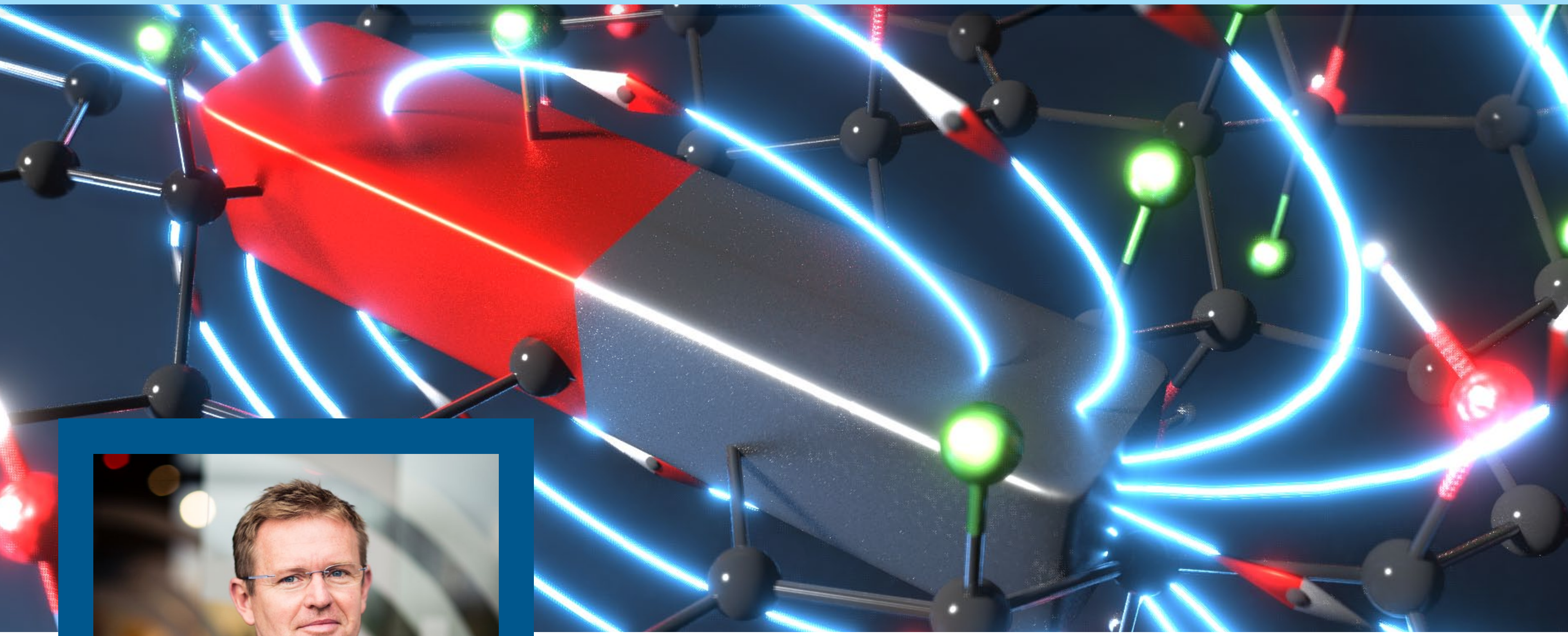
RCPTM NEWSLETTER

1/2017

REGIONAL CENTRE OF ADVANCED TECHNOLOGIES AND MATERIALS
Regionální centrum pokročilých technologií a materiálů

Palacký University Olomouc



Dear Ladies and Gentlemen,

You are reading the first edition of our quarterly newsletter. Its aim is to introduce the activities of the Regional Centre of Advanced Technologies and Materials (RCPTM), and to acquaint both professionals and the general public with the research we do and our results. Since its establishment, RCPTM, which belongs to the Palacký University in Olomouc, has become an important part of the Czech scientific scene. The newsletter will highlight important recent publications from the Centre, introduce key individuals working here, and showcase some of our extraordinary technologies, grant projects, lecture series, and successful examples of applied research and technology transfer. This first edition focuses on the Centre's research on the properties and applications of carbon nanostructures, particularly graphene and its derivatives.

Enjoy the read!

Best regards,

Radek Zbořil
General Director

The world's first non-metallic magnet

A breakthrough discovery that defies existing theories and has many applications. The first non-metallic magnet was recently created from graphene by scientists working at the Regional Centre of Advanced Technologies and Materials (RCPTM). This new carbon-based material retains magnetic properties up to room temperature and has characteristics that lend themselves to applications in biomedicine and electronics. Its discovery was reported in February in the prestigious journal *Nature Communications.*

"We suspected that magnetic carbon systems could be prepared from graphene – a single layer of carbon atoms. Its chemical treatment with fluorine, hydrogen, and oxygen created new sources of magnetic moments that communicate with each other even at room temperature. This represents a huge step towards practically useful organic magnets," said Radek Zbořil, the project's principal investigator and RCPTM director.

