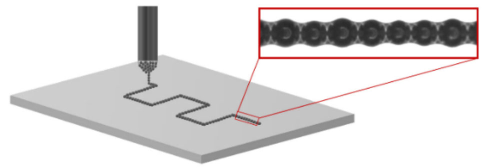
Efficient fabrication of single-particle-thick micropaths, their characterization and applicability



Inkjet printers—we used them regularly either at our homes or at work. Most of them operate in the so-called a drop-on-demand mode, in which droplets of ink are one by one fired from a cartridge onto a paper. Imagine now that instead of droplets of ink, small particles leave the cartridge one after another forming a thin structure that resemble a pearl-necklace in appearance. Such process, which could be called particle-on-demand, would enable deposition of particles side by side on substrate and creation of micropaths with a single-particle resolution. It turns out, that such particle micropaths are studied world-wide in regards to their unique properties, as well as from a perspective of their applicability. Unfortunately, these particle micropaths, which can be made several times thinner than a human hair and invisible for human eye, cannot be widely exploited these days. The main reason for that is the difficulty in their fabrication. Although there are several different methods for assembling particles in chain-like structures on substrates, each of the methods has one or more of the following disadvantages: it is expensive, time-consuming, inefficient, unsuitable for formation of non-linear structures, unable to position the particle microstructures, or suitable for formation of structures only in bulk liquids; requires access to advanced tools; or enables assembly of particle structures with limited lengths.

The goal of this research project is to formulate and develop a method that will overcome all the above-mentioned limitations, and enable efficient (thousands of particles per second), continuous production of single-particle-thick micropaths (in form of linear and nonlinear patterns) on different substrates (ceramic, polymeric, made of paper or natural fabrics, on either rigid or flexible substrates, as well as on substrates that are flat or uneven) composed of solid particles (electrically conductive or resistive), soft particles, microcapsules, or other types of particles. These one-dimensional structures will then be investigated for their physical properties (e.g., mechanical or electrical properties), which is intriguing from the perspective of both the fundamental research and applied research. For a physicist, an academic (and generally the scientific community) it is important and fascinating to understand the details of the mechanism of particle "printing"; the interplay of the electrostatic and capillary interactions; the formation of liquid capillary bridges between particles in the microstructure; the mechanism of mechanical stress absorption by the particle structure; or how the electric field influence the bending stiffness of the material, etc. A non-scientist will most likely ask how the knowledge gained through the realization of this project can be used in practice. One of the scientific hypotheses proposed here is that the pearl-necklace micropaths, owing to their properties, will find applications in many industrial fields, particularly in conventional and flexible electronics. For example, conductive particle micropaths can be used as an element of electronic circuit—conductive paths that provide a route through which current flows. Such conductive paths composed of particles aligned side by side along that path have superior electronic properties than similar conductive paths formed of aggregated nanoparticles used commercially today. Its worthy noting that conductive micrometre-size particles, for example, made of copper, are several times cheaper than their nanometric counterparts. Moreover, the particle structure's periodicity at mesoscale facilitates sintering of particles to form permanent solid conductive paths. Thus, the combination of the method and the characteristics of the single-particle-resolution micropaths forms a great opportunity for further research and development activities and eventually the commercialization of the method and fabricated devices within four to six years from now. This may, in turn, lead to great financial profit due to the enormous value of the global market related to the fabrication technology of such structures. In addition, this action will improve the Polish excellence and competitiveness by advancing the technological frontiers of material fabrication and technologies with patent and market potential.

This interdisciplinary research project, which draws upon methodological approaches from physics, chemistry, electronics and material engineering, will be carried out in Poland but in collaboration with scientists from Harvard University, Northwestern University and the University of Oslo. This will greatly enhance the visibility of the project's activities and its result. Several persons will be engaged to this project, including Master's students, a PhD candidate, post-doctoral researchers, and other scientist. These team members will have a great opportunity to work with researchers from the top universities in the world, which will significantly impact their scientific productivity.