MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Faculty of Physical Engineering
Departments physics of metals

Presentation on the topic: «Determination of Structure Features and Properties of High Entropy Alloys of AlCuFeCrNiCo and CuFeCrNiCo Systems Deposited from Vapor Phase»

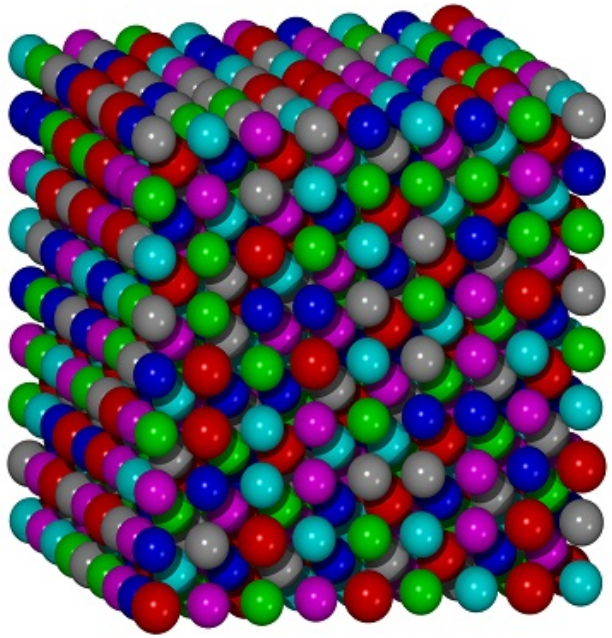
Student IV-th course, gr. PhM-32
Kuzmenko O.V.

Kyiv 2017

Plan:

1. Introduction.
2. High entropy alloys (HEA).
3. Production and preparation of samples.
4. Electron-beam method of precipitation of multicomponent coatings.
5. Method of gradient substrate by Vekshinsky.
6. Method of conducting X-ray diffraction studies.
7. Research results.
8. Conclusion.

Introduction

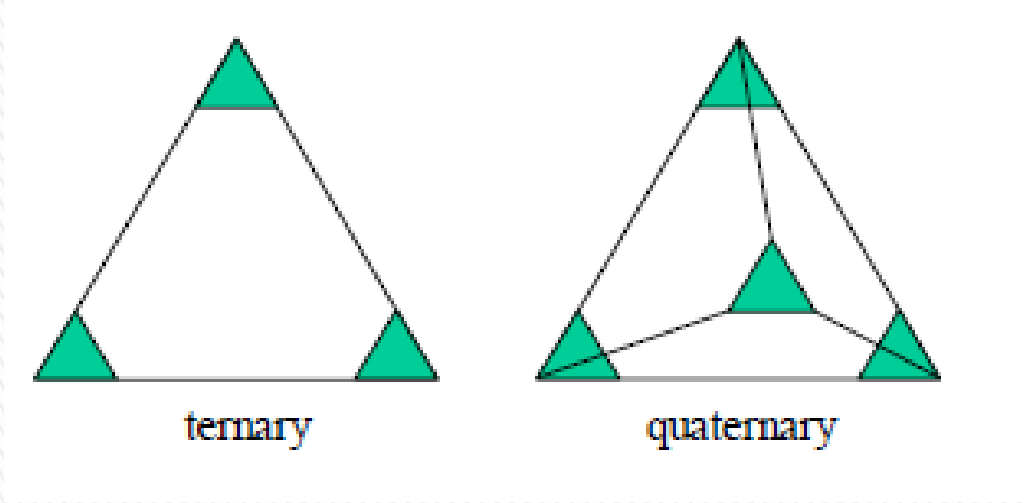


High entropy alloys (HEAs) are substances that are constructed with equal or nearly equal quantities of five or more metals. These alloys are currently the focus of significant attention in materials science and engineering, because they have properties such as: high hardness and temperature strength, high corrosion and mechanical resistance, and good weldability (due to heterogeneity of metals in their composition). These properties make the HEAs useful as functional coatings or components for aerospace industry.

State of the art of High Entropy Alloys study

Possible element combinations

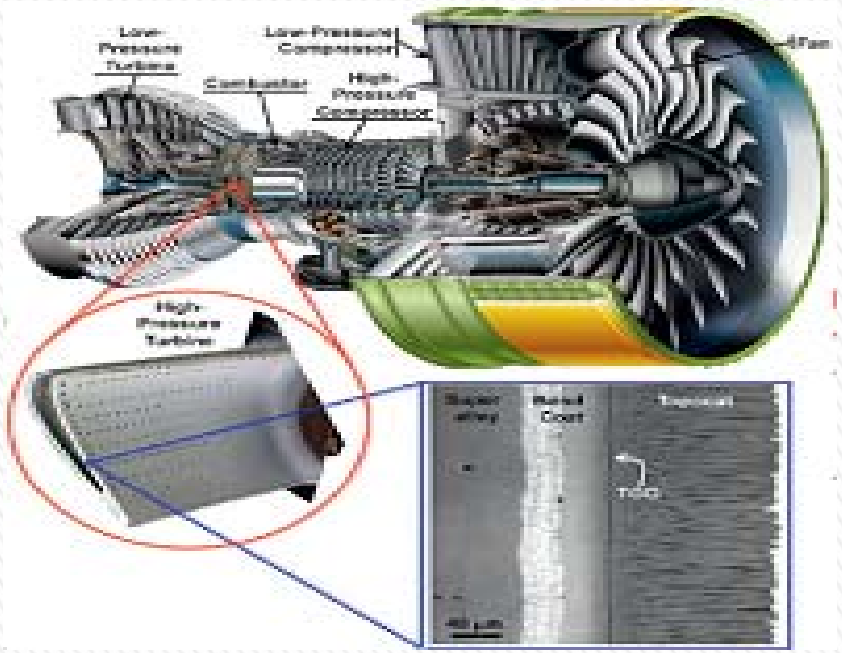
Number of elements	Number of combination	Researched %
2	3160	~ 81
3	82160	~ 5
4	$1.58 * 10^6$	~ <1
5	$2.40 * 10^7$	~ <1
6	$3.00 * 10^8$	~ <1
7	$3.18 * 10^9$	~ <1
8	$2.90 * 10^{10}$	~ <1