The scientists have also presented a theoretical model to explain the origin of magnetism in these carbon materials. "In metallic systems, magnetic phenomena result from the atomic and electronic structure of the metals. In contrast, the magnetic properties of our organic magnets emerge from the behavior of non-metallic chemical radicals that carry free electrons," explained Michal Otyepka, who co-developed the theoretical model and whose involvement in the project is supported by a prestigious grant from the European Research Council (ERC).

Although there is a long way to go before this discovery can be used in practical devices, it has many potential applications. The scientific community will definitely be keen to explore the opportunity to combine graphene's huge surface area, conductivity, and electronic properties with magnetism. "These organic graphene-based magnets will enable new applications in spintronics and electronics, and also in medicine for targeted drug delivery and the separation of molecules using external magnetic fields," suggested Jiří Tuček, an expert in solid-state magnetism.

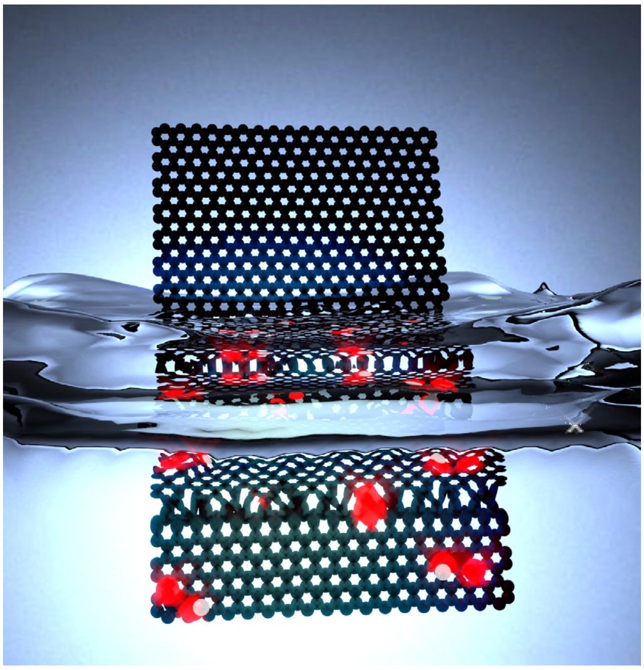
Besides carbon-based magnets, the Olomouc research team recently created the world's smallest metal-based magnets, which was also reported in *Nature Communications* (Tuček J. et al. *Nat. Commun.* 7, 12879, 2016). They are currently seeking to develop molecular magnets whose magnetism can be manipulated at room temperature.

Tuček J., Holá K., Bourlinos A.B., Błoński P., Bakandritsos A., Ugolotti J., Dubecký M., Karlický F., Ranc V., Čépe K., Otyepka M., Zbořil R.: Room temperature organic magnets derived from sp^3 functionalized graphene, *NATURE COMMUNICATIONS* 2017, 8, 14525. IF = 11.329

Scientific Results

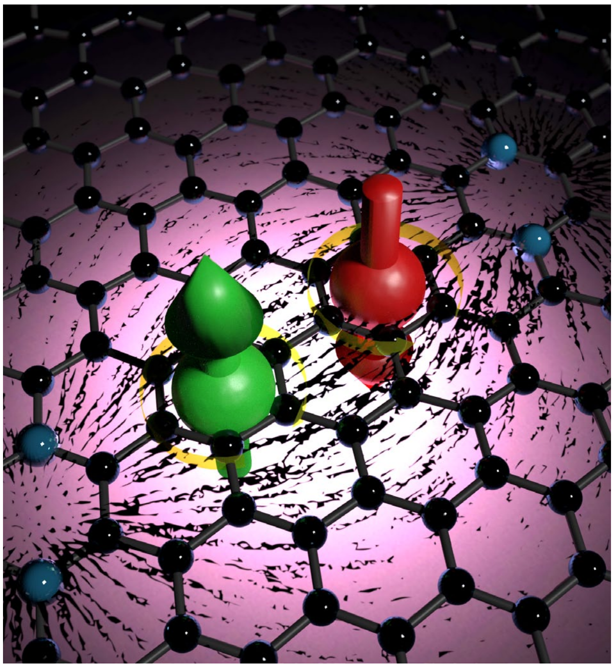
Two-dimensional acid – A recipe for rapprochement between graphene and water

