Thematic Section: Research into New Technologies. **Full Paper**
Subsection: Composite Materials.
Reference Object Identifier – ROI: jbc-01/17-52-11-89
The Digital Object Identifier – DOI: 10.37952/ROI-jbc-01/17-52-11-89
Submitted on November 14, 2017.

Thermal study of Mo-15.3Si-REM (Sc, Y, Nd) *in situ* composites obtained under nonequilibrium crystallization conditions

© **Rosa I. Gulyaeva**,[1] **Lyudmila Yu. Udoeva**,[1+]
Vladimir M. Chumarev,[1]* and **Sofia A. Petrova**[2]
[1] *Laboratory of Non-Ferrous Metals Pyrometallurgy.* [2] *Laboratory of Physical Chemistry of Metallurgical Melts. FSBIS Institute of Metallurgy. Ural Branch of the Russian Academy of Sciences. Amundsen St., 101. Yekaterinburg, 620016. Russia. Phone: +7 (343) 232-90-81. E-mail: lyuud@yandex.ru*

*Supervising author; +Corresponding author

Keywords: Mo-Si alloys, in situ composites, doping, yttrium, scandium, neodymium, thermal analysis, phase composition.

Abstract

The results of thermal analysis of alloys based on Mo-15.3Si doped with REM (Sc, Y, Nd), that have the structure and phase composition of in situ composites are presented.

In samples obtained by vacuum-arc method, the possibility of formation of nonequilibrium phases was assumed. In the 25-1500 °C range, for all samples except for the alloy with Nd, two exothermic effects were detected on the DSC heat flow line: a pronounced maximum in the 810-860 °C region and a weak maximum at 1170-1230 °C. The alloy with Nd turned out to be thermally stable. According to XRD data, after the thermal action, additional phases were formed in the alloys as well as the change of parameters of the main phase components (Mo_{ss} and Mo_3Si) were noted, which could result from processes of recrystallization and ordering of the structure of composites. It is suggested that for temperature-stabilizing annealing of Mo-Si-REM alloys with the studied compositions, a required temperature is at least 900 °C, but experimental verification is necessary.

References

[1] H. Chen, Q. Ma, X. Shao, J. Ma, C. Wang, B. Huang. Microstructure, mechanical properties and oxidation resistance of Mo_5Si_3–Al_2O_3 composite. *Materials Science & Engineering.* **2014.** Vol.A592. P.12-18.
[2] A.K. Vasudevan, J. Petrovic. A comparative overview of molibdenium silicide composites. *Materials Science & Engineering.* **1992**. Vol.A155. P.1-17.
[3] L. Ingemarsson, K. Hellström, L.G. Johansson, J.E. Svensson, M. Halvarsson. Oxidation behaviour of a $Mo(Si,Al)_2$ based composite at 1500 °C. *Intermetallics.* **2011**. Vol.19. P.1319-1329.
[4] M.M. Rakhmankulov, V.M. Parashchenko. Technology of high-temperature alloys casting. *Moscow: Intermet Engineering.* **2000**. 464p. (russian)
[5] I. Rosales, J.H. Schneibel. Stoichiometry and mechanical properties of Mo_3Si. *Intermetallics.* **2000**. No.8. P.885-889.
[6] P.A. Nikolaychuk, and A.G. Tyurin. Thermodynamics of chemical and electrochemical stability of the Mo–Si system alloys. *Butlerov Communications*. **2011**. Vol.24. No.2. P.95-100. ROI: jbc-02/11-24-2-95
[7] E.P. Domashevskaya, V.A. Terekhov, S.Y. Turishchev, D.A. Koyuda, N.A. Rumyantseva, Y.P. Pershin, V.V. Kondratenko, N. Appathurai. Synchrotron investigations of Si/Mo/Si. . .c-Si(100) multilayered nanoperiodic structures. *Physics of the Solid State.* **2013**. Vol.55. No.3. P.634-641. (russian)
[8] S-H. Ha, K. Yoshimi, K. Maruyama, R. Tu, T. Goto. Compositional regions of single phases at 1800 °C in Mo-rich Mo-Si-B ternary system. *Mat. Sci. Eng. A.* **2012**.Vol.552. P.179-188.
[9] P. Jehanno, M. Saage, M. Boning, H. Kestler, J. Freudenberger, S. Drawin. Assesstment of the high temperature deformation behavior of molybdenum silicide alloys. *Mat. Sci. Eng.* 2**007**. A463. P.216-223.
[10] H. Qiang, M. Chaoli, Z. Xinqing, X. Huibin. Phase equilibrium in Nb-Si-Mo ternary alloys at 1273 K and 2073 K. *Chanese Journal of Aeronautics.* **2008**. Vol.21. P.448-454.
[11] N. Sekido, K. Hildal, R. Sakidja, J.H. Perepezko. Stability of the Nb_5Si3 phase in the Nb-Mo-Si system. *Intermetallics.* **2013**. Vol.41. P.104-112.

