1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan, all in English)

Project title:

Application of new task-specific ionic liquids as metal ion carriers in polymer inclusion membranes.

1.1. Project goals

Application of new task-specific ionic liquids for recovery of metal ions

Optimization of the method for preparing polymer inclusion membranes (PIMs) for metal ions separation

Determination of operational parameters influencing the membrane transport effectiveness

Identification of the membrane morphology change during the membrane transport process

Elaboration of physico-chemical model for description of the transport kinetics

1.2. Outline

Nowadays, metals such as cobalt, nickel, cadmium, zinc, and indium are recognized as critical and strategic, because they are difficult to substitute in a particular industrial application. Therefore recovery of these metals from so called secondary resources (various wastes) become increasingly important. Understandably, the development of more efficient, economic, and environmental-friendly processes capable to recovery metals from poor and complex feed materials is still a priority. Among numerous separation techniques applied for recovery of valuable and/or toxic metals from waste water, the membrane techniques seems to be the most appropriate.

One of the intensively developing directions of research is the application of polymer inclusion membranes (PIMs) for recovery and/or separation of metal ions from aqueous solutions. PIMs are obtained by slow evaporation of a volatile organic solvent from a solution containing: a polymer, carrier, and plasticizer. As a carrier, a compound typically used in the liquid-liquid extraction is applied. The carrier binds to the substance present in the feed solution and enables (or facilitate) the transport through the membrane. One of the new research directions is the application of ionic liquids (ILs) as carriers in PIM. Compared to typical carriers, ILs possess a number of advantages, such as very low vapor pressure, non-flammability, thermal and electrochemical stability, and the ability to dissolve organic and inorganic substances depending on the structure. Because of their properties, they are also called "green solvents", by analogy to "green chemistry", i.e. environmentally friendly chemistry. Task-specific ionic liquids (TSILs) depending upon user's need possess the desired physical, chemical, and biological properties. In the case of TSILs, which can be applied as carriers, it is required that the molecule have to possess the ion-exchange group which enabling metal ion transport through PIMs as well as a chemically reactive group capable of

bonding with the polymer matrix (e.g. with cellulose tri acetate). This second group is necessary for reduce or eliminate the leakage of the carrier from the membrane phase. Such PIM which is resistant to the carrier leaching by its chemical and physical immobilization can be applied for metal ions recovery from electroplating waste water, electronic waste, sewage sludge, mining waste, etc.

1.3. Work plan

a) Synthesis of new task-specific ionic liquids with collaboration of Department of Organic Chemistry staff
b) Preparation and optimization of the composition of PIMs
c) Examination of the membrane structure by contact angle measurements, vibrational spectroscopy (FT-IR, Raman), atomic force microscopy, scanning electron microscopy, etc. as well as determination the structure influence on the transport effectiveness
d) Application of response surface methodology for optimization of transport selectivity and efficiency
e) Elaboration of physico-chemical model for membrane transport kinetics
f) Application of optimized membranes for recovery and separation of metal ions from real waste water solutions (electroplating, e-waste)

1.4. Literature

[1] European Commission, Report on ad hoc working group on defining critical raw materials. Report on Critical Raw Materials for the EU, 2014, available at http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm.
[2] M.I.G.S. Almeida, R.W. Cattrall, S.D. Kolev, *J. Membr. Sci.* 415 (2012) 9–23.
[3] R. Giernoth, *Angew. Chem. Int. Ed.*, 49 (2010) 2834–2839.
[4] A.E. Visser, R.P. Swatloski, W. M. Reichert, R. Mayton, S. Sheff, A. Wierzbicki, J.H.J. Davis, R.D. Rogers, *Chem. Commun.*, 1 (2001) 135–136.

1.5. Required initial knowledge and skills of the PhD candidate

- Knowledge about general, physical, and polymer chemistry
- Self-discipline
- Motivation to achieve the goal (i.e. PhD degree)

1.6. Expected development of the PhD candidate's knowledge and skills

- Better understanding of physico-chemistry of membrane transport
- Practical knowledge and skills about membrane morphology analysis
- The ability to work independently
- Gaining experience in conducting analysis according to principles of good laboratory practice (GLP)
- The advanced ability of data processing and statistical/chemometric analysis