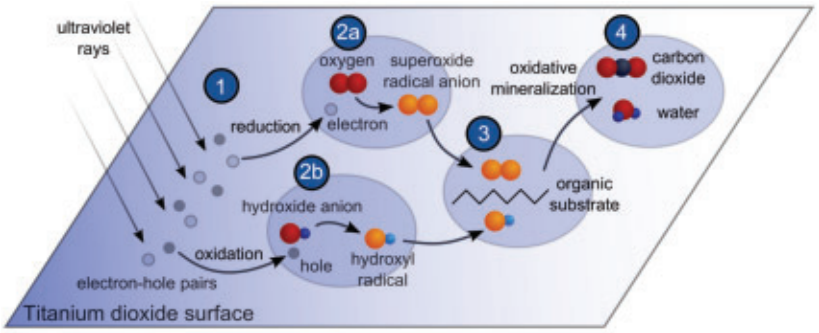
Cleaning by photoactive nanosurfaces

The complex study of unique photoactive materials…

The Research Centre for Nanosurface Engineering (NANOPIN) was established in 2005 under a research and development programme of the Ministry of Education, Youth and Sports of the Czech Republic as a seven year project. It represents an association of five cooperating research teams of two technical universities (Institute of Chemical Technology, Prague and Technical University of Liberec), two institutes of Academy of Sciences of the Czech Republic (Institute of Inorganic Chemistry and J Heyrovský Institute of Physical Chemistry) and one private company (Advanced Technology Group Ltd). The centre is chaired by Dr František Peterka.

The prominent subjects of the scientific activity of NANOPIN comprise the complex study of unique photoactive materials based on nanocrystalline titanium dioxide and research of their practical utilisation in the field of photocatalytic self-cleaning and antibacterial/antivirus coatings, as well as water and air disinfection and detoxification.

František Peterka, Coordinator of Research Centre for Nanosurface Engineering, demonstrating devices for ISO self-cleaning standard tests designed by NANOPIN



Principle of light cleaning: Photocatalytic semiconducting materials, eg. titanium dioxide, decompose any organic structure, including microorganisms, placed on their illuminated surface. As a result, all organic substances are transformed into simple inorganic compounds such as water, carbon dioxide and the corresponding mineral acids. These processes are based on the absorption of photons in the semiconductor material evoking production of electron-hole pairs (1). The positive holes oxidise hydroxide anions of water to hydroxyl radicals (2b), while electrons reduce oxygen to superoxide radical anions (2a). Both radicals are strongly oxidising, attack organic substrates (3) in the surrounding water or air and initiate their oxidative degradation leading finally to harmless mineral products (4)

The research includes several subtopics:

- Synthesis of nanoparticles of titanium dioxide with high photocatalytic activity, preparation of doped or mixed materials with an extended spectral response to visible region;
- Preparation of thin films, including composite or functionalised multilayers, of nanocrystalline titanium dioxide and/or other appropriate materials, either from gas phase by plasma deposition techniques or from liquid phase by means of various chemical procedures, including advanced techniques based on supramolecular templating by micelles of surfactant molecules;
- Physicochemical characterisation of the synthesised nanoparticles and thin films focused on exploration of the relationships between the material structure and its photoactivity;
- Development of the photoactivity testing methods, including direct participation in ISO and CEN standardisation and normalisation procedures;
- Construction and optimisation of working conditions of various types of photoreactors for disinfection and purification of air and water;
- Study of kinetics and mechanism of photocatalytic processes, both oxidative degradation and mineralisation of harmful organic substances, including identification of potentially toxic intermediates.

Since the foundation of NANOPIN in 2005, until 2010, its research and education activities have resulted in 168 papers in reviewed international journals, 342 contributions on scientific conferences, 7 monographs, 11 patents, 13 theses, 17 diploma works, as well as 8 reports for industrial partners.

