PHYSICAL AND TECHNOLOGICAL SCIENCES

The group of polymers for bio- and nanotechnology

Keywords: *brush polyelectrolytes; biolubricants; bioadhesives; gene transfection; polymeric carriers; immobilization of enzymes*

Vilnius University

Research group activities

The group explores possibilities of reversible deactivation radical polymerization, click-chemistry and selective modification of polymers which allows the synthesis of amphiphilic multiblock brush copolymers, polyelectrolytes, targeted chitosan derivatives, poly(vinyl alcohol) based polyurethane microparticles and microcapsules, and polydimethylsiloxane modified elastomers. We have prepared dozens series of various polymers – bottle-brush polymers, multiblock copolymers, cationic polymers, polymeric carriers for immobilization of enzymes and elastomers for tissue engineering, – which were studied and used by many scientific and industrial partners.

Research group efforts are directed towards these four main challenges:

Development and synthesis of polymers of complex architecture that capture and mimic the structural essence of biolubricants and bioadhesives. Such polymers are of great importance as they could be applied in biomedicine, personal care products, and nanodevices. A consortium of research groups from many universities, including the present group of Vilnius University, is trying to mimic Nature and develop very efficient lubricants and adhesives for aqueous systems.

Development and synthesis of cationic polymers for interaction with DNA. Gene delivery has become a valuable research instrument and a potential means of treating many human diseases. Cationic polymers are able to condense DNA into small particles and initiate cellular uptake via endocytosis. Many efforts of the group are directed towards development of cationic polymers with lower toxicity, better biodegradability and very high transfection efficiency.

Development and synthesis of new polymeric carriers for immobilization of enzymes. The reactions catalysed by enzymes are becoming very important in many biotechnological processes including production of chemicals from renewable resources. Immobilization of enzymes facilitates separation of these biocatalysts from reaction mixtures and makes them suitable for multiple usage. Unfortunately, polymeric carriers used for immobilization of enzymes usually reduce activity of the biocatalysts, or the immobilized preparations lose activity during storage. A progress in this area is foreseen by the use of new polymeric structures and novel methods of synthetic chemistry.

Development and synthesis of new elastomers for tissue engineering. Recent advances have enabled 3D printing of biocompatible materials, cells and supporting components into complex 3D functional living tissues. Our group takes part in development of mechanically stable, elastic, biocompatible and 3D printable material for functional artificial tissue.

Proposal

- synthesis of brush polyelectrolytes in laboratory scale for decoration of nanoparticles and flat surfaces preventing agglomeration and providing lubricating and protein-repelling properties;
- synthesis of water-soluble and ionisable polymers for separation science and biotechnology;
- chemical modification of chitosan making it suitable for antibacterial coatings and the coatings promoting endothelization;
- synthesis of polymeric carriers and immobilization of enzymes in laboratory scale.

The group is seeking for partnership with the scientists of surface chemistry and physics, nanotechnology and biotechnology to study effects of the adsorbed layers of the brush polymers and efficiency of the immobilized enzymes.

Meet our team

Head - Prof. Dr. Ričardas Makuška

He is co-author of about 300 publications including 80 papers in international scientific journals. He is an expert in polymer synthesis including newest methods of reversible deactivation radical polymerization and modification of naturally-occurring polymers. Prof. R. Makuska has deep knowledge of polyelectrolytes, brush polymers, multiblock copolymers, chitosan derivatives, and cationic polymers as reagents for gene transfection.

Research staff:
Prof. Dr. Saulutė Budrienė, Dr. Tatjana Kochanė , Dr. Aušvydas Vareikis, Dr. Tatjana Krivorotova, Dr. Alma Bočkuvienė, Dr. Jūratė Jonikaitė-Švėgždienė, Dr. Vaidas Klimkevičius.

PhD students:
Medeina Steponavičiūtė, Povilas Radzevičius, Sandra Mačiulytė.

Research outcomes

During the last 10 years, the group has over 70 papers in high level international scientific journals including MACROMOLECULES, LANGMUIR, EUROPEAN POLYMER JOURNAL, REACTIVE & FUNCTIONAL POLYMERS, and many others.

- **N. Gorochovceva, R. Makuška.** Synthesis and study of water-soluble chitosan-O-poly(ethylene glycol) graft copolymers. European Polymer Journal, 40 (4), 685-691 (2004).
- **T. Pettersson, A. Naderi, R. Makuska, P.M. Claesson.** Lubrication properties of bottle-brush polyelectrolytes: An AFM study on the effect of side chain and charge density. Langmuir, 24 (7), 3336 -3347 (2008).

Members of the group are co-authors of two US patents: US Patent No 7799194 (2010), Electrophoretic gels and their manufacture and US Patent No 9102796 (2015), Transfection reagent.

- **C. Visnevskij, R. Makuska.** SARA ATRP in aqueous solutions containing supplemental redox intermediate: controlled polymerization of [2-(methacryloyloxy)ethyl] trimethylammonim chloride. Macromolecules, 46, 4764-4771 (2013).
- **A. Bockuviene, K. Slavuckyte, A. Vareikis, S. Zigmantas, L. Zaliauskiene, R. Makuska.** Intracellular delivery and triggered release of DNA using biodegradable poly(2-hydroxypropylene imine)s containing cystamine units. Macromolecular Bioscience, 16, 1497–1505 (2016).
- **P. Radzevicius, M. Steponaviciute, T. Krivorotova, R. Makuska.** Double thermoresponsive pentablock copolymers: synthesis by one-pot RAFT polymerization and self-assembly in aqueous solutions. Polymer Chemistry, 8, 7217-7228 (2017).

Resources

The laboratories are equipped with thermal, UV, microwave and calorimetric reactors for the synthesis of polymers, ultrafiltration, gel-filtration and freeze-drying units for separation and purification of polymers, size exclusion chromatography with tetra-detection for determination of molecular weight and dimensions of macromolecules, dynamic light scattering for determination of hydrodynamic characteristics, several spectroscopic techniques (1H and 13C NMR, FT-IR, Raman, UV -Vis) for evaluation of composition of polymers and chemical changes during modification, DSC and TGA for evaluation of thermal properties.

Contacts

Prof. Dr. Ričardas Makuška
Faculty of Chemistry and Geosciences

Phone: +370 5 2193227
E-mail: ricardas.makuska@chf.vu.lt

More about the faculty: http://chgf.vu.lt