Graphene has many remarkable properties – it is an extremely strong and flexible conductor of heat and electricity, with a large surface area and unique optoelectronic properties. Sadly, it does not interact favorably with water, which limits its usefulness in biomedicine, analytical chemistry, and biotechnology. Several research groups have therefore attempted to modify graphene to make it hydrophilic without sacrificing its conductivity. In the RCPTM labs, we have pursued so-called graphene functionalization for many years (see e.g. Georgakilas V. et al. *Chem. Rev.* 116, 5464–5519, 2016; Georgakilas V. et al. *Chem. Rev.* 115, 4744–4822, 2015; Georgakilas V. et al. *Chem. Rev.* 112, 6156–6214, 2012). This has resulted in the development of new graphene derivatives such as fluorographene, the world's thinnest insulator (Zbořil R. et al. *Small* 6, 2885–2891, 2010), and thiographene, an excellent DNA sensor (Urbanová V. et al. *Adv. Mater.* 27, 2305–2310, 2015). A recent article from our laboratories published in *ACS Nano* describes the preparation of a new graphene derivative with excellent dispersibility in aqueous environments, which we have named graphene acid – the first two-dimensional carboxylic acid. This material is completely nontoxic, biocompatible, and has excellent conductivity and colloidal stability. It therefore has potential applications in fields such as detecting pollutants and pathogens, biosensing, and targeted drug delivery.



Bakandritsos A., Pykal M., Błoński P., Jakubec P., Chronopoulos D.D., Poláková K., Georgakilas V., Čépe K., Tomanec O., Ranc V., Bourlinos A.B., Zbořil R., Otyepka M.: Cyanographene and Graphene Acid: Emerging Derivatives Enabling High-Yield and Selective Functionalization of Graphene. *ACS Nano* 2017, 11 (3), 2982–2991. IF = 13.334

Nitrogen-doped graphene – A challenge for spintronics

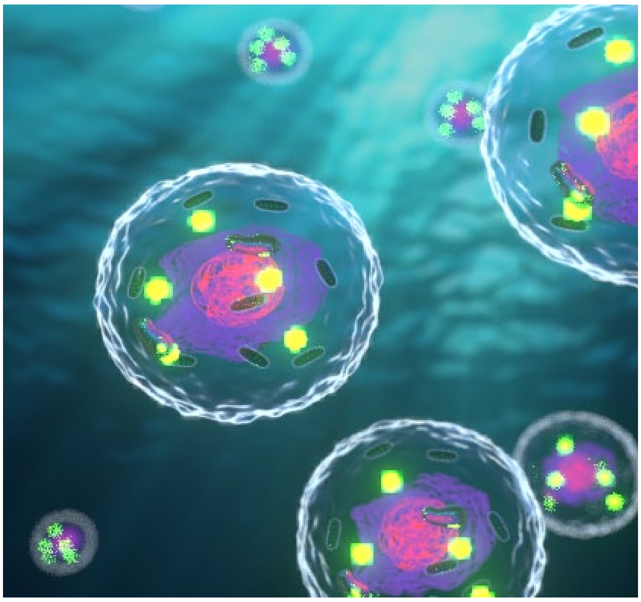


Unmodified graphene is non-magnetic, which limits its range of applications. One widely recognized strategy for creating graphene derivatives without this limitation is to dope the graphene lattice with non-carbon atoms. Last year, RCPTM researchers identified a way to prepare strongly ferromagnetic graphenes doped with sulfur atoms (Tuček J. et al. *Adv. Mater.* 28, 5045–5053, 2016). More recently, in a study reported in the *Journal of the American Chemical Society*, we showed that ferromagnetism can evolve in graphene if nitrogen atoms are substituted into its lattice. The emergence of magnetic properties was shown to depend on the concentration of the nitrogen centers and their coordination. Specifically, it seems that strong ferromagnetic behavior is triggered if nitrogen adopts a graphitic configuration in the graphene lattice. Nitrogen doping represents an elegant method for producing graphene derivatives with sustained magnetism and spin-polarized conductive behavior – a very important feature for materials to be used in spintronic elements and devices. This work was highlighted as an "Editor's Choice" paper by the American Chemical Society.

Błoński P., Tuček J., Sofer Z., Mazánek V., Petr M., Pumera M., Otyepka M., Zbořil R.: Doping with Graphitic Nitrogen Triggers Ferromagnetism in Graphene, *Journal of the American Chemical Society* 2017, 139 (8), 3171–3180. IF = 13.038

