

Modern industry increasingly requires materials that are not only extremely strong but also resistant to plastic deformation at room and elevated temperatures. Unfortunately, in traditional metallic materials, improving one property often comes at the expense of another, increasing strength usually results in a loss of ductility. The goal of this project is to find a way to overcome this limitation.

Therefore, the project aims to develop a new method of strengthening modern metallic alloys (so-called high-entropy alloys or alloys with complex chemical compositions) by combining intensive mechanical processing with precise heat treatment. A key role is played by *hydrostatic extrusion*, compressing the material under high pressure, followed by a short annealing process at elevated temperatures.

Preliminary results are impressive. This method led to a sixfold increase in alloy strength (reaching 3020 MPa), making it one of the strongest known metallic materials. Importantly, the material still retains its ductility, which is rare for materials with such high strength.

The cause of these excellent properties lies in the microstructure. As a result of plastic deformation, so-called *twins*, ordered crystal structures, form within the metal. At the intersections of these twins, ideal conditions arise for the formation of nanometer-scale particles (precipitates) with a different crystal structure (bcc-type). These particles, forming a three-dimensional network resembling tetrahedrons, significantly strengthen the phase boundaries within the material, making it far more resistant to plastic deformation.

The unique properties of this alloy result from two key factors:

- Very low stacking fault energy, which promotes disorder in the alloy and the formation of twins and other deformation mechanisms;
- Complex chemical composition, which enables the formation of both stable and metastable (but strengthening) precipitates.

However, to fully understand the material's potential and the underlying mechanisms, the project aims to answer several key questions:

1. How does mechanical processing affect the kinetics and mechanisms of precipitation?
2. What is the significance of the initial grain size and their crystallographic orientation?
3. How does the chemical composition of the material influence its structural transformations, such as twin formation or phase changes?
4. What are the exact properties of the nanometer-scale particles: their size, composition, crystal structure, and resistance to high temperatures?

Answering these questions will enable the development of new strategies for designing alloys that are not only extremely strong but also plastically resilient and suitable for the most demanding applications, such as in aerospace, energy, or the space industry.