National Institute for Laser, Plasma and Radiation Physics

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Contact: Director Dr. Rares Medianu, rares.medianu@inflpr.ro
Tel: +40-21-4574489, Atomistilor 409 Str., P.O. Box MG-36, 077125 Bucharest, ROMANIA

Laser Photochemistry Laboratory

Nanostructured materials obtained by Laser Pyrolysis with applications in magnetism, biomedicine, catalysts, sensors

Nanostructures, fabricated by laser pyrolysis:

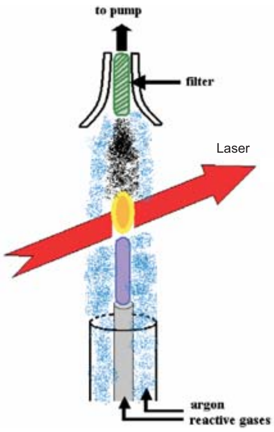
1. Carbon nanostructures from different hydrocarbon/sensitized precursors; 2. Gamma iron oxide (maghemite)/iron carbides nanopowders adding oxidizer/hydrocarbon precursors, respectively
3. Titania and titanium-doped iron oxides adding $TiCl_4$ vapours
4. Iron-carbon nanocomposites (core-shell structure) by specific experimental conditions; 5. Nanofibres/multi-wall carbon nanotubes: a) by LCVD method; b) by laser heating on seeded substrate
6. Siloxane polymer/iron shell-core nanostructures prepared from iron pentacarbonyl vapours and HMDSO (hexamethyl disiloxane)

The **principle of laser pyrolysis** from gas phase reactants :

Powerful and versatile tool: for producing nanostructures of various chemical compositions: Si-based compounds (Si, SiC, Si/C/N, Si_3N_4), carbon, iron, iron oxides, iron carbides, etc.

Advantages of this method:
- pure products (no contact with surface of the chamber);
- extremely fine powders (d=1-50 nm);
- small distribution of sizes;

Continuous synthesis by using a cross-flow configuration



Experimental scheme

Results:

- A modern and versatile method was employed for the synthesis of different nanopowders and composites.
- The existing equipment for laser pyrolysis allows us to approach the fabrication of a large variety of nanostructures.

The presented results demonstrate that the laser pyrolysis technique may produce nanomaterials whose specific properties open new opportunities for modern applications in magnetism, biomedicine, sensors and catalysis:

◆ Soot containing different carbon nanomaterials were obtained by the laser pyrolysis of different hydrocarbons

◆ Nanometric size γ-Fe_2O_3 particles were obtained from gas-phase reactants (iron pentacarbonyl (vapours) and air as oxygen donor)

◆ Different titanium-based iron oxide nanocomposite powders prepared from $TiCl_4$/ $Fe(CO)_5$/air/ C_2H_4 precursors showing different degrees of titanium incorporation, mainly by simply penetrating the iron oxide network (mean size between 1.5 and 8 nm)

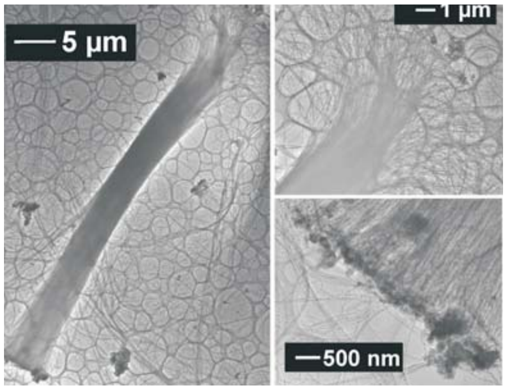
◆ Siloxane polymer/iron shell-core nanostructures were obtained using iron pentacarbonyl and HMDSO mixtures

◆ Single-step experiment was leading to the synthesis of Fe-C nanocomposites formed of iron nanoparticles (4.5-6 nm mean diameters) with a low degree of agglomeration, which are covered by carbon layers

◆ Preliminary LCVD experiments demonstrate the catalytic properties for growing fibers/nanotubes of the as-prepared Fe-C nanocomposites.