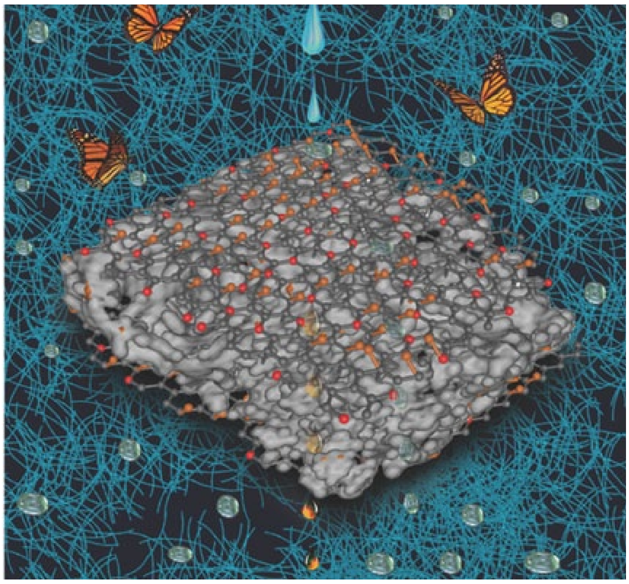
Carbon dots as thermometers in living cells

Nanothermometry is a new but increasingly important field of study that exploits changes in nanomaterials' properties for the purpose of temperature monitoring. When deployed in living cells, nanothermometers can provide important information about functional changes in the cellular environment. The ability to routinely acquire such information could have a huge impact in biology, medical diagnostics, and therapy. Carbon quantum dots are ultrasmall graphitic objects that emit light at various wavelengths depending on the properties of the incident light, the particles' size and structure, and their surface functionalization. Researchers at RCPTM have been examining the preparation and applications of carbon quantum dots since 2008 in collaboration with colleagues from the USA and Hong Kong (e.g. Georgakilas V. et al. *Chem. Rev.* 115, 4744–4822, 2015; Holá K. et al. *Nano Today* 9, 590–603, 2014; Bourlinos A.B. et al. *Chem. Mater.* 24, 6–8, 2012). A paper recently published in *ACS Nano* by the RCPTM group reported the first use of these nontoxic and biocompatible nanomaterials for *in situ* thermometry inside living cells based on changes in excited state lifetimes. The advantage of this method is its independence on external conditions such as particle concentration, pH, or ionic strength.



Kalytchuk S., Poláková K., Wang Y., Froning J.P., Čépe K., Rogach A.L., Zbořil R.: Carbon Dot Nanothermometry: Intracellular Photoluminescence Lifetime Thermal Sensing, *ACS Nano* 2017, 11 (2), 1432–1442. IF = 13.334

A new composite gel for separating oil from water



New materials with high affinities for oil fractions that also repel water are needed to support the development of improved separation processes and environmental technologies. RCPTM researchers together with the group of Prof. Roland Fischer from the Technical University of Munich have recently prepared such super-oleophilic and super hydrophobic materials using a simple procedure based on introducing 2D layers of fluorinated graphene oxide into the structure of mixed organic-alumina networks. This yields ultra-light porous composite gels with exceptional capabilities for separating oils and organic solvents in aqueous environments. This work, which was recently published in the journal *Advanced Materials*, is the result of a collaboration between the two research groups focusing on the creation and applications of two-dimensional inorganic and organic materials (see e.g. Jayaramulu K. et al. *Angew. Chem. Int. Ed.* 55, 1178–1182, 2016; Jayaramulu K. et al. *J. Mater. Chem. A* 4, 18037–18042, 2016).

Jayaramulu K., Geyer F., Petr M., Zbořil R., Vollmer D., Fischer R.A.: Shape Controlled Hierarchical Porous Hydrophobic/Oleophilic Metal-Organic Nanofibrous Gel Composites for Oil Adsorption, *ADVANCED MATERIALS* 2017, 29 (12), 1605307. IF = 18.96

Other publications from RCPTM

Presolski S., Wang L., Loo A.H., Ambrosi A., Lazar P., Ranc V., Otyepka M., Zbořil R., Tomanec O., Ugolotti J., Sofer Z., Pumera M.: Functional Nanosheet Synthons by Covalent Modification of Transition-Metal Dichalcogenides, *CHEMISTRY OF MATERIALS* 2017, 29 (5), 2066–2073. IF = 9.407

Chronopoulos D.D., Bakandritsos A., Lazar P., Pykal M., Čépe K., Zbořil R., Otyepka M.: High-Yield Alkylation and Arylation of Graphene via Grignard Reaction with Fluorographene, *CHEMISTRY OF MATERIALS 2017*, 29 (3), 926–930. IF = 9.407

Han H., Riboni F., Karlický F., Kment Š., Goswami A., Sudhagar P., Yoo J., Wang L., Tomanec O., Petr M., Haderka O., Terashima C., Fujishima A., Schmuki P., Zbořil R.: α-Fe_2O_3/TiO_2 3D Hierarchical Nanostructures for enhanced Photoelectrochemical Water Splitting, *NANOSCALE* 2017, 9 (1), 134–142. IF = 7.76

