Reg. No: 2015/18/M/ST3/00403; Principal Investigator: dr hab. Anna Maria Maciolek

In recent years, inspired by biological molecular motors, scientists have tried to construct artificial devices which deliver mechanical work or propel themselves in a liquid environment. This is a difficult task because the standard macro-scale rules do not work at the nanoscale. For example, the macro-scale mechanism of propulsion is based on the transfer of momentum to the liquid. This mechanism cannot work for nano- and microparticles for which the effects of inertia are dominated by surface and viscous forces. New strategies are needed for the development of self-propellers.
One approach is to mimic natural microorganisms such as bacteria E. Coli or Spiroplasma and design an artificial``swimmers" which move after deforming their shapes in a cyclic time-irreversible way. Another approach is to use a phoretic transport mechanism. For example, in the case of diffusionphoresis an asymmetric distribution of solute particles generates a hydrodynamic flow of an ambient fluid around the particle. Because the colloid and the thin interfacial region around it are mechanically isolated, the conservation of the momentum require that this flow set the particle in the motion. Similar mutual interactions are involved in electro- and thermophoresis. This phoretic transport mechanism was used in designing self-propelled particles. The idea was that a particle itself provides a gradient which causes directed motion. This was achieved by using Janus particles (which are particles made of two half having different physical properties). For the self-diffusophoresis the particles have to be covered asymmetrically by a catalyst, which activates a chemical reaction in the surrounding solution generating gradients of the reaction products along the particle’s surface.

An interesting alternative for making self-propelled colloidal particles was proposed by Bechinger at co-workers at the University of Stuttgart. The idea was to use Janus particles half-coated by a metal suspended in a solvent which is a mixture of two liquids being close to their demixing temperature and laser heating. The metal patch adsorbs energy from the laser beam and converts it into heat, which is then released in the surrounding solution. This generates the temperature gradients across the particle surface and along its instantaneous direction which drives local demixing of a binary solvent and the propulsion of particle. It has been observed that the propulsion velocity depends on the laser power - it is of the order of few microns per second for low laser intensity. As pointed out by the inventors of these microswimmers, in comparison to other mechanisms proposed in the literature, the main advantage of this mechanism is that very low light intensities can be used, which excludes optical forces and allow to accurately tune the active Brownian motion of the particle. Such type of light activated self-propellers are very desirable, because one
can easily study them as a function for their swimming behavior, without altering their other physical or chemical properties and because the “fuel” driving the microswimmer regenerates once the particle has moved to a different region of the sample. Bechinger group in Stuttgart demonstrated experimentally how Janus particles
navigate through environments presenting complex spatial features, which more closely mimic the conditions inside cells, living organisms and future lab-on- a-chip devices.

The complex transport mechanism of light-activated self-propellers is not well understood. It is not clear whether the motion is caused by self-diffusophoresis or by the chemical potential difference at the diffuse interface of a nucleated droplet, arising from a balance of diffusive and advective fluxes. This project aims at gaining more physical insight into these problems by systematic theoretical and numerical studies. Self-propelled microswimmers hold tremendous potential as autonomous agents to localize, pick-up and deliver nanoscopic objects,
e.g., in bioremediation, drug-delivery and gene-therapy. Construction and studying of a suitable model system could lead to an understanding of the complex behavior of active matter. The project will significantly advance our knowledge of active matter, with benefits for development and implementation of new technologies that involve
self-propelled carrier in Polish industry.