Abstract for the general public

The fabrication of patterns made of single microparticles is still very challenging. The existing methods are either complicated, expensive, and time-consuming or imprecise and limited to the objects of certain properties, such as magnetic particles. These drawbacks hinder the development of new materials and devices. Therefore, the main objectives of the project are to develop an efficient and accurate method for the deposition of single particles on various types of substrates and to understand the physical mechanisms accompanying this process. The method should be versatile so that different types of particles of arbitrary sizes can be easily deposited, preferably, on any type of substrate.

The results of the preliminary experiments we have conducted this year revealed that combining an electric field with capillary interactions yields the efficient deposition of microparticles on a substrate and enables the formation of out-of-plane structures. However, we do not fully understand the physical mechanisms behind the particle deposition process, which encumbers the method development. The physical limitations of the method—for example, in terms of particle size and shape—are also unclear. Therefore, we are applying for funding for the medium-term project (24 months), in which part of the costs will be used to cover the salaries of two experienced researchers, the purchasing of consumables (microparticles, fluids, substrates, etc.), and the purchasing of advanced research equipment (the currently used budget experimental setup is insufficient). Because the proposed research is multidisciplinary (knowledge of physics, electronics, chemistry, material science, and engineering is required), we have scheduled small but important portions of the research to be performed in collaboration with partners from Norway and the United States. The partners from SINTEF Digital, Oslo, and the University of South-Eastern Norway, Vestfold, will provide support within the fields of electronics and chemistry, whereas the partners from Harvard University, Cambridge, United States, will back us up with the knowledge of physics of particle assembly.

The most important research task will be to understand and explain the physical mechanisms behind the process of deposition of single-particle systems on various types of substrates. Accomplishing this task will enable method optimization. We will also perform independent tasks aimed toward the physical characterization of deposited particle structures, including the out-of-plane structures (e.g., one-dimensional pillars composed of stacked microparticles). In addition, we will validate the suitability of the method for the production of chip connections and the fabrication of porous materials. We expect that the proposed electric method will allow depositing single particles of different shapes (spherical, rod-shaped), structures (e.g., solid-core, core-shell, multi-shell), sizes (from 1 μm to 1 mm), and electrical properties on different substrate materials, including smooth (e.g., glass panes), rough (e.g., wooden planks), irregular (e.g., fabrics), and water-absorbing (e.g., porous materials) surfaces.

If the method proposed here turns out to be (as we believe) efficient and easy to implement and enables the accurate deposition of particles as small as human hair in diameter or even smaller, the methodologies currently used in the different branches of the industry will have to be revised. For example, in the electronic industry, the interconnection of semiconducting dies is often performed using the flip-chip method, in which solder microparticles are arranged in a regular grid. The currently used cheap methods by the industry enable the deposition of particles with sizes down to around 100 μm. Depositing smaller particles requires the use of advanced and expensive techniques. As assured by one of the technology leaders of the largest companies producing equipment for depositing microparticles (PacTech, Germany), our method can be a game changer. This research proposal offers an excellent opportunity for basic research to advance fundamental knowledge in the field of particle bottom–up assembly and will lay the groundwork for the subsequent R&D studies and ultimately commercialization of the method in the near future.