3D printing of metals is a dynamically developing industry that allows the production of metal parts with complex shapes using powders as raw materials. Given current market trends, the global 3D printing (metals) market is forecast to reach $ 19 billion in 2029. Currently, the dominant area of application of additive technologies is the sphere of rapid prototyping, present in almost every industry where the final product is made in the form of a physical detail. As a result of the wide range of applications, the requirements for their properties are also increasing. In particular, the accuracy and quality of surface topography is expected to be improved, as well as the mechanical strength.

Compared to traditional production methods such as casting, the innovation of additive technologies is a disadvantage to some extent, but this also means that there are many interesting development opportunities. The research conducted so far on a laboratory and industrial scale has been focused primarily on improving mechanical properties through: assessment of the influence of manufacturing parameters, heat, chemical, or surface treatment. Only a few works are devoted to alternative post-process machining in which intensive plastic deformation is the last stage.

The basic technological problem resulting from the synergistic integration of both technologies, i.e. selective laser melting (SLM) and intensive plastic deformation, is the low susceptibility to plastic processing of metal alloys obtained from 3D printing. This is due, inter alia, to residual stresses of thermal origin. On the other hand, very high cooling rates in the SLM process (10^5–10^6 K/s) favor the formation of a unique heterogeneous microstructure composed of hard (shell) and soft (core) areas.

Our proposed solution to the above problem is to design / adapt the heat treatment process of 3D printed elements in such a way as to preserve the unique (metastable) heterogeneous microstructure as much as possible, while improving the indicators describing the ductility.

The concept of an innovative technology for the production of high-strength and ductile Al-Si alloys with takes advantage of the heterogeneous nature of the microstructure, the soft Al core / hard Si shell. During severe plastic deformation, the existing deformation gradient will cause long-range internal stresses. These stresses will be accommodated by the geometrically necessary dislocations (GNDs). Moreover, these dislocations will constitute obstacles to the movement of statistically stored dislocations (moving in the dominant slip system), thus intensifying the process of microstructure refinement.

The increase in strength will be achieved as a result of the synergistic interaction of several strengthening mechanisms - fragmentation of the microstructure and additional accumulation of defects / obstacles (for statistically stored dislocations) by geometrically necessary dislocations (GNDs) generated at an early stage of plastic deformation of a heterogeneous material, while increased ductility due to the existing deformation gradient accommodated by the resulting long-range stresses.

The research carried out as part of the project will concern the observation of the basic deformation phenomena on a micro and nanometric scale to determine the contribution of stress recovery to the deformation strengthening capacity (the ability to store plastic deformation energy) of Al-Si alloys obtained with the selective laser melting technology (SLM). The main goal of the observations performed is to determine the influence of microstructural heterogeneity on the deformation strengthening capacity of Al-Si alloys obtained by the selective laser melting technology.