CVD METHOD FOR GRAPHENE SYNTHESIS AND ENHANCEMENT OF ITS OPTICAL PROPERTIES BY COMBINATION WITH PHOTONIC CRYSTALS

M. Rybin[a,b*], **M. Garrigues**[a], **A. Pozharov**[b]
E. Obraztsova[b] and **P. Viktorovitch**[a]

[a]Lyon Institute of Nanotechnologies, 36 avenue Guy de Collongue, 69134 Ecully, France
[b]A.M. Prokhorov General Physics Institute, 38, Vavilov str, 119991, Moscow, Russia
[*]Corresponding author: *rybmaxim@gmail.com*

Graphene is a two-dimensional hexagonal carbon lattice with one atom thickness [1]. Graphene possesses a specific electronic structure resulting in unusual electronic properties; for instance, graphene shows an anomalous quantum Hall effect, giant electron mobility, etc. Graphene has quite interesting optical properties too. A graphene monolayer exhibits a steady and very large bandwidth 2,3% absorption rate of incident light, ranging from ultraviolet to far infrared and the absorbance value increases proportional with adding of graphene layers. A saturation of the absorption for relatively low incident flux is another outstanding optical property of graphene. These characteristics make graphene a very suitable material for optical and optoelectronic applications, including the achievement of ultra-fast light saturable absorption. But large scale graphene samples are necessary for such needs. Several methods for graphene preparation are currently used [2]. Here we present a modified CVD method [3] for graphene synthesis and optical characterization of prepared samples with further improving of them by using photonic crystals structures.

A hand-made cold-wall chemical vapor deposition (CVD) installation has been designed at first. The sample was heated by an electrical current. It is a main difference of our CVD chamber comparing with the others. There were two steps in the experiments. The first step consists in annealing the nickel foils in hydrogen at a pressure of 0.5 bar and at 1000°C for 10 min. This annealing treatment is followed bygraphene deposition on the foil. Methane was introduced to reach the concentration ranging from 5% to 50%. The gas mixture pressure in the chamber was varied from 50 mbar to 500 mbar. The critical temperature of the graphene film deposition has been determined for each value of the methane concentration and pressure. The nickel foils were cooled down to room temperature by a simple turning off the current after the deposition of the carbon atoms, so the cooling was quasi instantaneous. In Fig. 1A the nickel covered with a graphene film is shown. Transfer of the graphene film grown on a nickel foil also consisted of two steps. At first, the nickel foil was etched: iron chloride or nitric acid can be used for this process, which takes around 24 h for a complete etch-out of the nickel foil (see Fig. 1B). The etching solution was then washed out with distilled water to eliminate the iron chloride. As a result, the graphene appears to float on top of the liquid and it can be fished out from below by a substrate. It was done very carefully to prevent any breaks into the film. The SiO_2/Si (Fig. 1D) and the glass (Fig. 1C) were used like target substrates for further measurements. At the end the polymer was

dissolved by acetone. The samples were submitted to various optical characterizations. The optical microscope was used for the graphene flake visualization. The Raman spectrometer with an excitation laser at λ=514.5 nm was used for the Raman spectra registration [4]. The spectrophotometer was used for transmittance measurements [5].

As it was mentioned, a single graphene monolayer absorbs 2.3% of the incident power. But if we combine absorbing material with an appropriate optical resonance provided by a photonic crystal structure, the latter confines the photons due to and, as a result, the time of the interaction of photons and graphene increases. Thereby we can increase absorption up to 100%. Concerning the saturable absorption effect, it could be observed with much lower incident flux. The reflector membrane structure of photonic crystal was chosen for combining with graphene. The reflectivity coefficient could be 1 due to the Fano resonance between guided modes and radiated modes. The quality factor of the reflective membrane is proportional to the lifetime of Fano resonance. Due to increasing of lifetime of photons in the photonic crystal membrane, the absorbance in absorbing material is increased because longer continuous interaction between confined photons and electron in graphene is achieved. 1D photonic crystal was chosen to implement optimal conditions light absorption in the grapheme layer bonded onto the PC structure. The reflective membranes were fabricated with Q-factor up to 1500. Reflectivity spectra of membrane without and with graphene film were measured. Also the simulation reflectivity spectra of the same sample were done, using Rigorous Coupled wave Analysis. The experimental data are in rather good agreement with the simulation data. The absorbance of a four-layer graphene film at the resonance is almost 50% instead of 9.2% for suspended graphene film. Therefore a fivefold increase of the absorbance of graphene is induced by the photonic crystal resonance. The saturable absorbing measurements of graphene combining with photonic crystals were also done and it showed decreasing of the requested incident intensity for saturation of grapheme (this remains to be done).

In conclusion we can summarize that graphene has exciting optical properties which can be strengthened by integration of the material with photonic crystal structures, opening the way to new ultra-fast nanophotonic devices.
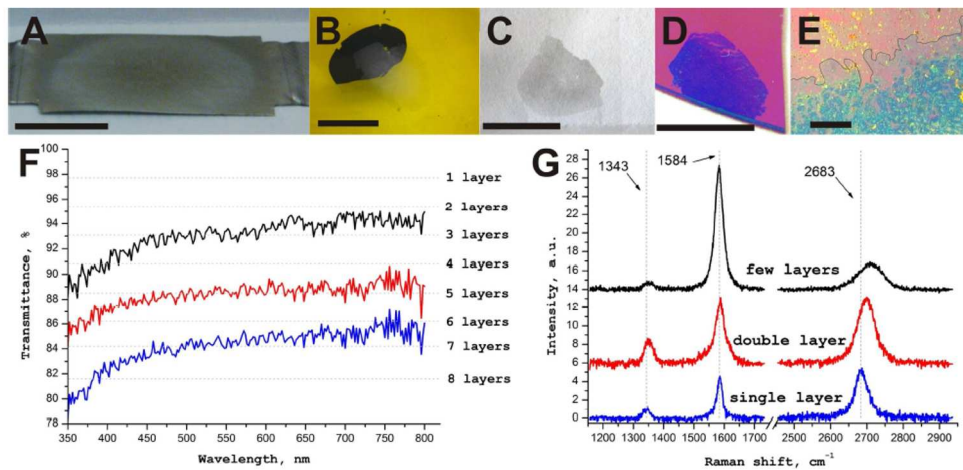
Figure 1: A) A photograph of the nickel foil with graphene grown on it. B) A photograph of the graphene film floating on the top of the iron chloride solution and the nickel etched and sunk in the solution. A photograph of the graphene film transferred onto glass (C) and onto SiO_2/Si (D). The scale bars of A, B, C, D pictures are 5 mm. E) An optical microscope image of the edge of graphene film: the scale bar is 100 μm. F) The light transmission spectra of the sample C in different points. G) The Raman spectra of the graphene sample E in different points.

References

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