[12] M.E. Ghayoumabadi, A. Saidi, M.H. Abbasi. Lattice variations and phase evolutions during combustion reactions in Mo-Si-Al system. *J. Alloy Compd.* **2009**. Vol.472. No.1-2. P.84-90.
[13] L. Ingemarsson, K. Hellstrom, L.G. Johansson, J.E. Svensson, M. Halvarsson. Oxidation behavior of a $Mo(Si,Al)_2$ based composite at 1500 ^oC. *Intermetallics*. **2011**. Vol.19. P.1319-1329.
[14] M. Mousa, N. Wanderka, M. Timpel, S. Singh, M. Krüger, M. Heilmaier, J. Banhart. Modification of Mo–Si alloy microstructure by small additions of Zr. *Ultramicroscopy*. **2011**. Vol.111. P.706-710.
[15] A.B. Gokhale, G.j. Abbaschian. The Mo-Si (Molybdenum-Silicon) System. *J. Phase Equilib.* **1991**. Vol.12. No.4. P.493-494.
[16] A.V. Larionov, L.Y. Udoeva, and V.M. Chumarev. Thermodynamic simulation of phase formation in the Mo-Si, alloys doped with scandium or neodymium. *Butlerov Communications.* **2015**. Vol.43. No.9. P.89-96. DOI: 10.37952/ROI-jbc-01/15-43-9-89
[17] A.V. Larionov, L.Y. Udoeva, V.M. Chumarev, and A.N. Mansurova. Thermodynamic simulation of phase formation in the Mo-Si alloys doped with yttrium. *Butlerov Communications.* **2015**. Vol.43. No.9. P.84-88. DOI: 10.37952/ROI-jbc-01/15-43-9-84
[18] A.N. Mansurova, A.V. Larionov, S.N. Tyushnyakov, and L.A. Marshuk. Phase composition and microstructure of the obtained under nonequilibrium crystallization conditions Mo-Si alloys. *Butlerov Communications.* **2015**. Vol.43. No.9. P.97-101. DOI: 10.37952/ROI-jbc-01/15-43-9-97
[19] Удоева Л.Ю., Чумарев В.М., Ларионов А.В., Жидовинова С.В., Тюшняков С.Н. Влияние редкоземельных элементов на структурно-фазовое состояние in situ композитов Mo-Si-X (X=Sc, Y, Nd). *Перспективные материалы.* **2017**. №7. С.24-33
[20] L.Yu. Udoeva, A.V. Larionov, V.M. Chumarev, A.N. Mansurova, and S.N. Tushnyakov. The phase formation study of the hypoeutectic Mo-Si alloys, doped with REM (Sc, Y, Nd). *Butlerov Communications.* **2016**. Vol.47. No.8. P.106-114. DOI: 10.37952/ROI-jbc-01/16-47-8-106
[21] NETZSCH Proteus Software. Thermal Analysis. Version 4.8.3.
[22] DIFFRAC^{Plus}: *Eva* Bruker AXS GmbH, Ostliche. Rheinbruckenstraße 50, D-76187, Karlsruhe, *Germany.* **2008**.
[23] Powder Diffraction File PDF4+ ICDD Release **2015**
[24] J. Laugier, B. Bochu. LMGP-Suite of Programs for the interpretation of X-ray Experiments. ENSP. Grenoble: *Lab. Materiaux Genie Phys.* **2003**.
[25] DIFFRAC^{Plus}*: TOPAS* Bruker AXS GmbH, Ostliche. Rheinbruckenstraße 50, D-76187, Karlsruhe, *Germany.* **2008**.
[26] K. Yoshimi, S. Nakatani, S. Hanada, Se-Hyun Ko & Yong-Ho Park. Synthesis and high temperature oxidation of Mo-Si-B-O pseudo in situ composites. *Science and Technology of Advanced Materials.* **2002**. Vol.3. P.181-192.