Control of the gold nanoparticle generation process with applications in lithography

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Introduction

- **Gold nanoparticles (AuNP) applications:**
  - *Electronic devices*
  - *Biosensing*
  - *Detection*
  - *Catalysis*

  ➡ **Depend on the AuNP** → **size**

  → **shape**

- **The size and shape depend on the process parameters (irradiation power, irradiation time, polymer concentration).**

Objectives and approach

- **Mathematical modeling of the heat and mass transfer that occur in the gold nanoparticle generation process:**
  - *Study the light excitation process*
  - *Study the heat transfer process*
  - *Study the mass transfer process*
  - *Mathematical model*
- **Study the influence of the process parameters upon the nanoparticle dimension**
- **Improvement of the hardware infrastructure performance**
- **Predictive control system of the lithography process quality**

ID	Task Name	Duration	Start	Finish										2015												2016												2017								
					A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	**The control of the gold nanoparticle generation process with applications in lithography**	**738 days**	**Fri 10/10/14**	**Tue 8/8/17**																																							
2	**Study the photochemical process**	**314 days**	**Fri 10/10/14**	**Wed 12/23/15**																																							
3	*Study the light excitation process*	*44 days*	*Fri 10/10/14*	*Wed 12/10/14*																																							
4	*Study the heat transfer process*	*57 days*	*Mon 12/15/14*	*Tue 3/3/15*																																							
5	*Study the mass transfer process*	*45 days*	*Wed 3/4/15*	*Tue 5/5/15*																																							
6	*Influence of the process parameters upon the nanoparticle dimension*	*89 days*	*Wed 5/6/15*	*Mon 9/7/15*																																							
7	*Develop the mathematical model*	*75 days*	*Thu 9/10/15*	*Wed 12/23/15*																																							
8	**Improvement of the hardware infrastructure performance**	**152 days**	**Mon 1/4/16**	**Tue 8/2/16**																																							
9	**Predictive control of the lithography process quality**	**262 days**	**Mon 8/8/16**	**Tue 8/8/17**																																							

Current state

- **Study the light excitation process**

- **Study the heat transfer process**

- **Project proposal in the young team competition:** *"Fabrication of new nano/microstructured materials using laser radiation and applications".*

Light excitation process

- **Advantages** → *clean process*
  - *AuNP – fabricated in various mediums*
  - *fast formation of the AuNP*

- **Photochemical synthesis mechanisms:**
  - *Direct photoreduction*
  - *Photosensitized photoreduction*

- **2 step fabrication of AuNP:**
  - *Nucleation*
  - *Coalescence of atoms – leads to the formation of clusters*

- Masanori S., Mamoru F., Tetsuro M., *"Light as a construction tool of metal nanoparticles: Synthesis and mechanism"*, Journal of Photochemistry and Photobiology C: Photochemistry Reviews, **2009**, 33–56;
- Mallick K, Witcomb M., Scurrell M., *"Polymer-stabilized colloidal gold: a convenient method for the synthesis of nanoparticles by a UV-irradiation approach"*, Applied Physics. A 80, **2005**, 395–398;

Heat transfer process

- **Heat – can be seen as a broadened incoherent statistical set of vibrations**

- **Heat transport – ensured by carriers (elementary particles: electrons, phonons, photons)**

- **AuNP - exposed to an incident light in the visible spectral domain, gain energy by absorbing photons through electron transitions.**

- **The main relaxation process – electron-phonon scattering.**

- **The particle temperature – balance between:**

  - *Gain of energy from the electron-phonon collisions*

  - *Heat release towards the host medium*

- **The AuNP temperature also depends on:**

  - *Nanoparticle radius*

  - *Metal concentration*

- C. Louis, O. Pluchery, "*Gold nanoparticles for physics, chemistry and biology*", Imperial college press, **2012**,75-80;
- Govorov A. and Richardson H., *"Generating heat with metal nanoparticles"*, Nano Today, Volume2, Issue 1, **2007**, 30–38;

Near Future

- **Write an article based on the master thesis:** "*Neural network modeling of the parameterized gold nanoparticles generation through photo-induced process*".

- **Mathematical modeling of the heat generated at interaction of the laser radiation with the chemical system, respectively the gold nanoparticles.**