Laser-enhanced Atomic Mobility and Nanoparticles Formation in Porous Glass

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Introduction

Adsorption, desorption and surface interaction.

➡ Adsorption and desorption influence atom/substrate interaction.

➡ Direct influence on atomic mobility: dynamics and evolution at the nanoscale.
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Adsorption, desorption and surface interaction.

➡ Adsorption and desorption influence atom/substrate interaction.

➡ Direct influence on **atomic mobility**: dynamics and evolution at the nanoscale.

➡ Adsorption and desorption can be controlled by light.

[A. Gozzini et al., Il Nuovo Cimento D 15, 5, 709, 1993]
Photodesorption and applications

**RT vapor density stabilization and modulation:** all-optical atomic dispenser.

[A. Bogi et al., Opt. Lett. 34, 17, 2643, 2009]
Photodesorption and applications

→ RT vapor density stabilization and modulation: all-optical atomic dispenser.

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Photodesorption and applications

RT EIT in optically stabilized vapors: constant, improved C and 33 kHz FWHM.

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RT EIT in optically stabilized vapors: constant, improved C and 33 kHz FWHM.

Optical response of metal nanoparticles

Localized Surface Plasmons.

- Interaction between photon EF and CB e⁻ metal NP.
- Non propagating ➞ Localization.
- \( k = 0 \) ➞ PM with incoming radiation.
- Quasi-static and dipole approximation ➞ \( 2a < 20 \) nm
Optical response of metal nanoparticles

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Optical response of metal nanoparticles

Localized Surface Plasmons: Gans approach.

\[ \alpha_j(\omega) = \varepsilon_0 \frac{\varepsilon(\omega) - \varepsilon_m}{\varepsilon_m + [\varepsilon(\omega) - \varepsilon_m]L_j} V \]

\[ \sigma_{Gans}^{ext} = V \frac{\omega}{3c} \frac{\varepsilon_m^{3/2}}{\varepsilon_m} \sum_{j=a,b,c} \frac{\varepsilon_2(\omega)/L_j^2}{\varepsilon_2^2(\omega) + \left[ \varepsilon_1(\omega) + \varepsilon_m \frac{1 - L_j}{L_j} \right]^2} \]
Optical response of metal nanoparticles

Localized Surface Plasmons: Gans approach.

\[ \begin{align*}
\alpha_j(\omega) &= \varepsilon_0 \frac{\varepsilon(\omega) - \varepsilon_m}{\varepsilon_m + [\varepsilon(\omega) - \varepsilon_m]L_j} V \\
\sigma_{Gans}^{ext} &= \left( \frac{L_j}{L_j} \right)^2 [Bohren, Huffman 1983]
\end{align*} \]
Porous glass

PG: a small flat on a fingertip.

- SiO$_2$ 96%
- B$_2$O$_3$ 3%
- Traces: Na$_2$O, Al$_2$O$_3$, ZrO$_2$

Spinodal decomposition:
- domains $\sim t^{1/2}$
- average radius $\sim t$
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Porous glass

PG: a small flat on a fingertip.

- Average pore diameter: 20 nm.
- Free volume: 0.55.
- Internal surface: 31 m².
Light-induced phenomena in PG

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Light-induced atomic desorption in PG [A. Burchianti et al., Europhys. Lett. 67, 6, 983, 2004].
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Experimental apparatus

“Static” characterization: absorbance analysis.

\[ \text{Abs} \equiv - \log \frac{T(\lambda)}{I_0} \]
Experimental apparatus

“Dynamic” characterization: time evolution.

