Structural and phase states of concentrated solid solutions based on V-Nb-Ta-Ti irradiated with helium ions

V.V. Uglov[1], M.M. Belov [1], S.V. Zlotski[1], K. Jin[2], A.E. Ryskulov[4], M.V. Zdorovets[3,4], L.A. Kozlofsky[4], A. E. Kurakhmedov[4], D.A. Mustafin[4], E.D. Sapar[4], E.V. Bihert[4]

[1]Belarusian State University, Minsk, Belarus
[2]Beijing Institute of Technology, Beijing, China
[3]L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan
[4]Institute of Nuclear Physics, Nur-Sultan, Kazakhstan

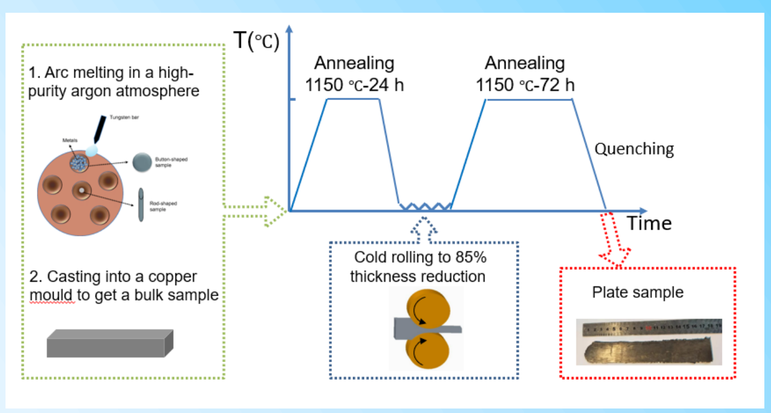
Context and motivation

One of the promising areas of research in modern materials science is the study of properties and methods for producing high-entropy alloys [1]. It is believed that maximizing the configuration entropy of high-entropy alloys promotes the formation of a single-phase disordered solid solution instead of the formation of complex intermetallic or second phases, as a result, the alloy has a simple microstructure with improved properties compared to traditional alloys. Numerous studies have shown that high-entropy alloys have a high elastic limit, wear resistance, creep resistance, thermal resistance and radiation resistance [2].

Experimental procedure

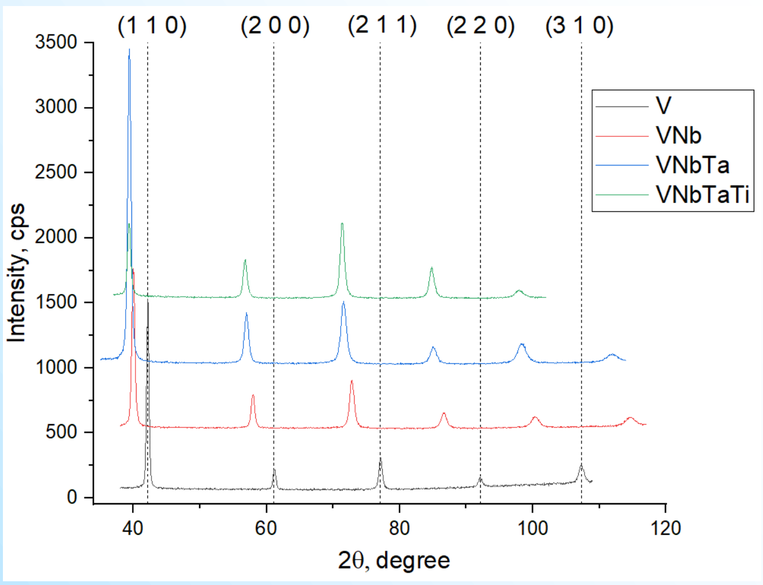
Multicomponent solid solutions based on V-Ti-Nb-Ta were synthesized using high-purity metals (>99.9%) by arc melting followed by homogenization. Then annealing was carried out for 24h and 72h at a temperature of 1150°C with cold rolling up to 85 % reduction in thickness.

The samples were irradiated at room temperature with He^{2+} ions with an energy of 40 keV and a fluence of 2×10^{17} cm^{-2}.