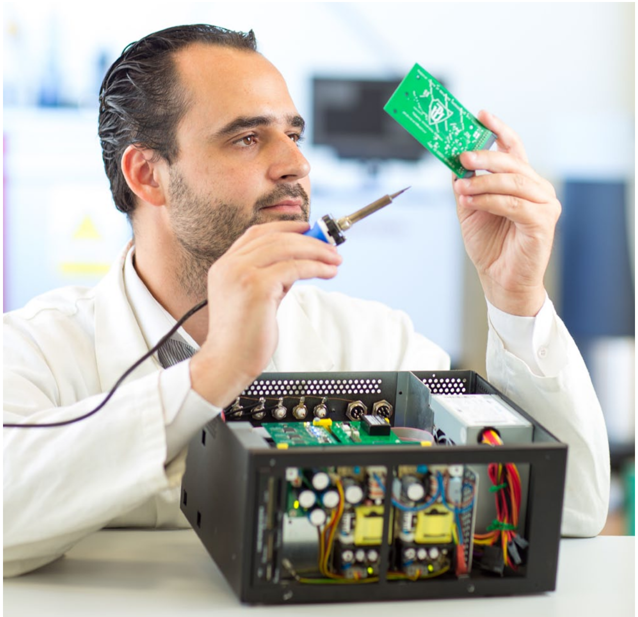
Froning J.P., Lazar P., Pykal M., Li Q., Dong M., Zbořil R., Otyepka M.: Direct Mapping of Chemical Oxidation of Individual Graphene Sheets Through Dynamic Force Measurements at the Nanoscale, *NANOSCALE* 2017, 9 (1), 119–127. IF = 7.76

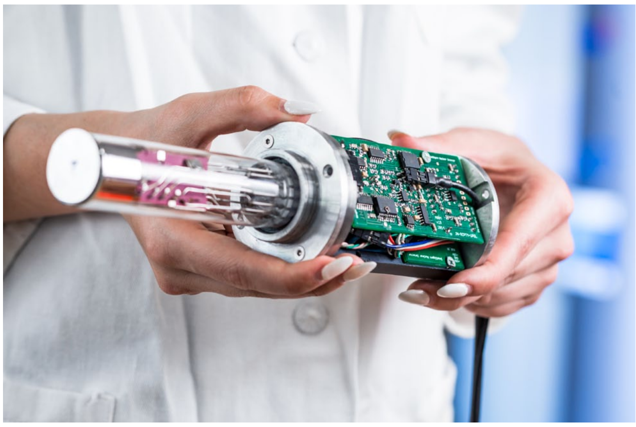
Urbanová V., Bakandritsos A., Jakubec P., Szambó T., Zbořil R.: A Facile Graphene Oxide Based Sensor for Electrochemical Detection of Neonicotinoids, *BIOSENSORS AND BIOELECTRONICS* 2017, 89, 532–537. IF = 7.476

Goswami A., Rathi A.K., Aparicio C., Tomanec O., Petr M., Pocklanová R., Gawande M.B., Varma R.S., Zbořil R.: In Situ Generation of Pd–Pt Core–Shell Nanoparticles on Reduced Graphene Oxide (Pd@Pt/rGO) Using Microwaves: Applications in Dehalogenation Reactions and Reduction of Olefins, *ACS APPLIED MATERIALS & INTERFACES* 2017, 9 (3), 2815–2824. IF = 7.145

Practical Applications

Mössbauer spectrometers developed at RCPTM are conquering the world





Mössbauer spectroscopy is a powerful tool for studying the structural, electronic, and magnetic properties of solid state systems. Researchers at RCPTM recently developed and helped to build a new class of Mössbauer spectrometers that are enabling scientists around the world to study these systems in new ways. RCPTM is one of the few facilities capable of acquiring Mössbauer spectra at extremely low temperatures (2 K) and in high magnetic fields of up to 10 T. These spectrometers are used, for example, to determine how the structures of iron- and iron oxide-based nanomaterials affect their photocatalytic, magnetic, physiological, and biomedical properties (e.g. Tuček J. et al. *Nat. Commun.* 7, 12879, 2016; Kment S. et al. *ACS Nano* 9, 7113–7123, 2015; Magro M. et al. *Adv. Funct. Mater.* 25, 1822–1831, 2015; Zoppellaro G. et al. *Chem. Mater.* 26, 2062–2074, 2014).

On a long-term basis, RCPTM is working to further develop and optimize this unique technology with a focus on user friendliness, increased accuracy, and the ability to acquire Mössbauer spectra over a wide range of temperatures. Constructed spectrometers have been delivered to several major labs and research centers around the world, including the Oak Ridge National Laboratory in the USA, the University of Johannesburg in South Africa, the Korea Atomic Energy Research Institute in South Korea, Technische Universität Darmstadt in Germany, and Fujian University in China, where an Olomouc spectrometer will be installed this spring.