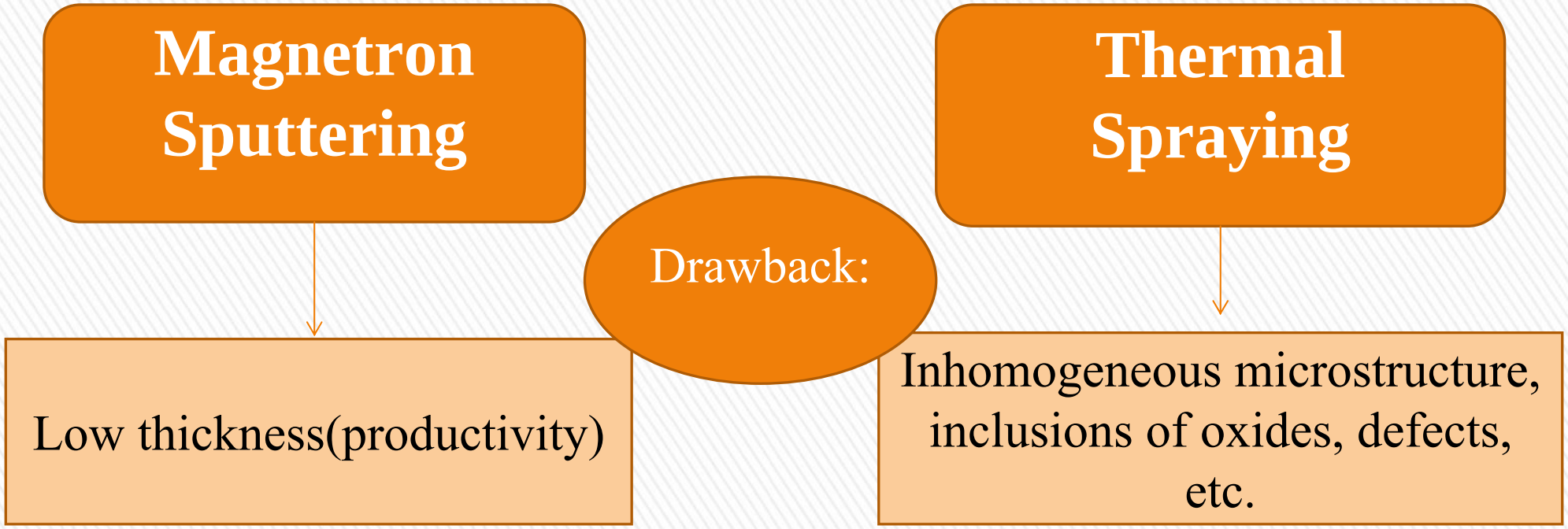
Information about alloys in the center of the phase diagram is limited for most ternary systems, and virtually non-existent for quaternary and higher order systems.

Development of HEA coatings

Due to high hardness and temperature strength, high corrosion and mechanical resistance, good weldability HEAs are believed to be promising candidates for the use of them as **functional coatings** or components for aerospace industry.

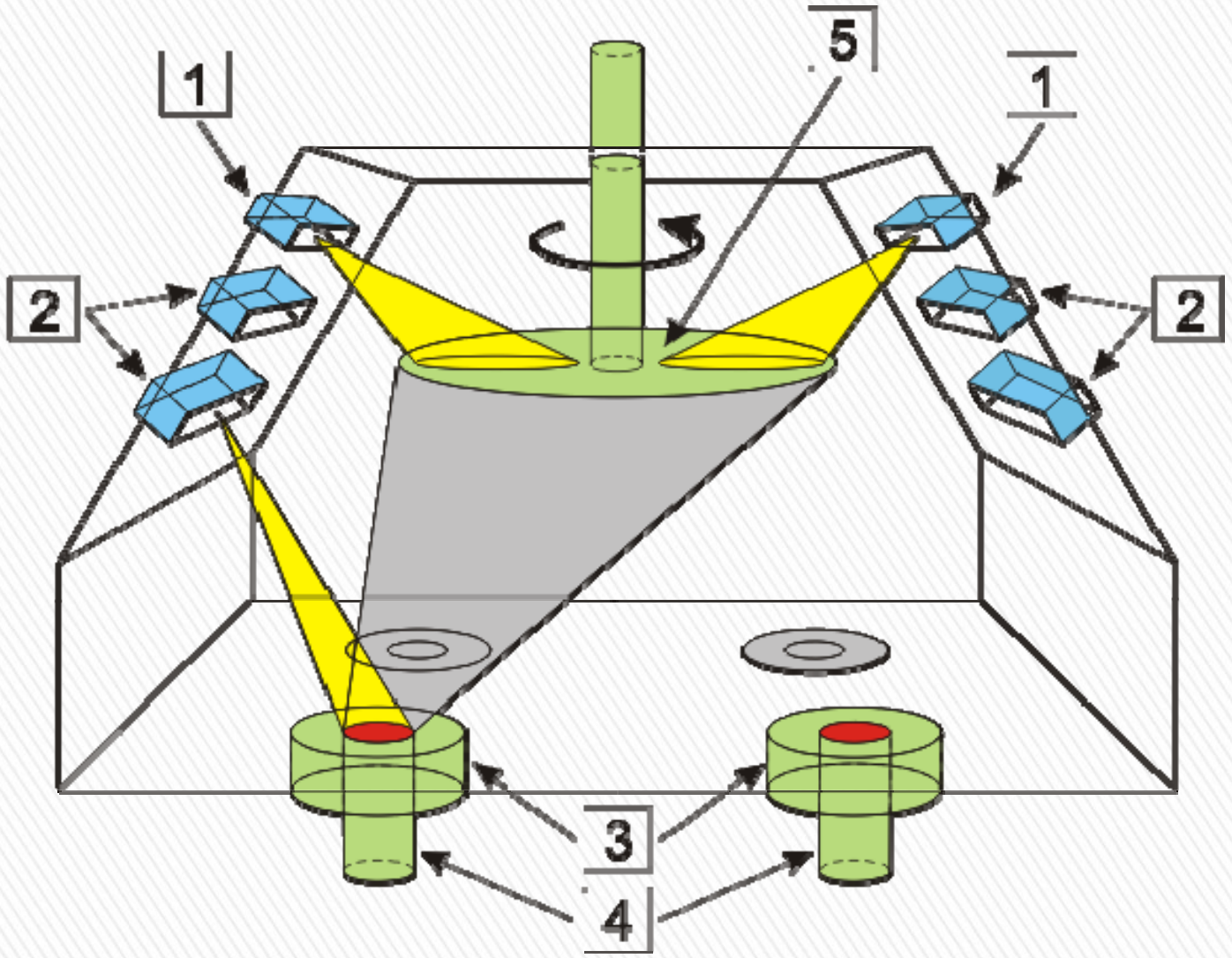


Known approaches for producing HEA coatings and films



Thus, we tried to use a high-rate EBPVD method in this work

Electron-beam method of precipitation of multicomponent coatings (EBPVD)



Scheme of the process of precipitation of condensate during evaporation from one source:

1 - electronic gun for heating the substrate;

