

Relevance:

The use of aluminum alloys has an undeniable advantage over many other alloys, primarily due to their low weight, good performance properties, high electrical conductivity, anti-corrosion properties and sufficient mechanical characteristics. However, to achieve a high level of these characteristics, alloying with expensive, usually rare earth elements, is required. This approach leads to a sharp increase in the cost of finished parts. Ceramics of the MeSi type (silicides) have high hardness and wear resistance. To solve the problem of improving the quality of aluminum-based parts, it was decided to develop a composite ceramic material AlxFeySi. The uniqueness of the material lies in the possibility of forming the Al₈Fe₂Si phase, which has a highly symmetrical crystal lattice, providing the ability of the resulting composite ceramic materials to perceive plastic deformation.

Project goal:

To develop a technology for synthesizing composite ceramic materials of the AlxFeySi system using an additive method to improve the quality of the structure of materials and parts based on them.

Expected and achieved results:

Results achieved in 2024:

- the Al-Fe-Si composite was synthesized by the surfacing method using aluminum plates, a steel electrode, and powdered silicon. A material with a uniform microstructure and improved mechanical properties was obtained;

- heat treatment modes have been developed that ensure phase transformation ($\beta \leftrightarrow \alpha$, $\theta \leftrightarrow \theta'$) and the formation of a structure enriched with aluminum or silicon;

- the plastic deformation of the material was studied, the deformation parameters were identified (up to 20%), high plasticity was determined (>5% under compression). Destruction occurs sequentially, the nature of destruction is comparable to silumins;

- materials were processed at elevated temperatures, plasticity was improved, and destruction during deformation was prevented.

Received publications for 2024

1. Andreyashchenko V.A. Study of the technology of synthesis of metal-ceramic material of the AlxFeySi system// Proceedings of the university No. 1 (94), 2024, 50-56.

2. Toleuova A.R., Andreyashchenko V.A. Computer modeling of the process of aluminum matrix formation using the thermo-calc program // EKTU Bulletin No. 1, 2024, pp. 244-251, DOI 10.51885/1561-4212_2024_1_244

Participated in 3 international scientific conferences with the publication of 4 reports, three of which are included in the scopus database:

1. V.A. Andreyachshenko; M.K. Ibatov Study of phase transformations in the Al 60 Fe 40-x Si x system//AIP Conf. Proc. 3251, 040001.<https://doi.org/10.1063/5.0234066>

2. A.Zh. Aiken; V.A. Andreyachshenko Evolution of microstructure and properties in Fe, Si-Rich AlFe-Si alloy // AIP Conf. Proc. 3251, 040006.<https://doi.org/10.1063/5.0234067>.

3. Andreyashchenko V.A., Aitzhan A.T. Suppression of alpha-beta transformation in AlFeSi system alloys// Works International scientific and practical conference «XVI Saginov readings. Integration of education, science and production», Vol.3, 14-15.

4. V.A. Andreyachshenko Application of ThermoCalc for the design of an alloy based on the Al-Fe-Si system//Proc in LINDI 2024

1 article published in Scopus database, percentile 48:

V.A. Andreyachshenko, M.K. Ibatov Optimization of the three-component Al-Fe-Si system composition // METALLURGICAL RESEARCH & TECHNOLOGY, 121, 3, 315. <https://doi.org/10.1051/metal/2024035>

Expected results:

- the composite will be synthesized, heat treatment parameters will be developed, and a pilot batch will be manufactured;
- the plastic deformation of the material was investigated, including deformation at elevated temperatures. The indicators of ultimate plasticity and the moment of destruction were determined;
- participation in two international conferences, publication of an article in journals indexed in Scopus (CiteScore ≥ 35) or Web of Science.