"For our research on iron compounds in high oxidation states, Mössbauer spectroscopy is a unique tool that allows us to differentiate between and quantify the different oxidation states in the solid phase. This helps us optimize synthetic procedures and reactions for water treatment technologies," said Prof. Virender K. Sharma from Texas A&M Health Science Center, who also uses the Olomouc Mössbauer spectrometer.

Mössbauer spectroscopy is based on the phenomenon of recoil-less resonant emission and absorption of gamma rays by atomic nuclei. It was first implemented in 1957 by the German physicist Rudolf Ludwig Mössbauer during his doctoral studies. In 1961, at the age of 32, he received the Nobel Prize for discovering the Mössbauer effect, becoming one of the youngest winners in the prize's history. The method has proved particularly useful for studying compounds containing iron and tin.

Patents for modifying materials using silver nanoparticles

Palacký University was recently granted a significant patent (European and American patent - Method of immobilization of silver nanoparticles on solid substrates, US 9505027, EP2701515), the inventors of which are Radek Zbořil and Jana Soukupová from RCPTM. This unique technology patent protects a method for modifying surfaces with covalently anchored silver nanoparticles, creating a very efficient antimicrobial coating that effectively prevents the formation of microbial films on materials used in medicine, filtration processes, and food or textile processing. The technology is based on years of research by RCPTM workers, who first quantified the antibacterial (see Panáček A. et al. *J. Phys. Chem. B* 110, 16248–16253, 2006, and the 1100 citations therein) and antifungal activity of nanosilver (Panáček A. et al. *Biomaterials* 30, 6333–6340, 2009, over 300 citations). RCPTM is collaborating with several partners to commercialize this technology (including Biomedica, spol. s r.o., Fatra, a.s., and INOTEX spol. s r.o.) and is also applying it in the context of the Competence Centre of Technology Agency of the Czech Republic project on alternative environment-friendly polymer-based antimicrobial agents for industrial applications.

Awards

Pavel Hobza won the Schrödinger Medal

Chemist Pavel Hobza, who is one of the scientific mainstays of RCPTM, recently added the Schrödinger Medal for 2017 to his collection of scientific awards. He is only the second Czech scientist to receive this prize, which is granted annually to an outstanding theoretical and computational chemist by the World Association of Theoretical and Computational Chemists (WATOC).

"It is a very prestigious award and I am honored to be part of such an accomplished group. I consider it a great privilege to have the chance to speak at the regular WATOC conference, which will welcome experts from around the world in Munich this year. It takes place every three years, and the Schrödinger Medal recipients since the last conference give the plenary talks. It is a unique opportunity to present one's work there," said Prof. Hobza.

Since 1987, the Schrödinger Medal has been awarded to two Nobel Laureates, John A. Pople and William Lipscomb. Another notable holder is Josef Michl from IOCB Prague. The eleventh WATOC conference will take place this year at the end of August and beginning of September.

Three representatives in the Highly Cited Researchers list

RCPTM is also proud to have three members of staff on the prestigious Highly Cited Researchers list in 2016. Pavel Hobza is on the list for the third time in a row, along with two foreign scientists working at Olomouc: Patrik Schmuki and Rajender S. Varma.

The recognition of these researchers as members of the world's scientific elite was welcomed by Radek Zbořil, the RCPTM director. "This shows that RCPTM is the most efficient scientific center established within the framework of the Operational Programme Research and Development for Innovations, and one of the most efficient centers in the Czech Republic," he said.

Professor Schmuki works in the field of electrochemistry in RCPTM, and also holds a position at the Friedrich-Alexander Universität in Erlangen – Nürnberg. Rajender S. Varma has a position at RCPTM and another with the US EPA. Researchers are included in the Highly Cited list based on analyses of highly cited works in the Web of Science database (ESI); the 2016 list features around 3000 researchers in total.

Recent publications by Highly Cited Researchers within RCPTM:

Hobza P. et al. *Chem. Rev.* 116, 5155–5187, 2016; IF = 37.369
Varma R.S. et al. *Chem. Rev.* Article ASAP, 2017; IF = 37.369
Schmuki P. et al. *Chem. Soc. Rev.* Article ASAP, 2017; IF = 34.09

