Chirality in flatland: molecular recognition, single-molecule manipulation, chiral switching and molecular motors at surfaces

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Many objects in our world have the property that they are incongruent with their mirror image. Such objects are called chiral or enantiomorphous. Examples are quartz crystals, shoes, snail shells, screws, etc. The most significant manifestation of chirality is the appearance of left- and right-handed molecules, so-called enantiomers. Chirality is ubiquitous in the biological world, but handedness comes unbalanced. That is, molecules of life, like sugars, proteins, and their building blocks the amino acids, appear basically in only one handedness. This has dramatic consequences, because the biological and pharmaceutical activity of enantiomers is directly related to their handedness and causes different physiological effects.
After presenting few examples of chirality in the physical and sociological sciences and a brief introduction into the history of molecular chirality and the important role it played for understanding the spatial structure of molecules, various aspects of surface chirality will be discussed.
Molecular recognition among chiral molecules on surfaces is of paramount importance in biomineralization, enantioselective heterogeneous catalysis, and for the separation of chiral molecules into their two mirror-image isomers (enantiomers) via crystallization or chromatography. Understanding the principles of molecular recognition in general, however, is a difficult task and calls for investigation of appropriate model systems. One popular approach is thereby studying intermolecular interactions on well-defined solid surfaces, which allows in particular the use of scanning tunneling microscopy (STM). We present an elucidation of chiral recognition of helical hydrocarbons at the single molecule level, in monolayers and in multi-layers. In a Pasteur-type experiment at the nanoscale, molecules that constitute a dimer are separated with a molecular STM tip and the subsequent determination of their absolute handedness with a metal tip. Moreover, we will present examples of chiral amplification via the so-called 2D ‘sergeant-and-soldiers’ effect, chiral restructuring of a copper surface by prochiral molecules and discuss role of chirality in electrical current-driven molecular machines.