Carbene as a new platform for highly ordered organic monolayers

Nowadays electronics plays fundamental role in development of science and technology making an unprecedented impact not only on the world economics but also directly on our civilization and society. The most characteristic feature of electronics, which is inherently responsible for this huge influence on our live, is the continuous and rapid development. To keep up with this trend new directions of electronics development are undertaken such as molecular and organic electronics. This new direction of development seems rather well justified considering that organic materials, as we all know, have been evolutionary selected to build up the extremely efficient electronic system such as our brain. Whereas the molecular electronics, which uses single molecule devices or monolayers of molecules to construct active electronic elements, is still at the very beginning of its development, the organic electronics which uses polymers and molecular crystals is already in use for smartphones and TVs screens production which are based on the organic light emitting diodes (OLED) technology being, literally, the most visible example.

Regardless whether we think of using organic or molecular electronics, we have to power such organic circuits and make them compatible with other parts of our devices, and for that we need to connect them with metals at some point. This connection is difficult concerning not only its technical realization but first of all concerning the physical differences between organic materials and metals which we want to connect together. These structural differences lead to the incompatibility of these two types of materials concerning electronic, thermal, chemical and mechanical properties which makes such metal-organic interface particularly difficult in purposeful design.

One of the most controlled way by which such thin interface can be created and optimized is by formation of molecular monolayers called SAMs (Self-Assembled Monolayers), which are formed spontaneously in the process of self-organization on metal substrates. Ideally such interface based on SAMs should be thermally and chemically stable, have well-defined molecular structure (crystalline form with low defects concentration), predefined electronic properties (eg. conducting, insulating or switching) and proper functionality which in the case of the molecular electronics should usually enable linking with another metal electrode or in the case of organic electronic permit linking with the thick organic film. So far most of SAMs were made using sulfur as binding atom to metal surface. In the current project we will analyze a new type of SAMs based on carbenes which, thermally and chemically, are much more stable than “standard” SAMs by using carbon atom for binding with the metal surface. However, carbene based SAMs have not been electrically characterized so far, and more importantly, failed in formation of dense crystalline structures which is essential considering for instance defects concentration as well as formation of well-defined structures down to the nanometer scale using lithography. These features are essential for building electronic systems same way as it is done for currently used inorganic semiconductors (such as silicon) for which electronic properties and structural perfection were optimized over the last few decades to enable current fabrications at the nanometer scale.

Fortunately, our preliminary experiments show that formation of well-ordered structures by carbene SAMs is not only possible but can be done much better than for standard SAMs systems. This opens up an exciting possibility to analyze within this project for the first time conductivity of these SAMs using differently constructed molecules having conducting, insulating and switching properties of these SAMs. Moreover, by using two different lithographic methods such as stamping and irradiation by the electron beam we will test ability of using this new type of SAMs for either fast and simple hand-made method of pattern formation at the micrometer resolution which can be done at the laboratory desk and is sufficient for basic research and many applications, and much more sophisticated projection method with electron beams which requires specialized system and analysis of electrons interaction with this new type of SAMs but can offer resolution down to the nanometer scale as it is in the current electronic systems.

In summary, we believe that this proposal is both scientifically appealing and technologically attractive within the very active field of nanotechnology which stimulates development of different areas of science and technology such as organic electronics, where as we pointed above SAMs are one of the most crucial players.