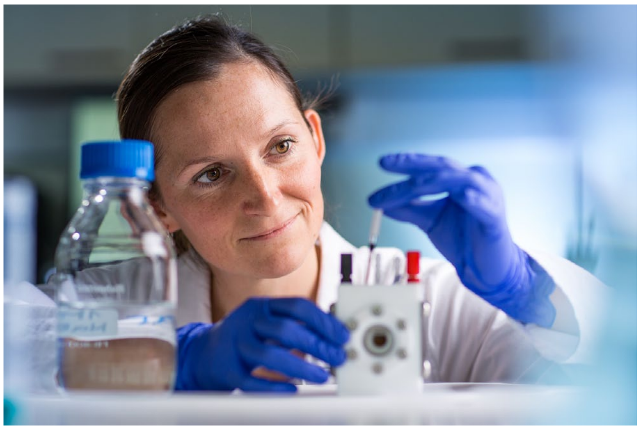
New Grants

Nanomaterials for cheap green energy from water

Scientists working on the project "Advanced Hybrid Nanostructures for Renewable Energy Applications" have been developing new hybrid nanomaterials based on metal oxides. These nanomaterials enable efficient solar water splitting and the production of hydrogen as an important sustainable source of energy. The team led by Patrik Schmuki – a world-leading researcher in the fields of materials chemistry, photoelectrochemistry, and renewable energy – aims to develop nanomaterials with enhanced photocatalytic efficiency, increase the volume of produced hydrogen, and make the technology suitable for large-scale practical use.

RCPTM researchers will focus primarily on optimizing semiconductor materials for the anodes of photoelectrochemical cells. In particular, they will seek to improve the properties of semiconductor nanomaterials based on iron(III) oxide or titanium dioxide, which offer advantages such as low costs, non-toxicity, ready availability, and chemical stability, but also have limitations that make them unsuitable for large-scale green energy production. "The project's goal is to eliminate these deficiencies by combining metal oxides with nanocrystalline systems, which we have been studying in our center for a long time. Systems of interest include new types of carbon quantum dots, two-dimensional graphene derivatives, and plasmonic nanoparticles of precious metals," clarified Radek Zbořil, the director of RCPTM.

"These hybrid structures could broaden the spectrum of absorbed solar radiation or improve the electrical transport at photoanodes, leading to increased conversion of solar energy into chemical energy stored in the form of hydrogen," stated Prof. Schmuki, who has a position at the Friedrich-Alexander Universität in Erlangen – Nürnberg in addition



to his role at RCPTM, and holds an Advanced Grant from the European Research Council – the most prestigious grant offered by that institution.

Funding of more than 130 million CZK from the Operational Programme for Research, Development and Education (OP RDE) will allow RCPTM scientists to connect with researchers from several countries and to obtain technical equipment that is unavailable elsewhere in the Czech Republic. For example, RCPTM has established collaborations with scientists from Cornell University in the USA, Aarhus Universitet in Denmark, EPFL in Switzerland, Université de Nantes in France, and the Center for Superfunctional Materials at the Ulsan National Institute of Science and Technology in South Korea.

In addition to supporting these international research efforts, the OP RDE funding will be used to purchase modern measuring systems. Scanning photoelectrochemical microscopy is a particularly attractive analytical technique that is currently not available anywhere in the Czech Republic. It can be used to determine the local photoelectrochemical response in a studied sample, with excellent spatial resolution, producing maps of the sample's photoelectrical activity as a function of some parameter of interest such as the concentration and distribution of hybrid nanoparticles in the structure of an anode material.

In total, 105 projects sought funding from OP RDE, and 32 received grants. The RCPTM project was awarded the highest score of these successful applications.

Interview

"I am glad to be part of that success story."

RCPTM has a long-term goal of attracting top scientists from abroad to join its teams, not only as postdoctoral researchers but also as professors or group leaders. That is why RCPTM is a highly international institute, with foreign scientists accounting for nearly a quarter of its staff. We are delighted to have globally renowned chemists such as Rajender S. Varma among our colleagues. Dr. Varma specializes in using nanotechnology for environmental applications. In this interview, he discusses his work and explains why he has chosen to work at RCPTM in parallel to his research for the United States Environmental Protection Agency.

You are a recognized expert – according to the Highly Cited Researchers 2016 list, you are one of the most cited researchers in the world. You therefore undoubtedly have many opportunities to collaborate with institutions all over the world. Why did you pick RCPTM?

I strongly believe everything is chemistry and it clicked when I met professor Zbořil a couple of years back. In view of our similar and intense love for what we engage in every day, we formed a bond instantaneously. His vision to have a world-class multidisciplinary research center with a diversity of researchers, in terms of both discipline and their origin, is very much aligned with my life-long thinking.

What does it mean to you to be mentioned on the prestigious list of highly cited researchers worldwide?

It is indeed a great honor to be on this list where most of the well-known researchers, including Nobel Laureates, are listed for their impactful contributions, especially in a mature and competitive subject like chemistry.

Could you describe your scientific activities at RCPTM?