Besides its own activities in fundamental and applied research, NANOPIN has worked out several technological innovations for various industrial enterprises, eg. for FAGOR Coop. (photocatalytic self-cleaning coating of electric oven), USSPA Ltd. (photocatalytic disinfection and purification of spa water), PRECHEZA Inc. (development of novel photocatalysts), HEXION Specialty Chemicals

Inc. (light-cleaning paints), EOXOLIT (novel composite photocatalysts), Blažek Glass Ltd. (antibacterial nail polishers), etc.

Cleaning by light

Light cleaning by photocatalytic nanosurfaces is a fascinating phenomenon promising applications in many industrial branches, such as self-cleaning and sanitary surface finishing of exteriors (frontages of buildings, roofs, window glass, roadways and sidewalks, concrete, metal and glass frames) and interiors (antibacterial tiles, paints, plastic and fabric surfaces), medicine (medical instruments and other aseptic materials), textile, glass and food industry, and last but not least, in the environmental protection (water and air disinfection and purification). To bring promising applications to real life, it has always been necessary to overcome barriers, such as designing photocatalytic systems with higher efficiency and sensitivity to visible light, and the introduction of a system of standardised methods (including field testing) to prove the advertised function and safe use of nanomaterials with photocatalytic function to all potential users.

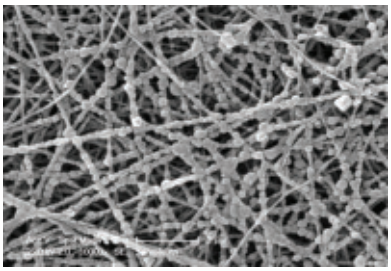
International activities

In 2006, NANOPIN initiated the COST Action 540 'Photocatalytic technologies and novel nanosurfaces materials – critical issues', which served as a network of researchers and practitioners in the field of photocatalysis in 21 joint European countries and Japan. In 2008, the COST action evoked establishing of European CEN standard TC 386 for photocatalysis. NANOPIN has close contacts to the world leading Photocatalysis Industry Association of Japan with František Peterka becoming an honorary member.

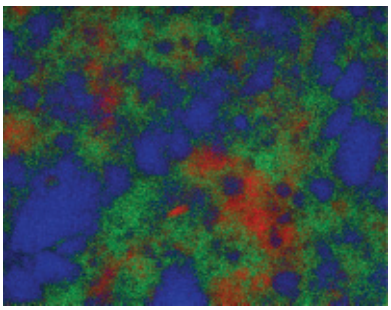
Future plans

During its existence in 2005-2011, NANOPIN has worked out a full knowledge of photocatalysis, both fundamental and applied. These activities have helped to overcome several important problems and the last trials with novel composite material have especially demonstrated clearly that air purifying surfaces of this kind have a future.

NANOPIN possesses all the necessary know-how and instrumentation in the field of inorganic syntheses of nanocrystalline materials, preparation of tailored composite nanostructure layers, plasma deposition of thin films, advanced material characterisation, kinetic and mechanistic studies of photoreactions in both liquid and gas phase, construction of various types of photoreactors, photoactivity testing, etc. That is why continuation of the NANOPIN team is planned in the framework of the new programme 'Competence Centres' of the Technology Agency of the Czech Republic. Among other topics, novel nanocomposite photocatalysts will be investigated and applied that were recently developed and patented by NANOPIN together with cooperating Belgian company EOXOLIT Ltd. First field tests showed a significantly increased performance of these nanocomposites in environmental applications (such as removal of nitrogen oxides).



Nanoparticles of titanium dioxide anchored on polyurethane nanofibres



Surface (95 x 75 micrometres) of self-cleaning paint based on novel nanocomposite photocatalyst scanned by Energy Dispersive X-ray (EDX) spectroscopy for present elements (titanium - green, silicon - red, calcium - blue)

The 21 European countries participating in Action COST 540 'Photocatalytic technologies and novel nanosurfaces materials – critical issues' initiated by the coordinator of NANOPIN

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