Many manufacturing processes both conventional and modern are based on the changes of state of matter. The treatment is carried out in solid or/and liquid states. There is no change of state in the many traditional technologies, only phase transformation in the solid state can be available. Another group of technologies uses liquid state (or semi-liquid) to form products or semi-products. Then, the controlled solidification (transition of state of matter) is expected. The next group of technologies very rapidly developing in recent years is additive manufacturing technologies (AM). Some AM allow to obtain products with shape and characteristics impossible to receive with traditional technologies. Some of these technologies use extensively the materials in different state of matter. These are, for example, SLM/SLS technology (Selective Laser Sintering/Melting), Laser Cladding and other. Also traditional technology – welding, sintering or powder metallurgy may be classified as technology with dual-transition transformation of aggregation state: melting-solidification.

The main objectives of the project are development of a platform for three-dimensional simulation and modeling of the additive layer manufacturing processes characterized by changes of state of matter: melting-solidification. Platform will be based on homogeneous modeling methods and fast parallel calculations on graphics cards.

SLS/SLM technology was chosen as basic for development of the holistic model with the change of state of matter. SLS/SLM consists of four basic processes, which take place sequentially or simultaneously: powder deposition, heating by the laser beam and melting, free flow of molten material and solidification. The models for these four processes will be developed in the project.

The last very important applications of SLS/SLM are connected with biotechnology, including human implant development. Almost every powdered material can be used in that technology: metals (alloys), ceramics, polymers, bioglasses, and composites. Products (including implants), which consist of materials of different mechanical and thermal properties, are manufactured in several stages. Firstly, material melted at higher temperature is formed, then materials with lower temperature. Often, however, a complicated shape and requirements for properties of the final products (for example, porosity) cannot be received in several stages, but in one stage only. Development of such a one-stage manufacturing process is an undeniable technological and scientific challenge. One of the elements, which allows for the design of such a SLS/SLM technology, is theoretical researches based on the modeling of entire process.

Currently, large holistic models use multi-scale approaches that rely on a combination of several methods operating on different principles and (or) in different scales. There are many variants to create multiscale holistic model. Most of different combinations use significantly inhomogeneous or heterogeneous methods that require complicated interfaces between the various components. It almost eliminates the possibility to complete full-scale calculations within a single numerical model without running independently the individual modules and combining their results afterwards. As a result, difficulties and limitations for development of such a multiscale heterogeneous holistic model arise and, at the same time, the question of feasibility of such approaches arises as well. That is why such holistic models or calculation platforms are not still created.

However, development of the holistic model based entirely on one or two homogeneous methods allows for modeling of very complex physical phenomena accompanying the manufacturing process because of elimination of the complicated interface, even for modeling highly complex processes and phenomena in the whole manufacturing process. Feasibility of this model is proved by preliminary modeling.

The primary theoretical research method will be computer modeling of the processes and phenomena that take place during additive manufacturing, as well as modeling of whole manufacturing process. Qualitative and quantitative verification will be carried out on the tests with use of modern methods of measurements. The data for analysis of real SLM/SLS process are expected to be obtained from University of Sheffield and Manufacturing Technology Centre (UK) and other sources.

As a result of the project implementation will be a ready-made tool for adequate modeling of the additive layer manufacturing, which can be used for design, development and optimization of SLS/SLM technologies. Results are planned to present on conferences, in journals, in master and PhD thesis, it may be published a book. Also it is planned to use the results for further development of the computer-aided systems of real complex processes of additive technologies. It will be also useful for other processes modeling, which join melting, solidification, heat transfer, liquid flow or sintering. Other applications of the model can be as following: water freezing and ice melting, preventing the ice-crusted, drop icicles or snow from the roof, snow avalanches in the mountains, fluid freezing in the pipe, etc.

The authors of the project have experience in the development and application of CA. The principal investigator has developed the FCA algorithm. The project will be attended by specialists in LBM. The unformal cooperation with research groups in United Kingdom, the Czech Republic and Ukraine is also expected.