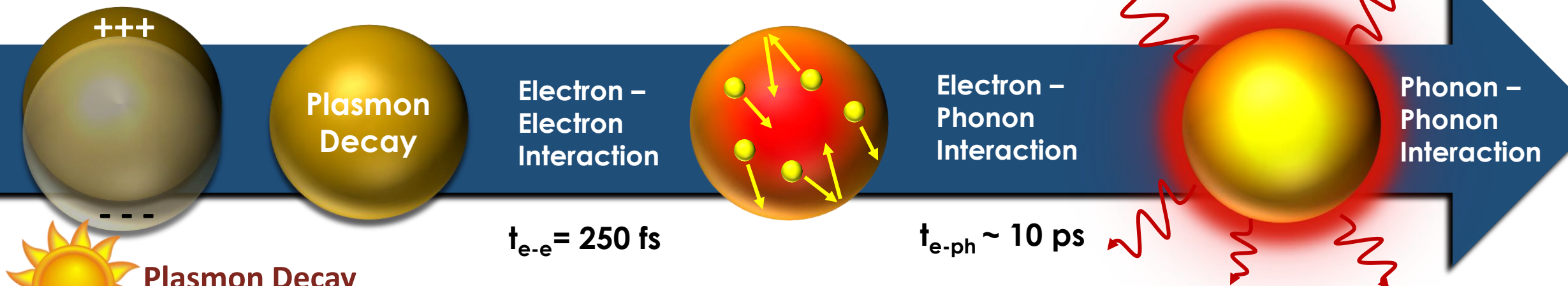
WORLD CONGRESS ON PARTICLE TECHNOLOGY  
September 18-22  
MADRID 2022  
wcpt9.org

# Hot-electron transfer/trapping



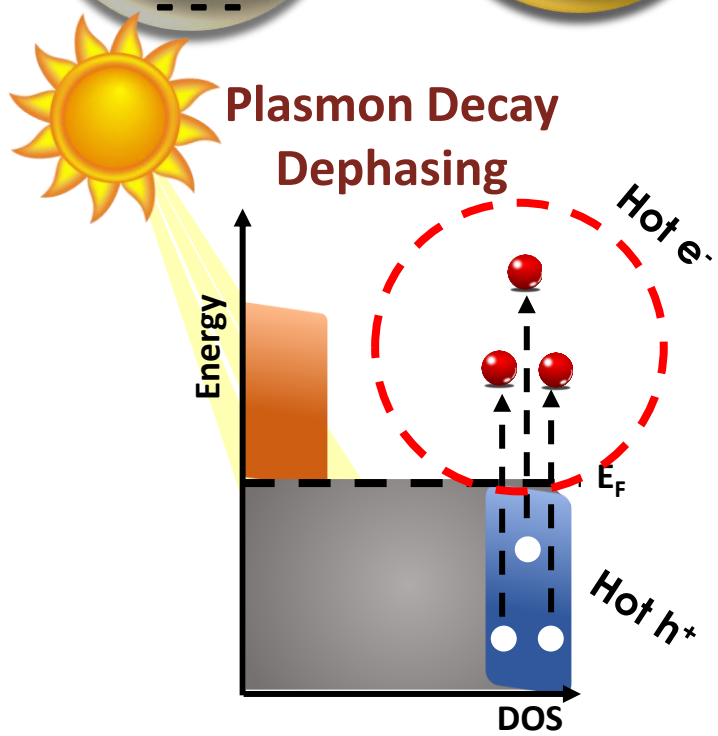


# Hot Carrier Dynamics

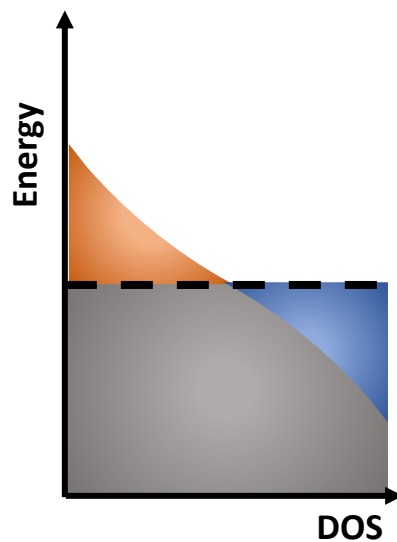


$t_{e-e} = 250 \text{ fs}$

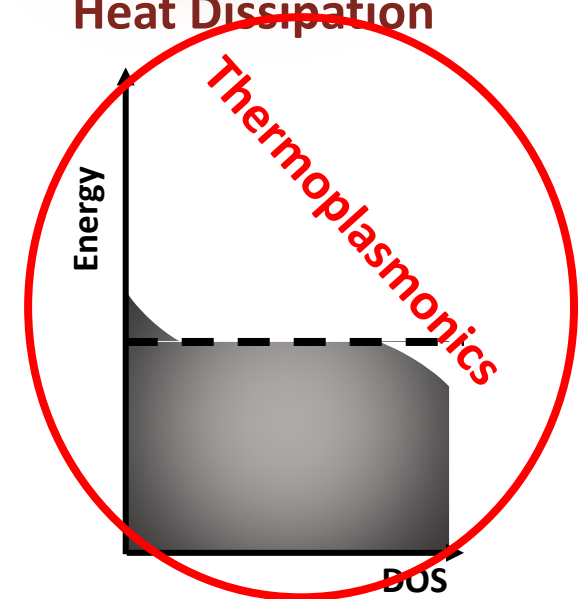
$t_{e-ph} \sim 10 \text{ ps}$



Hot Carrier Relaxation

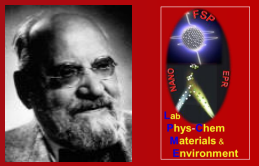


Heat Dissipation



Hartland, G. V. Optical Studies of Dynamics in Noble Metal Nanostructures. *Chem Rev* 2011

# Mie Theory



$$\sigma_{ext} = \frac{2\pi}{|k|^2} \sum_{L=1}^{\infty} (2L + 1) \text{Re}\{a_n + b_n\}$$

$$\sigma_{sca} = \frac{2\pi}{|k|^2} \sum_{L=1}^{\infty} (2L + 1) (|a_n|^2 + |b_n|^2)$$

$$\sigma_{abs} = \sigma_{ext} - \sigma_{sca}$$

$$a_n = \frac{\psi'_n(mx)\psi_n(x) - m\psi_n(mx)\psi'_n(x)}{\psi'_n(mx)\xi_n(x) - m\psi_n(mx)\xi'_n(x)}$$

$$b_n = \frac{m\psi'_n(mx)\psi_n(x) - \psi_n(mx)\psi'_n(x)}{m\psi'_n(mx)\xi_n(x) - \psi_n(mx)\xi'_n(x)}$$

$$\xi_n(x) = \chi h_n^{(1)}(x) \quad m = n/n_m$$

$$\chi = kR$$

| L     | Multipolar Excitations |
|-------|------------------------|
| 1     | Dipole                 |
| 2     | Quadrupole             |
| 3,... | Higher Modes           |

## Tunneling

$$T(L, E) = 16 \frac{E}{U_0} \left(1 - \frac{E}{U_0}\right) e^{-2\beta L}$$

