Development of multifunctional organic electroactive materials: synthesis and comprehensive characterization

Thanks to the accidental discovery of electrical conductivity phenomena in organic conjugated materials (A.J. Heeger, A.G. MacDiarmid, H. Shirakawa: The Nobel Prize in Chemistry 2000 “for the discovery and development of conductive polymers”), the significance of organic materials in such branches of science as electronics, photonics and optoelectronics have rapidly increased. The replacement of conventionally used inorganic by electroactive organic materials in applications like as e.g. organic light-emitting diodes and solar cells gives an opportunity to create innovative, lightweight and flexible optoelectronic devices and to decrease the use of rare earth metals and minerals, thereby offering a positive environmental impact. One of the greatest benefits of such compounds over inorganic materials, out of price and weight, is the possibility to tune their properties, including the color of emitted light, by modifying their molecular structure.
The industry in which organic electroactive materials have been successfully used is the display sector. Smartphones, tablets and televisions are equipped with displays based on organic light-emitting diode (OLED). These types of devices do not need backlight, they are thin and light. They operate on the principle of electroluminescence - light emission under the influence of applied voltage (electric current flow). One of the advantages of this type of display is the possibility of using them in the dark, but on the other hand, their usability is very limited on sunny days, when the display (e.g. telephone) is directly illuminated. Additionally, the big disadvantage of OLED displays is their impact on human eyes. The continuous emission of light through the display causes the fatigue of the human eye. There are even studies that combine the evening use of devices equipped with this type of displays with sleep disorders. In this respect, reflective displays, which are used in such devices like e-paper, do not emit any light, which makes them neutral to the human eye, seem to be a better option. Reading form such displays is like reading a traditional newspaper or a book. An example of devices operating in reflective mode are electrochromic displays - based on materials that change color under the influence of the applied voltage. Nowadays, the most widely used electrochromic materials are transition metal oxides, mainly tungsten (VI) oxide (WO_3), however, electrochromic organic materials such as poly(3,4-ethylene-1,4-dioxythiophene) (PEDOT) are also known. The use of organic materials in electrochromic displays, as already mentioned, brings many benefits. Nevertheless, due to the lack of backlighting that is not needed for the operation of reflective displays, they are useless under dark condition. This problem may be solved by displays operating, depending on the user's needs, in both reflective or emission mode.

The aim of this project is to develop new organic materials exhibiting both electroluminescence and electrochromism. The scope of work covered by this project is the design and synthesis of new electroluminescent and electrochromic organic materials, their comprehensive analysis using electrochemical, spectroscopic, spectroelectrochemical (UV-Vis-NIR, EPR, Fluorescence, IR, Raman, Impedance Spectroscopy) and microscopic (SEM, AFM) techniques. The properties of layers based on the tested compounds as well as interactions in multilayer systems will be also characterized.

It is believed that the approach proposed in the project will allow to obtain stable, multifunctional organic systems showing electrochemically controlled emission and coloration. Such systems may be used in "dual mode" type displays, operating, depending on the applied voltage, in the emissive mode through the electroluminescence or based on electrochromism in the reflective mode.