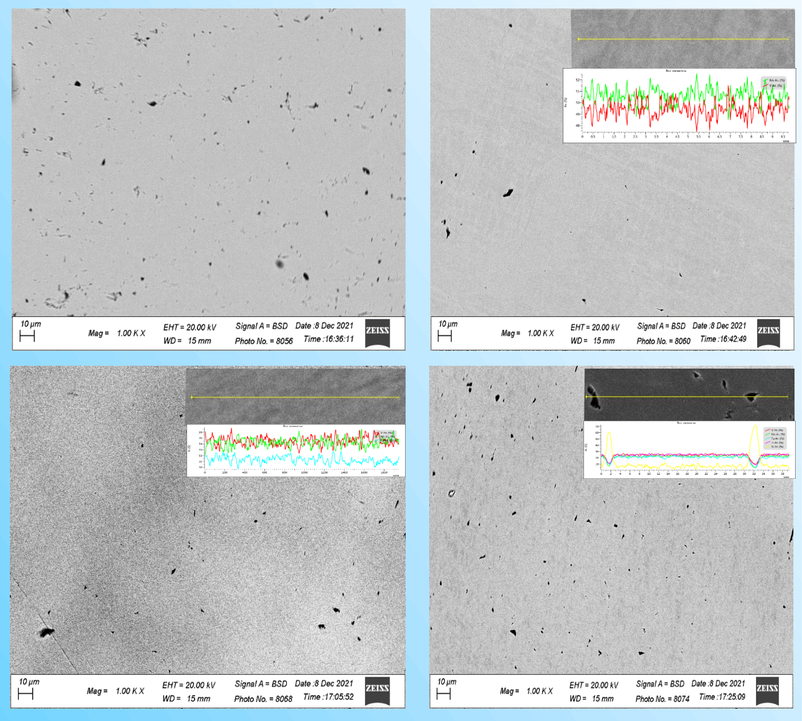
Initial samples

XRD investigations



- Formation of BCC solid solution.
- An increase in the number of elements in the alloy does not lead to the formation of intermetallic phases.

SEM

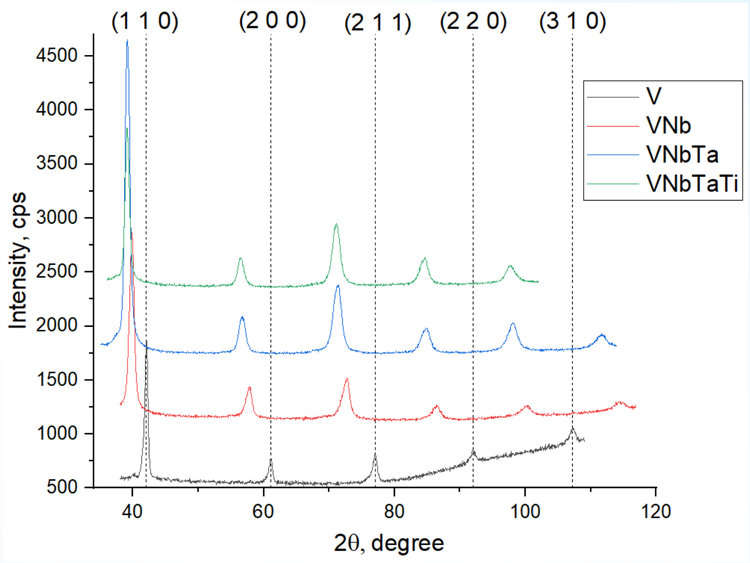


EDX

Samples	at.%			
	V	Nb	Ta	Ti
V	100	-	-	-
VNb	49.5	50.5	-	-
VNbTa	33.9	34.2	31.9	-
VNbTaTi	23.6	26.1	25.9	24.5

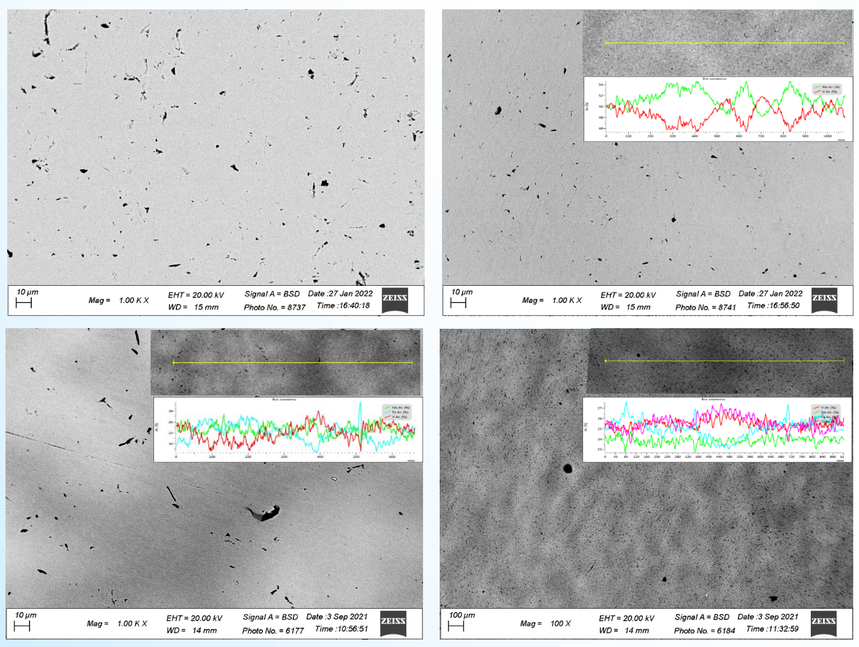
- An equiatomic and homogeneous distribution of elements over the surface is observed.
- Grain size in the VNbTaTi alloy was 100-200 nm.