Figure 1 –Work of the research group on the study of composite ceramic materials of the AlxFeySi system

Research group

No. p/p	Full name (if any), education, degree, academic title	Hirsch index, Researcher ID, ORCID, Scopus Author ID (if available)
1	Andreyashchenko Violetta Aleksandrovna, PhD, associate professor (associate professor) in the specialty metallurgy, head of ILIP «KORMS»	Hirsch index (Scopus) - 8 Hirsch index (WoS) - 6; Researcher ID: H-4328-2013; https://orcid.org/0000-0001-6933-8163 ; Scopus Author ID 55308057400
2	Bartenev Igor Anatolyevich, candidate of technical sciences, associate professor, associate professor of the department of TEME&SD	Hirsch Index (Scopus) - 1, Hirsch Index (WoS) – 1, Scopus Author ID:57207457067, ORCID: 0000-0001-8982-7319
3	Ibatov Marat Kenessovich, doctor of technical sciences, professor of the department. TE&LSD	https://orcid.org/0000-0001-5062-7790 , Researcher ID: N-9320-2017 Scopus Author ID: 57189211438, Hirsch Index (Scopus) – 4, Hirsch Index (WoS) - 2
4	Alina Arailym Altynbekovna, master, senior teacher of the department NMD	https://orcid.org/0000-0003-3577-4914 , Scopus Author ID: 57218196165, Researcher ID: DRQ-4173-2022, Hirsch Index (Scopus) – 1, Hirsch Index (WoS) – 1.

5	Malashkevichute-Bryan Elena Iozassovna, master, senior teacher of the department NMD	Scopus Author ID:5876248370 Hirsch index (Scopus) – 1
6	Yerzhan Aidana, master, PhD student in «Metallurgy»	https://orcid.org/0000-0002-6942-2020 Scopus Author ID: 56901129500, Hirsch Index (Scopus) – 1, Hirsch Index (WoS) – 1.
7	Tulepova Moldir Abylseitkyzy	-

List of publications

1. Andreyashchenko V.A. Influence of fluxes in the production of metal-ceramic materials of the Al-Fe-Si system// BULLETIN OF KSIU No. 2 (41) 2023, pp. 25-30.

2. Andreyashchenko V.A., Toleuova A.R. Modern methods of synthesis of metal-ceramic materials of the Al-Fe-Si system//Proceedings of the International scientific and practical conference «Innovations and complex processing of mineral raw materials - relevant components of economic diversification», dedicated to the 30th anniversary of the national center for complex processing of mineral raw materials of the Republic of Kazakhstan, Almaty, 2023, pp. 107-109.

3. Toleuova A.R., Andreyashchenko V.A. Computer modeling of phase processes in an aluminum matrix//Proceedings of the International scientific and practical conference «Innovations and complex processing of mineral raw materials - relevant components of economic diversification», dedicated to the 30th anniversary of the national center for complex processing of mineral raw materials of the Republic of Kazakhstan, Almaty, 2023, pp. 82-83

4. Andreyashchenko V.A. Study of the technology of synthesis of metal-ceramic material of the Al_xFe_ySi system/ /Proceedings of the university No. 1 (94), 2024, 50-56;

5. Toleuova A.R., Andreyashchenko V.A. Computer modeling of the process of aluminum matrix formation using the Thermo-Calc program // EKTU Bulletin No. 1, 2024, pp. 244-251, DOI 10.51885/1561-4212_2024_1_244

6. V.A. Andreyachshenko; MK Ibatov Study of phase transformations in the Al 60 Fe 40-x Si x system//AIP Conf. Proc. 3251, 040001.<https://doi.org/10.1063/5.0234066>

7. A.Zh. Aiken; V.A. Andreyachshenko Evolution of microstructure and properties in Fe, Si-Rich AlFe-Si alloy // AIP Conf. Proc. 3251, 040006. <https://doi.org/10.1063/5.0234067>.

8. Andreyashchenko V.A., Aitzhan A.T. Suppression of alpha-beta transformation in AlFeSi system alloys// works International scientific and practical conference «XVI Saginov readings. Integration of education, science and production», Vol.3, 14-15.

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10. V.A. Andreyachshenko, M.K. Ibatov Optimization of the three-component Al-Fe-Si system composition // METALLURGICAL RESEARCH & TECHNOLOGY, 121, 3, 315. <https://doi.org/10.1051/metal/2024035>

Information for potential users

The results of the project are applicable for the manufacture of machine elements operating in difficult conditions and subject to intensive wear. The use of the new alloy as a structural material allows for a significant reduction in the weight of finished products (more than 2 times) compared to steel products, while the hardness of the new composite material is higher.

Scope of application

The scope of application of the project results is the automotive and mechanical engineering industries. The target consumers of the obtained results will be mechanical engineering and automotive manufacturing enterprises, machine elements operating in difficult conditions and subject to intensive wear.

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