МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ

ЕлІТ

ФІЗИКА, ЕЛЕКТРОНІКА, ЕЛЕКТРОТЕХНІКА

ФЕЕ - 2025

МАТЕРІАЛИ
та програма

МІЖНАРОДНОЇ НАУКОВОЇ КОНФЕРЕНЦІЇ
молодих вчених

(Суми, 21-25 квітня 2025 року)

Суми,
Сумський державний університет
2025

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ

ФІЗИКА, ЕЛЕКТРОНІКА, ЕЛЕКТРОТЕХНІКА

ФЕЕ :: 2025

МАТЕРІАЛИ
та програма

МІЖНАРОДНОЇ НАУКОВОЇ КОНФЕРЕНЦІЇ
молодих вчених

(Суми, 21–25 квітня 2025 року)

Суми
Сумський державний університет
2025

Diffusion Processes in High-Entropy Thin Film Alloys

Shumakova N.I., *Associate Professor*; Shevchenko V.I., *PhD Student*

Sumy State University, Sumy, Ukraine

In previous works (see, for example, [1-7]), methods were proposed for investigating the physical properties and characteristics of high-entropy alloys (HEAs), either in thin-film or bulk form, based on Fe, Co, Ni, Cr, Cu, or Al. These studies are based on the concept of applying the principle of additivity [7] to so-called intrinsic rather than collective atomic parameters. It is important to note that the properties of thin-film HEAs remain underexplored (the research was initiated in [1]), while bulk high-entropy alloys have been primarily studied in terms of their mechanical and tribological properties. Given that the studies mentioned in [1-6] explored the strain resistive [1, 2] and magnetoresistive [1] properties, as well as dynamic characteristics (such as lattice parameter and Debye temperature) [3-5], and magnetization [6], we have attempted to analyze the features of kinetic (diffusion) processes in bulk HEAs. A key premise in this case is the thesis that the kinetic process in 5-6 component HEAs can be considered as the self-diffusion of individual atoms with a diffusion coefficient D close to the corresponding value in single-component metals. This approach is justified by the fact that in HEAs, the atomic sizes of the individual components are very similar (deviations r_i from the average atomic radius $\bar{r}$ do not exceed 5%). It should be noted that, at first glance, this deviation appears small, but it is precisely what enables the formation of the HEA state and the development of high macrostress values. We made an attempt to consider the influence of this size factor on the self-diffusion process. The working relation for a thin-film high-entropy alloy with n components can be written as follows:

$$D = a\left(\frac{1-x}{n-1}\sum_{i=1}^{n-1} D_i + x\,D_n\right),$$

where x – is the atomic fraction of the doping element, which alternates among all n metals; the factor $\frac{1-x}{n-1}$ indicates the equiatomic nature of the phase-forming group of atoms; a – is a factor that accounts for the atomic size effect. The factor a can be expressed as:

$$a = \bar{\alpha}\left(1 - \frac{r_n}{\bar{r}}\right)$$

where $\bar{\alpha}$ is the average value of an empirical coefficient that characterizes the degree to which self-diffusion is hindered by the atomic size factor. Its value can be calculated by comparing D for individual components and the high-entropy alloy.

The work was carried out with the financial support of the Ministry of Education and Science of Ukraine 2022-2024 pp. (№0122U000785).

1. S.I. Vorobiov, D.M. Kondrakhova, S.A. Nepijko, N.I. Shumakova, I.Y.Protsenko, *J. Nano- Electron. Phys.* **8** No 3, 03026 (2016).
2. L.V. Odnodvorets, IYu. Protsenko, A.K. Rylova, D.I. Tolstikov, *J. Nanomat.* **2022**, 2862439 (2022).
3. I.Yu. Protsenko, M.O. Shumakova, A.K. Rylova, N.I. Shumakova, *Metallofizika i Noveishie Tekhnologii* **45** No 7, 857 (2023).
4. S.I. Protsenko, L.V. Odnodvorets, N.I. Shumakova, O.O. Pasko, I.Yu. Protsenko, *Phys. Chem. Solid State* **25** No 2, 284 (2024).
5. I.Y. Protsenko, L.V. Odnodvorets, N.I. Shumakova, S.I. Protsenko, Yu.M. Shabelnyk, *Eur. Phys. J. Plus* **139** No 3, 252 (2024).
6. I.Yu. Protsenko, A.K. Rylova, N.I. Shumakova, *J. Nano- Electron. Phys.* **16** No 6, 06002 (2024).
7. Yu. Protsenko, *J. Nano- Electron. Phys.* **15** No 5, 05011 (2023).

Scientific advisor – Protsenko I.Yu., *Doctor of Science, Professor*,
Sumy State University, Sumy, Ukraine