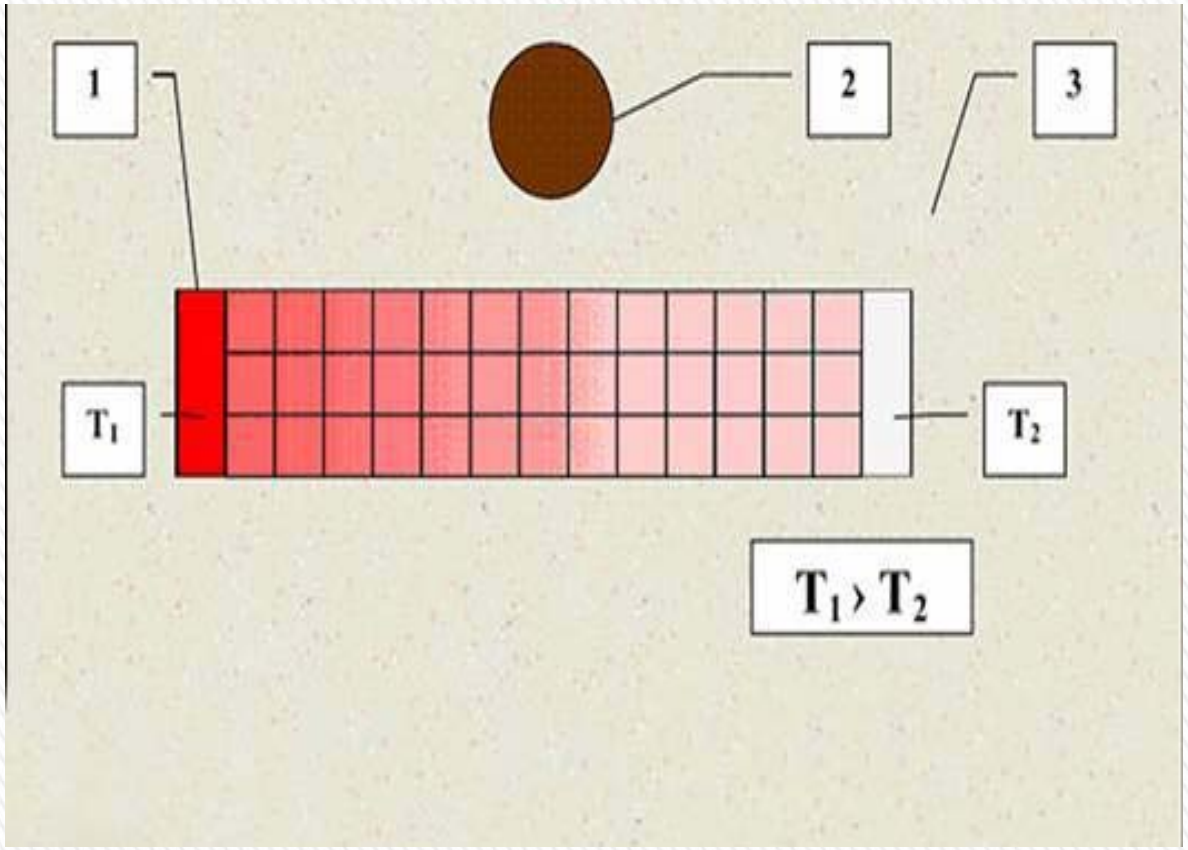
2 - electronic gun for evaporation of metal;

3- water-cooled crucible;

4 - ingot;

5 - holder of the substrate.

Method of gradient substrate by Vekshinsky



The layout of the substrate with a gradient of temperature along the length and gradient of concentrations, where 1 is the end of the heated substrate, 2 is the component ingots, and 3 is the cold end of the substrate.

The main tasks of the research

1. Study of the possibility of producing of multicomponent AlCuFeCrNiCo and CuFeCrNiCo alloys by means of a single electron-beam evaporation with the further vapor condensation onto substrate maintained at high temperatures.

2. Determination of both phase and chemical compositions of vacuum condensates deposited under the given evaporation conditions.

3. Study of the structure parameters of vacuum condensates deposited at various substrate temperatures.

4. Study of mechanical characteristics (Young's modulus, microhardness) of AlCuFeCrNiCo and CuFeCrNiCo High Entropy Alloys deposited from vapor phase.

The object of the research – the formation process of High Entropy Alloys from vapor phase at EBPVD , structure and properties of the alloys obtained.

The subject of the research – AlCuFeCrNiCo and CuFeCrNiCo PVD-condensates.

Methods of the research – X-ray diffraction, microstructural, duromatric analysis, evaluation of Young's modulus by the nanoidentity mothod.

Production and preparation of samples

Thick condensates of Fe-Ni-Co-Cr-Cu and Al-Fe-Ni-Co-Cr-Cu systems were produced by electron beam evaporation [13] of initial equiatomic FeNiCoCrCu and AlFeNiCoCrCu ingots, respectively, followed by a vapor condensation on heated steel substrate (CaF_2) at a specified temperature.

Melting of the initial samples was carried out in a vacuum-arc furnace.

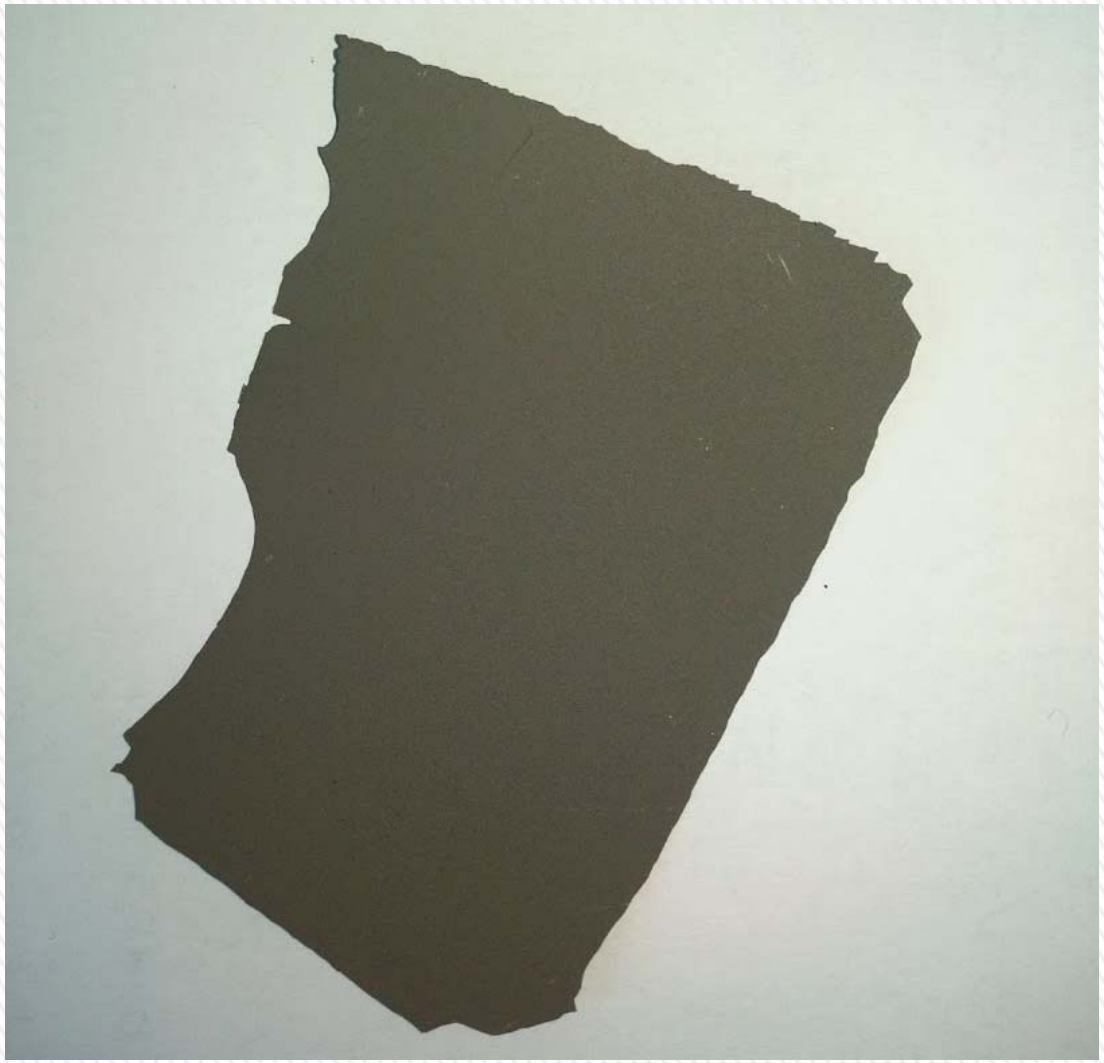
The ratio of the components of the output ingots (at%):