- K vapor density: ECDL @ 770.1 nm (K D1 line), ~2.5 GHz sweep, 47 Hz
- Desorbing lights: LD @ 660 nm, DPSSL @ 532 nm, LD @ 405 nm
- TPBs: LD @ 730 nm, 780 nm, 830 nm, 850 nm, 1460 nm
- DAQ: I/O multi-channel, background subtraction+resonance following, illumination timing
Light-induced processes in K PG

Two simultaneous processes.

\[ \delta_{max} = \frac{n(t_{max}) - n_0}{n_0} \]

\[ \hbar \omega_{exp} = 1.66 \pm 0.02 \text{ eV} \]
Light-induced processes in K PG

Two simultaneous processes.

\[ R = \frac{1}{n_0} \frac{dn(t)}{dt} \left|_{0^+} \right. \]

\[ \hbar \omega_{exp} = 1.66 \pm 0.02 \text{ eV} \]
Light-induced processes in K PG

Two simultaneous processes.
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Two simultaneous processes.
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Two simultaneous processes.

\[ \varepsilon_{eff} = 2.04 \]
\[ \hbar \omega_p = 3.72 \text{ eV} \]

\[ \hbar \omega_{LSP} = \frac{\hbar \omega_p}{\sqrt{1 + 2\varepsilon_{eff}}} = 1.65 \text{ eV} \]
Absorbance spectra

60 mW/cm² at 635 nm, 120 s: low desorption regime.
Absorbance spectra

350 mW/cm$^2$ at 532 nm: desorption regime.

Light as a NPs maker.
Absorbance spectra

5 mW/cm² at 405 nm: efficient desorption regime.

Light as a NPs maker.
Absorbance spectra


350 mW/cm² @ 532 nm

5 mW/cm² @ 405 nm
Absorbance spectra


350 mW/cm² @ 532 nm

5 mW/cm² @ 405 nm

2 nm prolates, AR=0.75
Absorbance spectra


350 mW/cm² @ 532 nm

5 mW/cm² @ 405 nm

2 nm oblates, AR=1.25

2 nm prolates, AR=0.75
Absorbance spectra

Near-infrared peak: relaxation in the dark.

After 350 mW/cm² @ 532 nm

After 5 mW/cm² @ 405 nm

2 nm oblates, AR=1.25

2 nm prolatess, AR=0.75
Optical control of NPs self-assembly

1. Adsorption in the dark.
Optical control of NPs self-assembly

I. Adsorption in the dark.

II. Light-induced desorption: enhanced atomic mobility.
Optical control of NPs self-assembly

1. Adsorption in the dark.

II. Light-induced desorption: enhanced atomic mobility.

III. NPs self-assembly.
Optical control of NPs self-assembly

350 mW/cm² @ 532 nm

5 mW/cm² @ 405 nm

2 nm oblates, AR=1.25

2 nm prolates, AR=0.75
Optical control of NPs self-assembly

350 mW/cm² @ 532 nm

5 mW/cm² @ 405 nm

Light as a NPs shaper.

2 nm oblates, AR=1.25

2 nm prolates, AR=0.75
Optical control of NPs self-assembly

After 350 mW/cm² @ 532 nm

![Graph showing the change in relative concentration over time for 2 nm oblates and prolates at 532 nm.](image)

- 2 nm oblates, AR=1.25

After 5 mW/cm² @ 405 nm

![Graph showing the change in relative concentration over time for 2 nm oblates and prolates at 405 nm.](image)

- 2 nm prolates, AR=0.75

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Optical control of NPs self-assembly

After 350 mW/cm² @ 532 nm

Spontaneous reversibility by intrinsic mechanisms.

2 nm oblates, AR=1.25

After 5 mW/cm² @ 405 nm

2 nm prolates, AR=0.75

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System time evolution

385 mW/cm² at 660 nm: low mobility regime.
System time evolution

40 mW/cm² at 532 nm: light-enhanced mobility regime.
System time evolution

5 mW/cm² at 405 nm: light-enhanced high mobility regime.
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.
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Light

Atomic desorption

\(\lambda\)-dependent enhanced mobility
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.

Light

Atomic desorption

λ-dependent enhanced mobility

Metastable NP self-assembly

Atomic diffusion inside pores
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.

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Conclusions

Light-enhanced atomic mobility, NP, atomic motion.

Light

Atomic desorption

λ-dependent enhanced mobility

Metastable NP self-assembly

Metastable NP evaporation

Atomic diffusion inside pores
Conclusions

Thank you for your attention
and
for these wonderful years together!

(See you soon)