Phase composition of V-Nb-Ta-Ti system after He irradiation



- The stability of the phase composition has been established.
- Asymmetry and displacement of peaks towards smaller angles were revealed, which indicates deformation of the crystal lattice after irradiation.

Surface morphology of V-Nb-Ta-Ti system

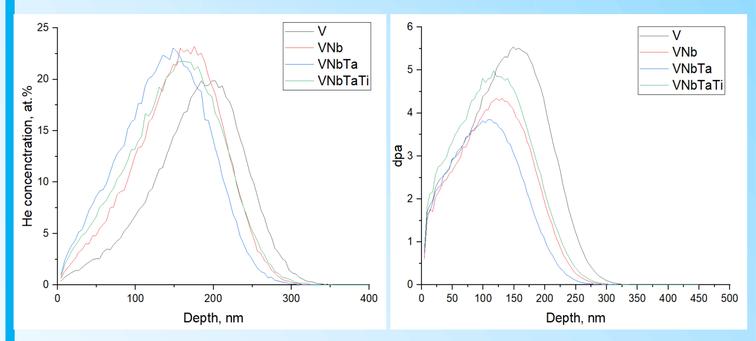


EDX

Samples	at.%			
	V	Nb	Ta	Ti
V	100	-	-	-
VNb	49.4	50.6	-	-
VNbTa	31.7	34.2	34.1	-
VNbTaTi	25.7	25.5	23.7	25.2

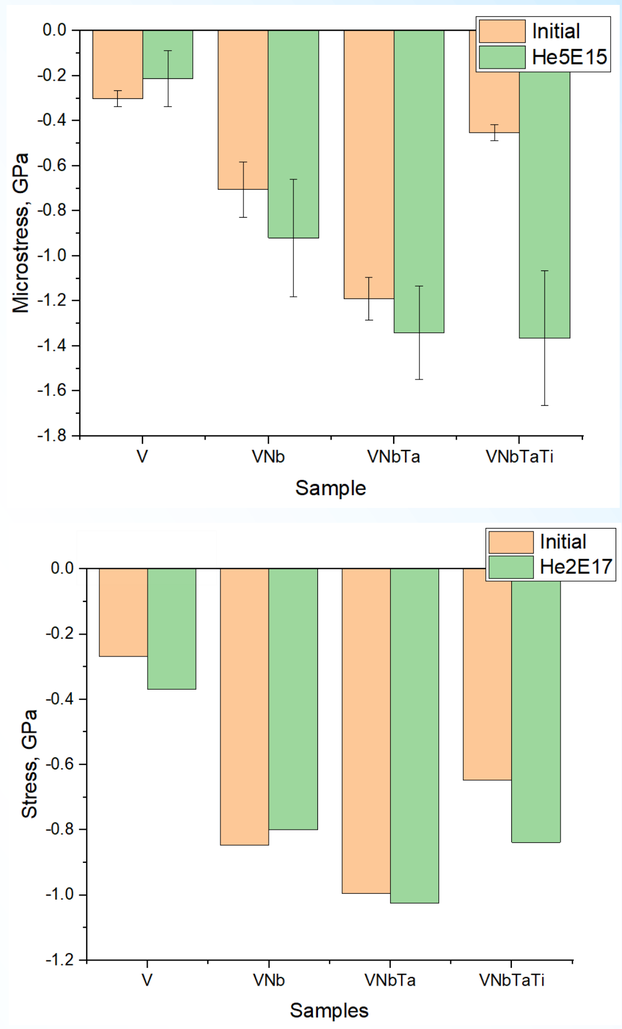
- Irradiation does not lead to the formation of blisters or segregation of elements.
- After irradiation with helium ions with an energy of 40 keV, a homogeneous and equiatomic distribution of elements on the surface is preserved.

SRIM calculation



Samples	dpa	He concentration, %	Projected range R_p of He ions, nm
V	5.5	19.8	195
VNb	4.4	23.2	170
VNbTa	3.5	22.9	147
VNbTaTi	4.8	21.2	161

XRD Residual Stress Measurment



- An increase in the number of elements in the V-Nb-Ta-Ti system leads to an increase in stresses of the first and second kind.
- There is an increase in micro- and macrostresses in multicomponent solid solutions after irradiation, in contrast to pure vanadium.

CONCLUSIONS

- Equiatomic single-phase multicomponent solid solutions based on the V-Nb-Ta-Ti system were obtained by arc melting with subsequent homogenization.
- The phase composition of a multicomponent solid solution based on V-Nb-Ta-Ti is resistant to irradiation with helium ions with an energy of 40 keV and a fluence of 2×10^{17} cm^{-2}.
- After irradiation, multicomponent solid solutions have a greater value of micro- and macro-stresses compared to single-component ones. It was assumed that increasing the number of elements in the V-Nb-Ta-Ti system reduces the mobility of defects created by irradiation, which leads to the formation of smaller clusters and increased stresses.

REFERENCES

[1] E.P. George, D. Raabe, R.O. Ritchie, Nat. Rev. Mater. 4 (2019), p. 515

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