Al~17%, Fe~17%,Ni~17%,Co~17%,Cr~17%,Cu~17%;

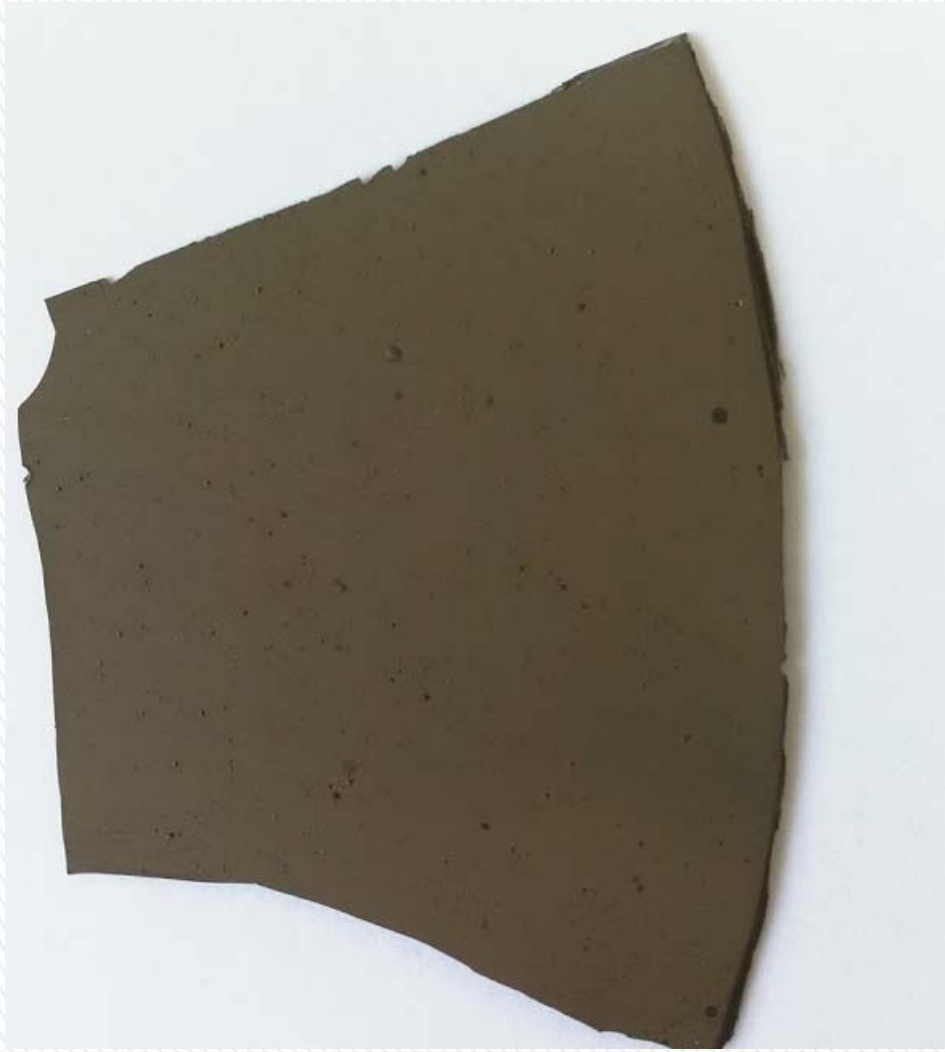
Fe~20%,Ni~20%,Co~20%,Cr~20%,Cu~20%;