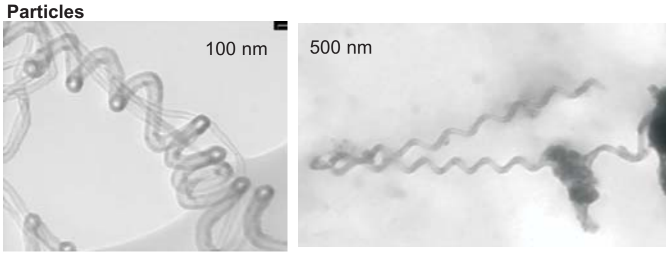
The ***LPL team*** involved in the presented experimental work: I. Morjan, I. Voicu, R. Alexandrescu, PhD students- F. Dumitrache, L. Albu, I. Soare, I. Sandu, M. Scarisoreanu, C. Fleaca, E. Popovici.

Images of the LCVD grown nanotubes with extremely dense packing



SEM analysis showing extremely dense packing

Carbon Nanotubes grown on seeded Si wafers with Fe-C Nanocomposite Particles



Contact: Dr. Ion Morjan, ion.morjan@inflpr.ro

Ultrafast laser facilities for micro- and nano-technologies

In the frame of the CEEX project "Picosecond and femtosecond laser systems for applications in nanotechnologies (NANOLAS)", two ultrafast laser systems will be developed in the Laser Department of the National Institute for Lasers, Plasma and Radiation Physics (NILPRP).

A femtosecond laser oscillator – regenerative amplifier has been purchased and will de installed in the first half of the current year (April 2006). The main parts of the CPA 2001 laser system (Figure 1), produced by Clark-MXR company (USA), are: a frequency doubled pulse mode-locked Erbium doped fiber laser oscillator, a pulse stretcher, a Ti:sapphire amplifier pumped by a pulsed frequency doubled Nd:YAG laser, and a pulse compressor. It is able to generate amplified laser pulses of less than 150 femtosecond duration at 775 nm wavelength, up to 600µJ pulse energy @ 2 kHz and through an alternative output port femtosecond pulses with 1 mW averaged power @ 35 MHz. As a result, it could be used for direct laser writing of micro- and nano-structures (optical waveguides, beam splitters, directional couplers, transmission gratings, 3D data storage, photonic crystals) in transparent materials by multi-photon absorption polymerization or by refractive index modification due to nonlinear phenomena, as well as for precise micro-machining of components .

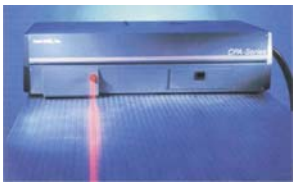


Fig.1. CPA 2001 femtosecond laser system.

A microchip laser oscillator-amplifier system with pulses of less than 500 picoseconds duration, generating in the near IR (1064 nm), visible (532 nm) and UV (266 nm), pulse energy in the range of 2-20 mJ at 10 Hz repetition rate, will be developed by the specialists from the Solid-State Laser Laboratory – Laser Department till the end of 2006 year. Figure 2 presents a similar nanosecond laser system manufactured by NILPRP. It consists in a diode pumped highly-doped Nd:YAG microchip laser oscillator, an optical isolator, a flash-lamp pumped Nd:YAG amplifier, a KTP crystal frequency doubler, and a BBO crystal for forth harmonic generation. The application of the picosecond laser will be in pulsed laser ablation and micro-machining at various wavelengths.

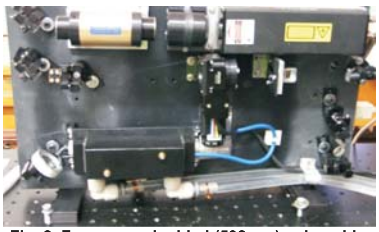


Fig. 2. Frequency doubled (532 nm), microchip laser oscillator-amplifier, manufactured by NILPRP

Both laser systems provide high-performance photonic tools for the Romanian scientists involved in the field of micro and nanotechnologies, partners in the NANOLAS project consortium: National Institute for Lasers, Plasma and Radiation Physics, National Institute for R&D in Microtechnologies, PRO OPTICA SA, University of Bucharest, Faculty of Physics, OPTOELECTRONICA 2001 SA.

Contact: Dr. Razvan Dabu, razvan.dabu@inflpr.ro