

**High-entropy alloys (HEAs)** are advanced metallic materials composed of multiple elements in comparable proportions. Their exceptional resistance to extreme conditions makes them a promising solution in materials engineering. However, their tribological properties—friction reduction and wear resistance—are not yet fully understood. The goal of this project is to develop friction reduction mechanisms in HEAs by introducing microalloying elements that promote the formation of protective surface layers during friction. We will particularly focus on elements such as Ag, Bi, Cu, Zr, Si, Mo, and W, which can dynamically alter the surface properties under mechanical stress and high temperatures, leading to a reduction in the friction coefficient and increased durability of HEAs. This project will involve experimental studies to assess the impact of different microalloying elements on the tribological properties of HEAs. The research will include:

1. **Synthesis of HEAs** – preparation of samples with Ag, Bi, Cu, Zr, Si, Mo, and W, aimed at influencing the formation of protective layers.
2. **Tribological testing** – friction tests over a broad temperature range (20–700°C) to evaluate wear resistance and friction coefficient.
3. **Microstructural and chemical analysis** – advanced microscopy and spectroscopy techniques (SEM/EDS, XRD) will be used to identify the microstructures and chemical compositions of protective layers formed during operation.
4. **Tribochemical modeling** – thermodynamic analysis will help predict friction reduction mechanisms and the formation of protective layers depending on the applied microalloying elements.

### Justification for the Research

Brake discs, bearings, engine components, and other machine parts undergo wear due to friction. In industry, developing materials that can self-regenerate their surface and reduce friction is crucial for minimizing energy losses and extending the lifespan of devices. HEAs, due to their resistance to high temperatures and corrosion, are ideal candidates for such applications.

The introduction of microalloying elements can significantly improve their tribological properties by:

- **Forming protective oxide layers** (e.g.,  $ZrO_2$ ,  $SiO_2$ ), which reduce friction and prevent surface degradation.
- **Creating a self-lubricating effect** (via Ag, Bi, Cu), allowing for friction reduction even under extreme conditions.
- **Increasing hardness and wear resistance** by stabilizing the microstructure (via Mo, W).

### Expected Outcomes

- **Identification of friction reduction mechanisms** in HEAs and how microalloying elements influence the formation of protective layers.
- **Development of HEAs with optimized microstructures**, exhibiting high wear resistance under various operating conditions.