Output of ingot

Samples of HEAs after deposition

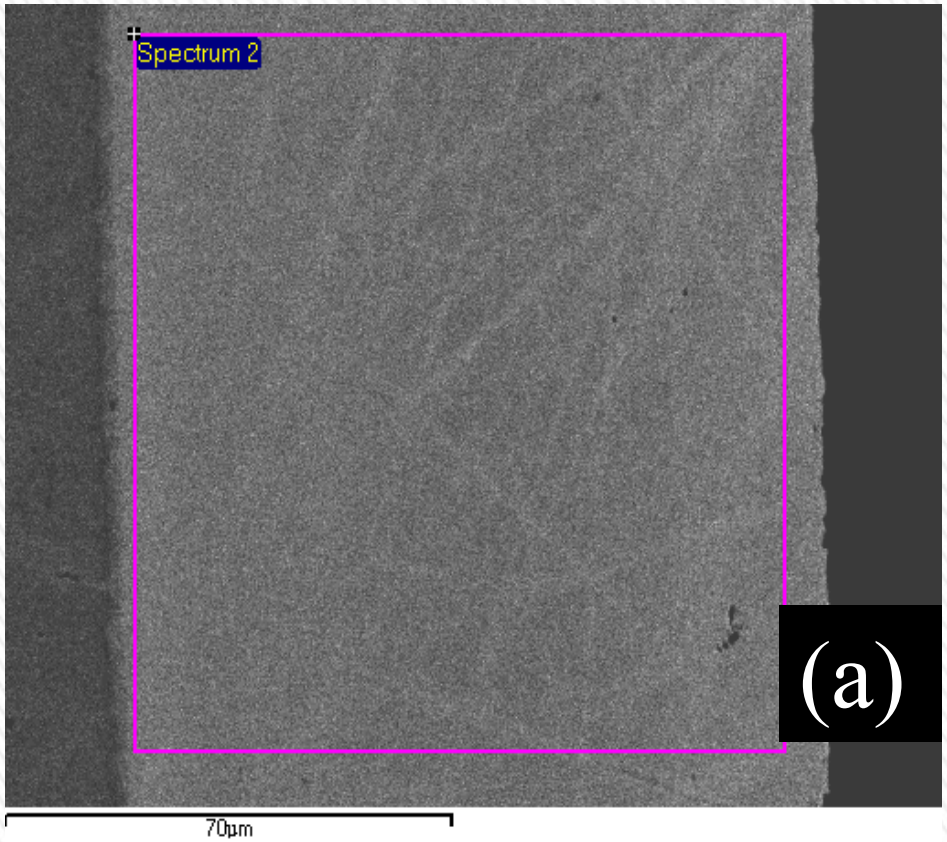


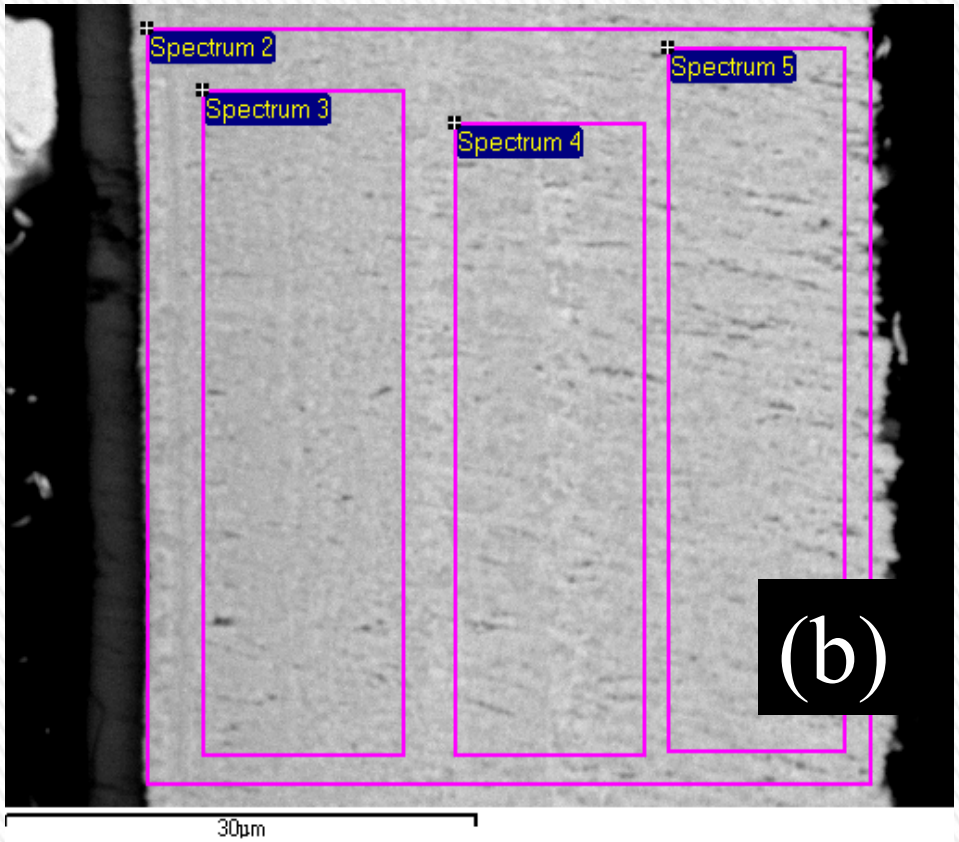
CuFeCrNiCo



AlCuFeCrNiCo

Research results





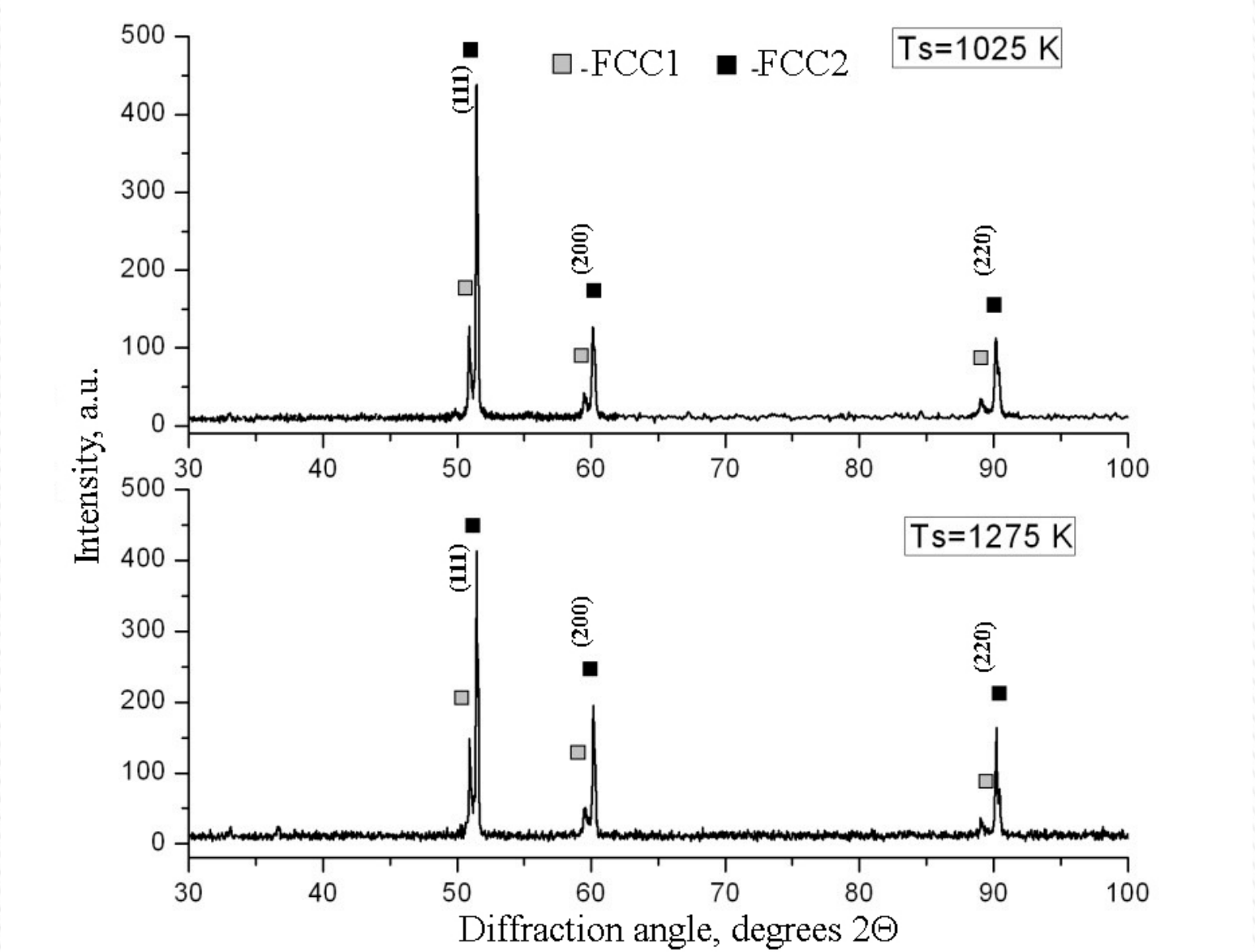
In figure (a, b) obtained structures of high-entropy alloys CuFeCrNiCo (a) and AlCuFeCrNiCo (b).