RCPTM has extraordinary facilities and many unique measurement techniques. Nevertheless, RCPTM is mainly its people. As it is staffed by enthusiastic and hardworking researchers, it is always a pleasure to interact with them, whenever I am physically present in Olomouc. I like visiting Olomouc and I go there regularly to oversee the Catalytic and environmental group. In view of the modern communication network, I am in constant touch with most of the researchers from the group throughout the year. I get to read the proposals, publications, and reports on regular basis, which accounts for most of my weekend activities. My research activities are focused on the use of a broad spectrum of nanomaterials mainly in catalysis and environmental technologies, especially in water treatment.

Which infrastructure of RCPTM do you use most often?

As I have already indicated, the local analytical facilities are simply wonderful for conducting state-of-the-art research in materials science and catalysis. Concerning catalytic applications, we mainly use a modern flow reactor. We have been developing hybrid multicomponent catalysts; that is why the possibility of chemical mapping and monitoring of mutual interaction of individual components by high-resolution transmission electron microscopy is very interesting for us.

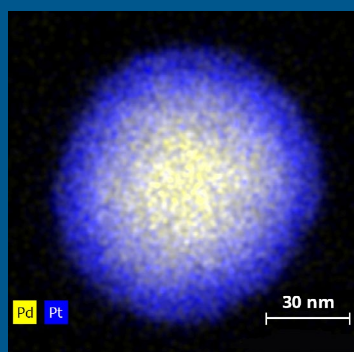
What are your plans for the near future?

Among other things, we would like to work on using waste and organic raw materials to prepare nanomaterials and explore their applications in environmental technology, in the spirit of "from the environment – for the environment". The facilities and staff at RCPTM have come a long way in a very short span of time. With its dedicated researchers and students, I am sure it will be an exemplary modern European research center for everyone to behold in the not very distant future. I am glad to be part of that success story.

Scientific Infrastructure at RCPTM

High-resolution electron microscopy (HRTEM) uses accelerating voltages in the range of 60 – 300 kV with a spot resolution of 0.08 nm. RCPTM has an FEI Titan G2 microscope, which uses an X-FEG electron source and allows researchers to perform detailed structural analyses of samples using SAED (selected area electron diffraction). The instrument can also be used for EELS (electron energy loss spectroscopy) and EDS (electron dispersive spectroscopy) analyses, both of which enable precise chemical mapping of materials and nanosystems.

Because of its high resolution, this microscope can be used to study the atomic structure of materials, defects in crystal structures, and the distribution of chemically non-equivalent phases in hybrid systems. Moreover, it can operate under cryogenic regimes and can therefore be used to characterize biological and molecular systems.



Chemical mapping of catalytically active core-shell Pd-Pt nanoparticles using EDS.

Goswami A. et al. In Situ Generation of Pd–Pt Core–Shell Nanoparticles on Reduced Graphene Oxide (Pd@Pt/rGO) Using Microwaves: Applications in Dehalogenation Reactions and Reduction of Olefins

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Coming Next...

The next newsletter will name the speakers who will deliver talks in Olomouc as part of the Rudolf Zahradník Lecture Series. The aim of this lecture series, which has been organized by RCPTM staff since 2013, is to introduce the most significant personalities in chemical and materials research in the Czech Republic and to give attendees the chance to hear talks from accomplished international speakers. In addition to Rudolf Zahradník, a pioneer of Czech quantum chemistry research and a former chairman of the Academy of Sciences of the Czech Republic, 12 scientists have given lectures in this series. Previous speakers include Peter Sadler from the University of Warwick, Mark Ratner from Northwestern University, Mario Ruben from Karlsruhe Institute of Technology, Toshiaki Enoki from Tokyo Institute of Technology, and Adi Eisenberg from McGill University, as well as scientists from the Czech Republic such as Pavel Jungwirth from the Institute of Organic Chemistry and Biochemistry of the Academy of Sciences of the Czech Republic, and Josef Michl, who also works at the University of Colorado.

What regards the grant projects, the results of the Competence Centre Nanobiowat - Environmental friendly nanotechnologies and biotechnologies in water and soil treatment will be presented. The project connects three academic and six industrial partners.

In addition, the next quarterly newsletter will highlight RCPTM's exciting research on the interactions of nanomaterials with molecules and the exploitation of these interactions in catalysis, environmental technologies, sensors, medicine, and biotechnology.

The section on practical applications of research will illustrate the successful transfer of nanotechnologies patented by RCPTM into the food industry, including an interview with the holder of the license agreement.

Another unique microscopic technique will also be introduced: ultrahigh vacuum scanning tunneling microscopy, which can be used to visualize the chemical bonds in molecules and monitor chemical reactions occurring at surfaces. Pavel Jelínek, an employee of RCPTM and the Institute of Physics of the Academy of Sciences of the Czech Republic will discuss joint projects using this technique and its use in studying interactions at nanomaterial-molecule phase interfaces.

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