Method of conducting X-ray diffraction studies

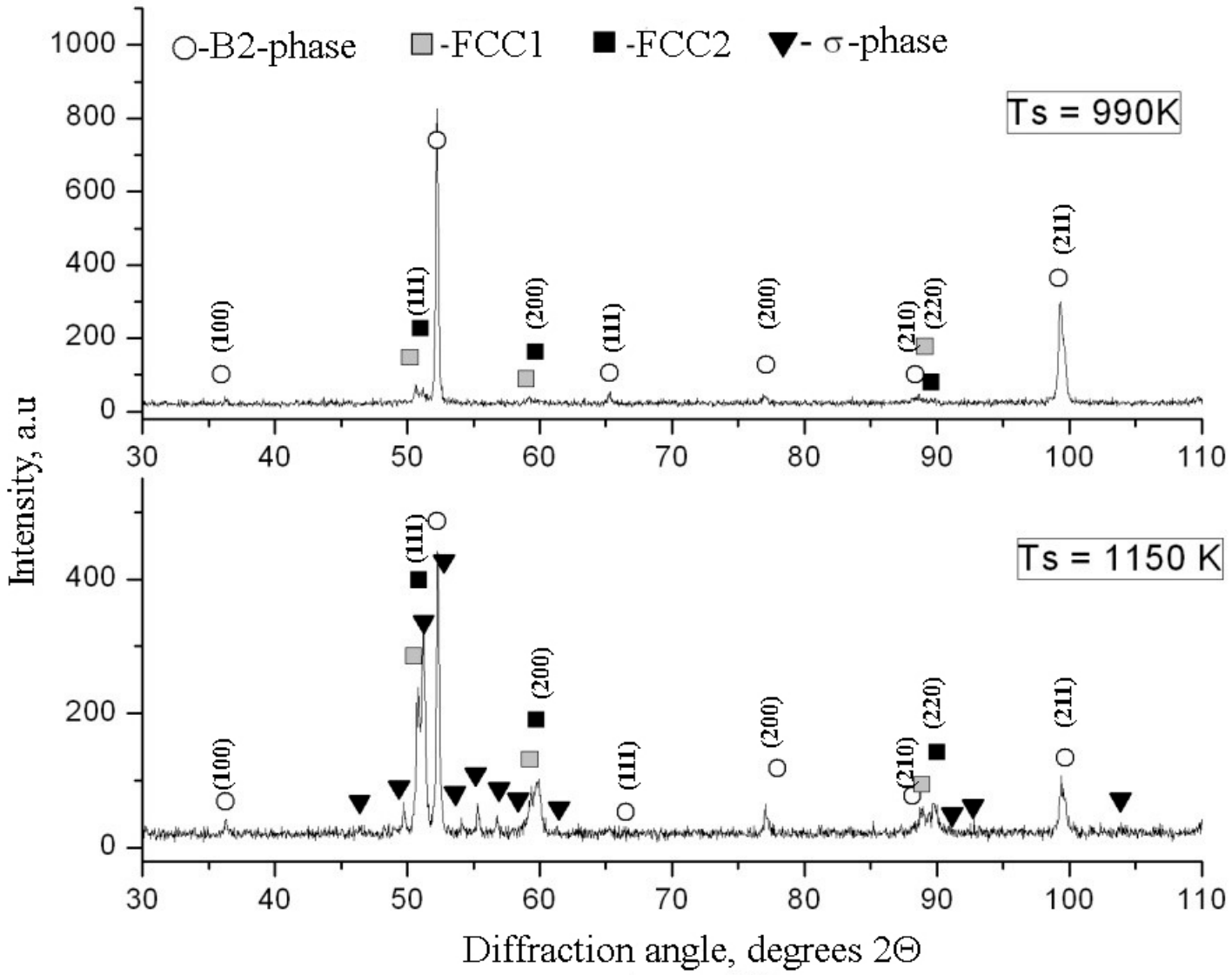
X-ray diffractometer DRON-4

X-ray diffraction researches were conducted using the X-ray diffractometer DRON-4 (with computer processing of the data obtained) from Co-K radiation.

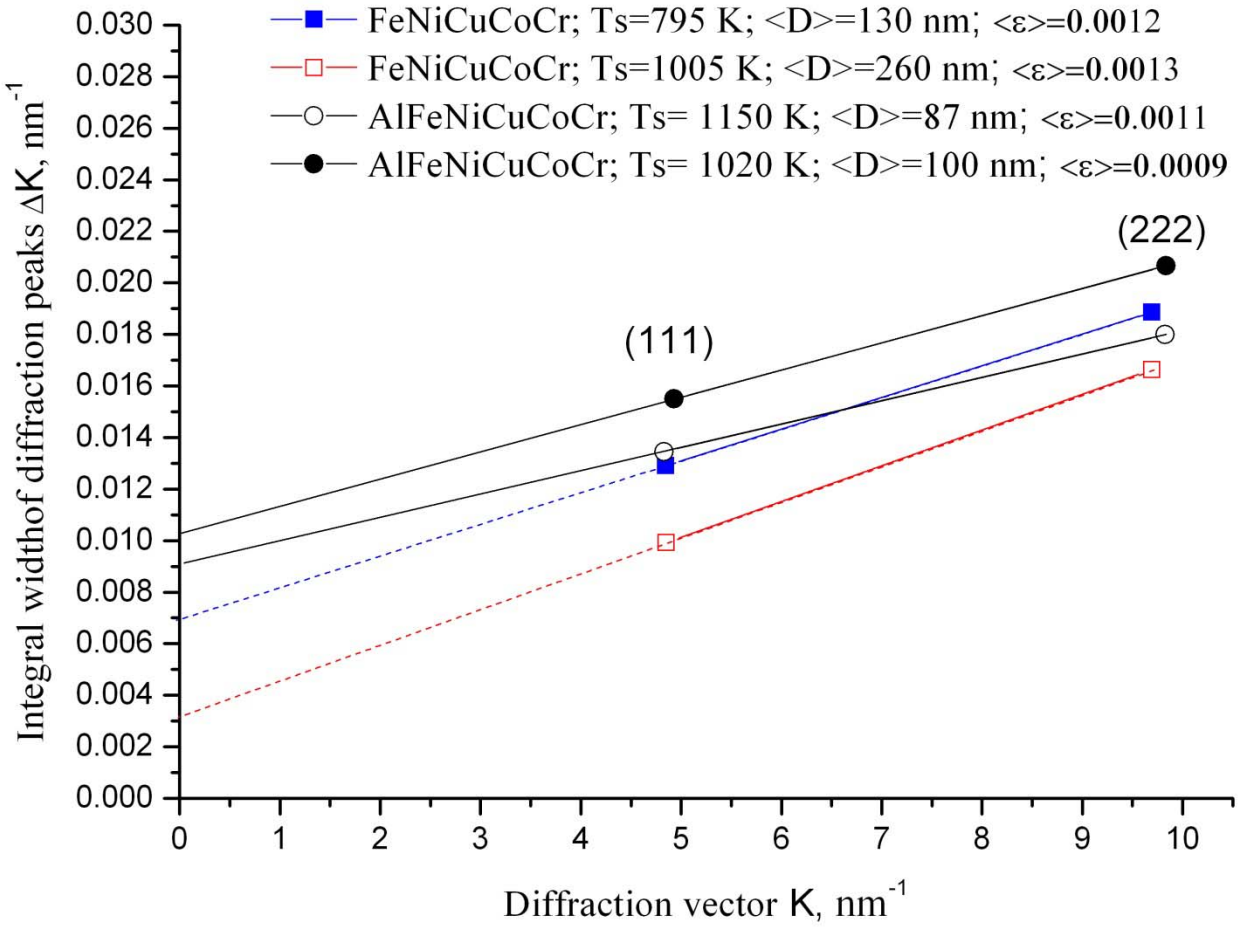
XRD patterns of FeNiCoCrCu , deposited at different substrate temperatures



XRD patterns of AlFeNiCoCrCu , deposited at different substrate temperatures

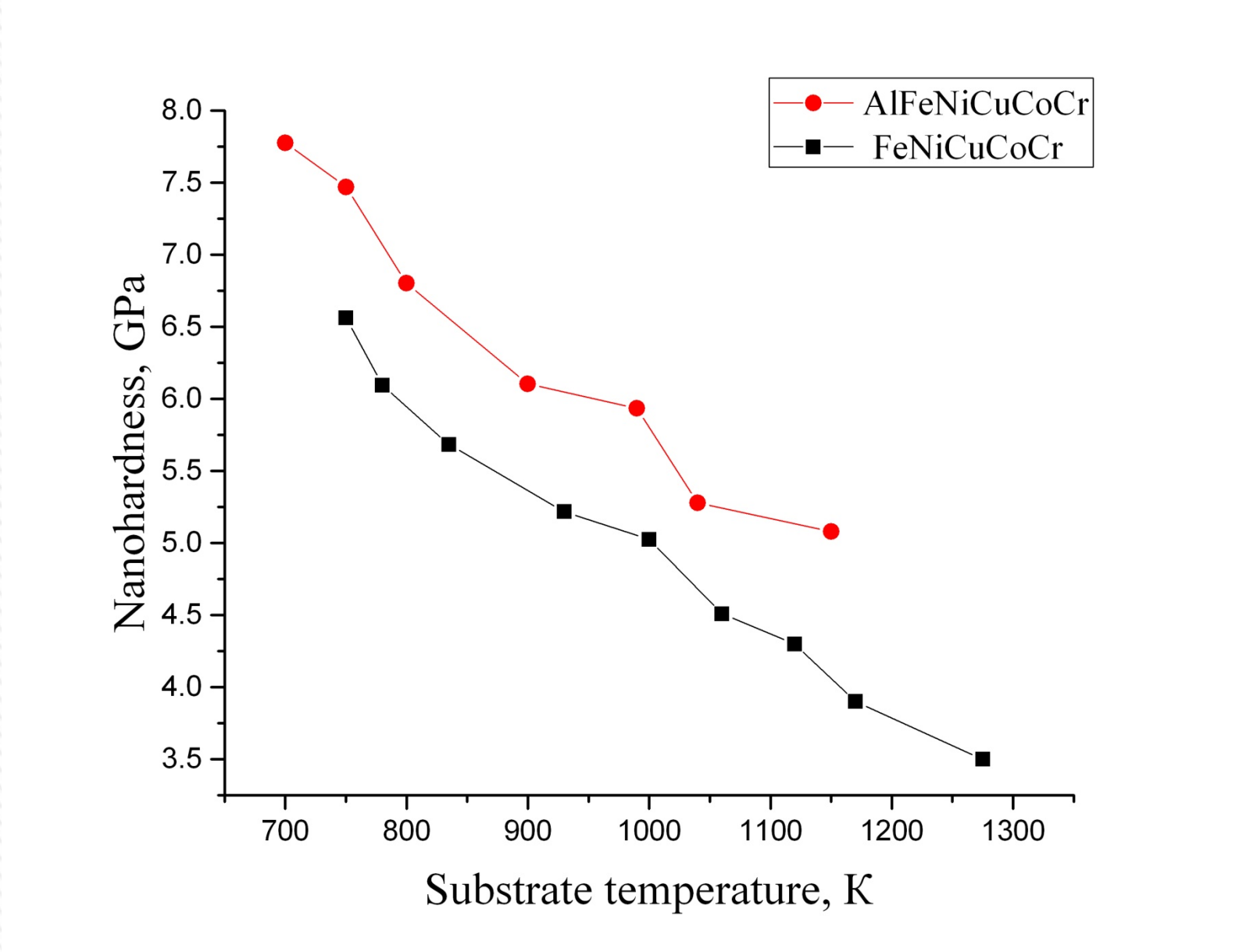


Effect of deposition temperature on coatings microstructure

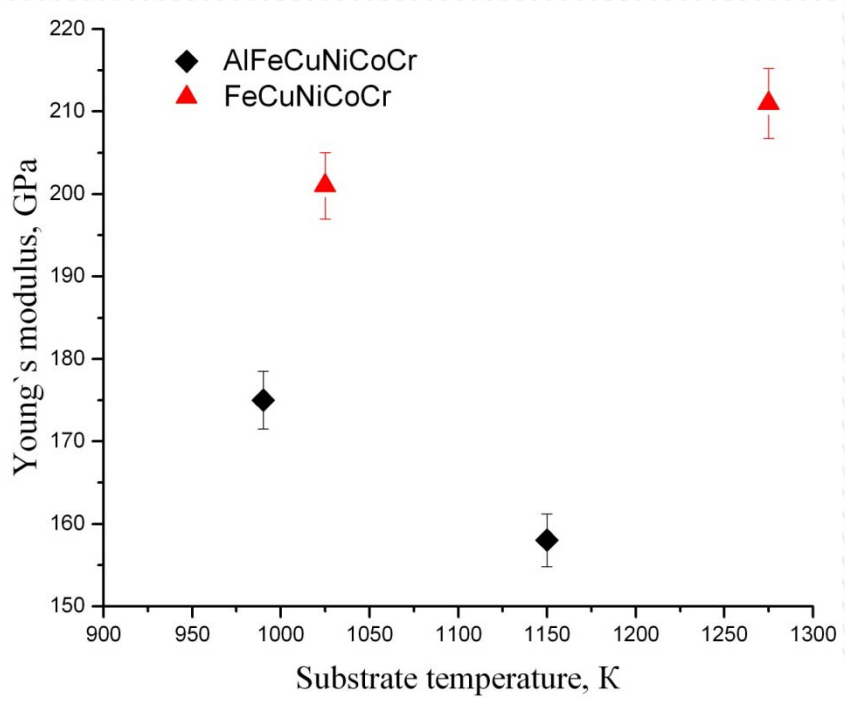


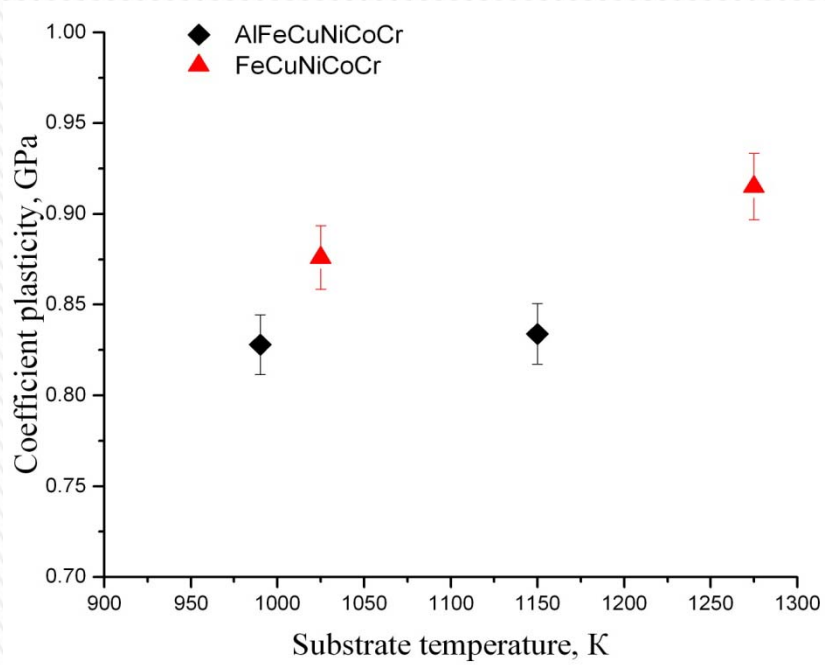
The Williamson-Hall plot for the integral width of diffraction peaks for AlFeNiCoCrCu and FeNiCoCrCu condensates deposited at different substrate temperatures

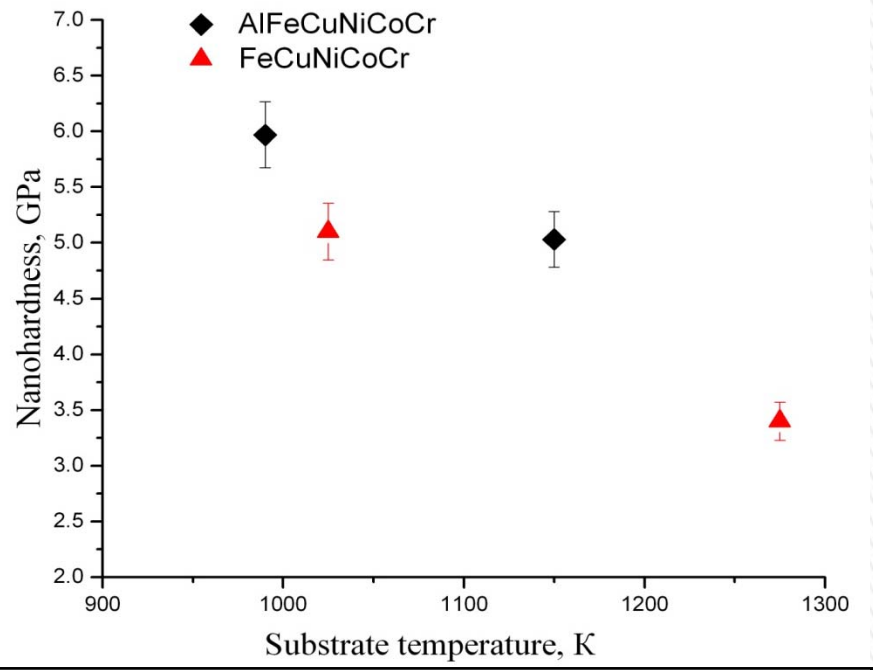
Nanohardness of AlCuFeCrNiCo and CuFeCrNiCo PVD-condensates



Mechenical properties of AlCuFeCrNiCo and CuFeCrNiCo PVD-condensates.







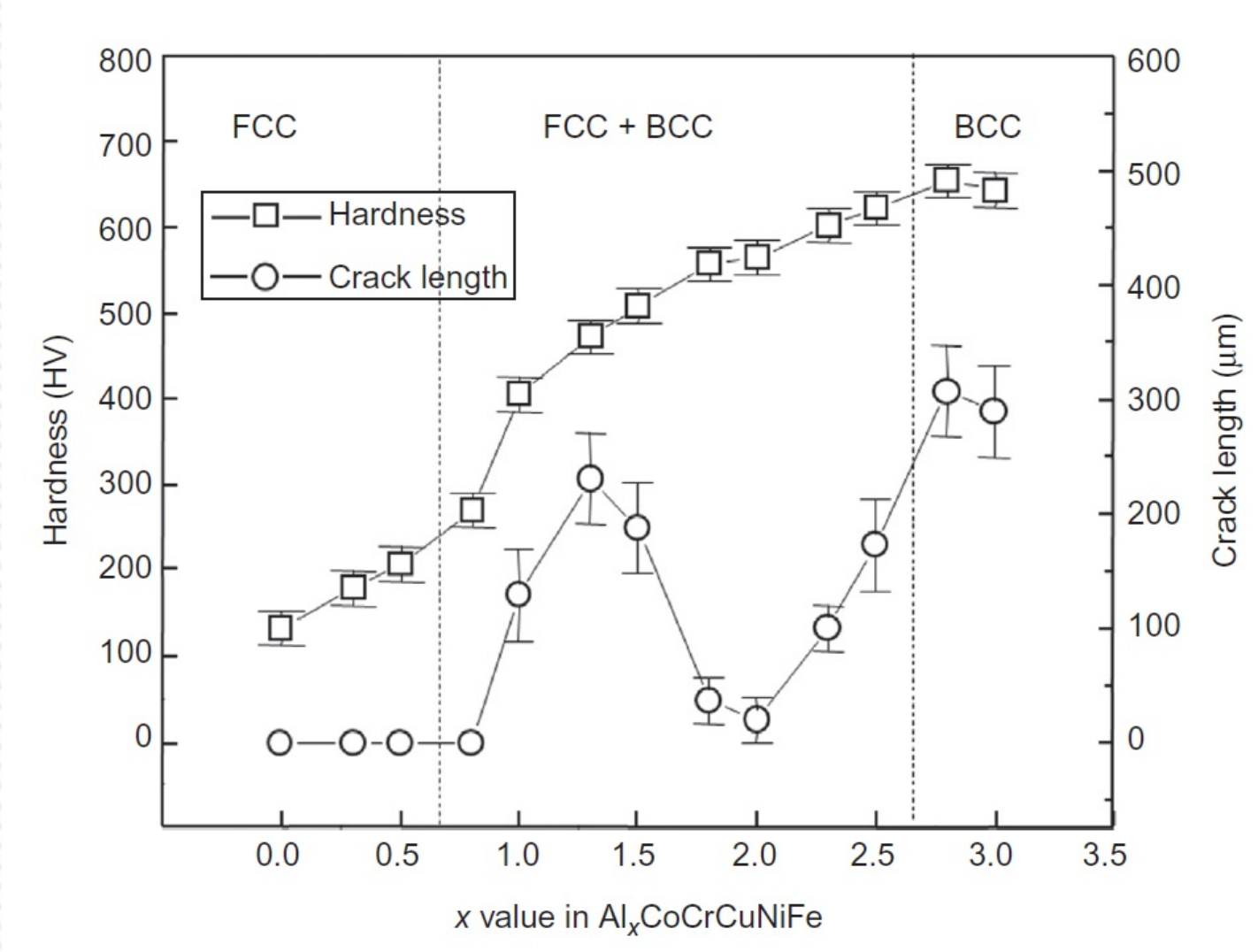
Conclusion

1. It was found that vacuum condensates of High Entropy Alloys FeNiCoCrCu and AlFeNiCoCrCu alloys, obtained by electron-beam deposition from the vapor phase, are characterized by the distribution of chemical elements close to corresponding outgoing ingots. However, obtained condensates are characterized by high hardness almost doubled compared with the original ingots, due to a smaller grain size in the condensates.

2. It was identified that phase composition condensates obtained at lower deposition temperatures 990 K corresponds to the composition of output ingots. Condensates of the system AlFeNiCoCrCu, deposited at higher deposition temperatures provide additional intermetallic compounds.

3. According duratometric studies it was found that the addition of Al increases the nanohardness of condensates by 20-40% depending on the receiving temperature. Also, a decrease in Young's modulus for condensates AlFeNiCoCrCu is observed, due to the increase in porosity of condensates.

Thank you for the attention!


FCC
FCC + BCC
BCC
Hardness
Crack length
Hardness (HV)
Crack length (μm)
x value in AlxCoCrCuNiFe
800
700
600
500
400
300
200
100
0
600
500
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5