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JOURNAL	World Science
p-ISSN	2413-1032
e-ISSN	2414-6404
PUBLISHER	RS Global Sp. z O.O., Poland

ARTICLE TITLE	THE INFLUENCE OF ULTRASOUND ACTIVATION ON MICROSTRUCTURE AND HARDNESS OF POROUS Ni-Ti SHAPE MEMORY ALLOYS
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ARTICLE INFO	Dovchinvanchig Maashaa, Tsetsegmaa Agvaantseren, Baasanjargal Narmandakh, Vasili Vasilievich Rubanik, Vasili Vasilievich Rubanik Jr. (2022) The Influence of Ultrasound Activation on Microstructure and Hardness of Porous Ni-Ti Shape Memory Alloys. *World Science*. 5(77). doi: 10.31435/rsglobal_ws/30092022/7863
DOI	https://doi.org/10.31435/rsglobal_ws/30092022/7863
RECEIVED	06 August 2022
ACCEPTED	21 September 2022
PUBLISHED	30 September 2022
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THE INFLUENCE OF ULTRASOUND ACTIVATION ON MICROSTRUCTURE AND HARDNESS OF POROUS Ni-Ti SHAPE MEMORY ALLOYS

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DOI: https://doi.org/10.31435/rsglobal_ws/30092022/7863

ARTICLE INFO

Received: 06 August 2022
Accepted: 21 September 2022
Published: 30 September 2022

KEYWORDS

Shape Memory Alloy, Energy Dispersive X-Ray Spectroscopy, Hardness, Microstructure.

ABSTRACT

A Ni-Ti shape memory alloy with a porous structure is obtained by the method of self-propagating high-temperature synthesis (SHS) and investigated the possibility of changing its microstructure and hardness. The research aimed to study the changes in the microstructure and hardness of the Ni-Ti shape memory alloy with a porous structure when the Ni and Ti metal powders are preliminarily subjected to ultrasound activation for different periods. The microstructure of the alloy surfaces was studied with using a Hitachi scanning electron microscope (SEM), and the hardness was measured with a Brinell electronic hardness tester. The results of the experiments showed that the porosity and hardness of the Ni-Ti alloy enlarged with an increase in the time of ultrasound activation of the components. The innovative aspect of this study is that prior to the synthesis of powder elements with a purity of Ni 99.9% and Ti 99.9% with an average particle size of 40 μm, they were previously subjected separately to ultrasound activation at different periods.

Citation: Dovchinvanchig Maashaa, Tsetsegmaa Agvaantseren, Baasanjargal Narmandakh, Vasili Vasilievich Rubanik, Vasili Vasilievich Rubanik Jr. (2022) The Influence of Ultrasound Activation on Microstructure and Hardness of Porous Ni-Ti Shape Memory Alloys. *World Science.* 5(77). doi: 10.31435/rsglobal_ws/30092022/7863

Introduction. The main feature of materials from metal alloys with shape memory is phase transformation of elastic, crystalline structure and cubic lattice or austenite structure at high temperatures transforms into a monoclinic lattice structure or martensite structure at low temperatures. Such material has unique properties, such as when its external shape is changed due to mechanical force or temperature, it remembers the shape before the change and returns to the same shape, and does not corrode [1]. The mechanical properties of shape memory materials are widely used in various fields of science and technology, especially in engineering, smart technology, and medical science [2]. Ni-Ti alloys with porous structures are widely used in modern medical science; such as dental implants, artificial organs, repair a hole in a heart valve, vasodilators, and bone connectors due to their lightness, flexibility, and corrosion resistance [3]. Much research is being done to improve the properties of Ni-Ti shape memory alloys - by changing the number of impurities [4], adding transition metals as tertiary elements [5], changing the heat treatment temperature, and investigating the change in the crystal structure, microstructure, phase transformation temperature, and in mechanical properties of the alloy.

Research materials and methods. Metal alloy Ni-Ti with a porous shape memory structure was obtained in the metallurgical laboratory of the Institute of Technical Acoustics of the National Academy of Sciences in Belarus.

We hypothesized that ultrasound preactivation of the Ni-Ti alloy components would promote proper self-propagating structure and result in improved alloy properties.

The samples were activated by the ultrasonic disperser UZDN-1M with frequency of 22 kHz for 30 minutes and 120 minutes. Afterward, the sample was processed through the method of SHS and a new alloy was obtained. The heat treatment was carried out for one hour at a temperature of 350°C. Ti50Ni50 alloy samples were synthesized with each element of the sample, having atomic weight of 50%, respectively.

The microstructure of the Ni-Ti alloy was examined by using a Hitachi TM-1000 scanning electron microscope (SEM).

The hardness was measured with an HBE-3000A Electronic Brinell Hardness Tester by pressing a ball 10mm in diameter with the force of 3000 N on cylindrical samples 2.4 cm high and 1.4 cm in diameter (Fig. 1).

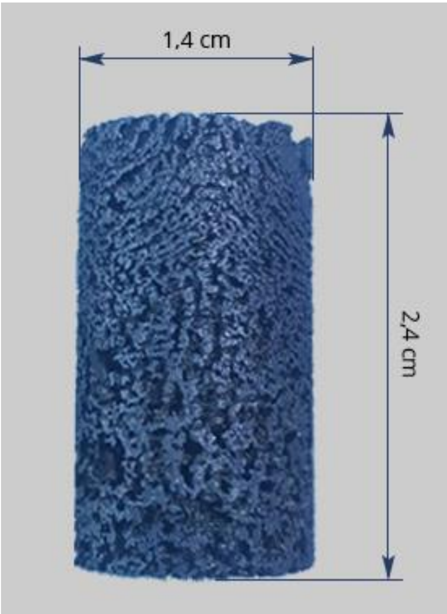

Fig. 1. Sample size used in the experiment

Then, the diameter d of the spherical depression created by the hardness tester ball was determined, and the hardness of the alloy was calculated by using the following formula (1).

$$HB = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)} \quad (1)$$

Results and discussion. As can be seen from the image of the microstructure of the lateral surface in the sample (Fig. 2), the average pore size of the samples not treated by ultrasound was 150 µm, while the pore size of the samples treated by ultrasound became larger and the width increased.

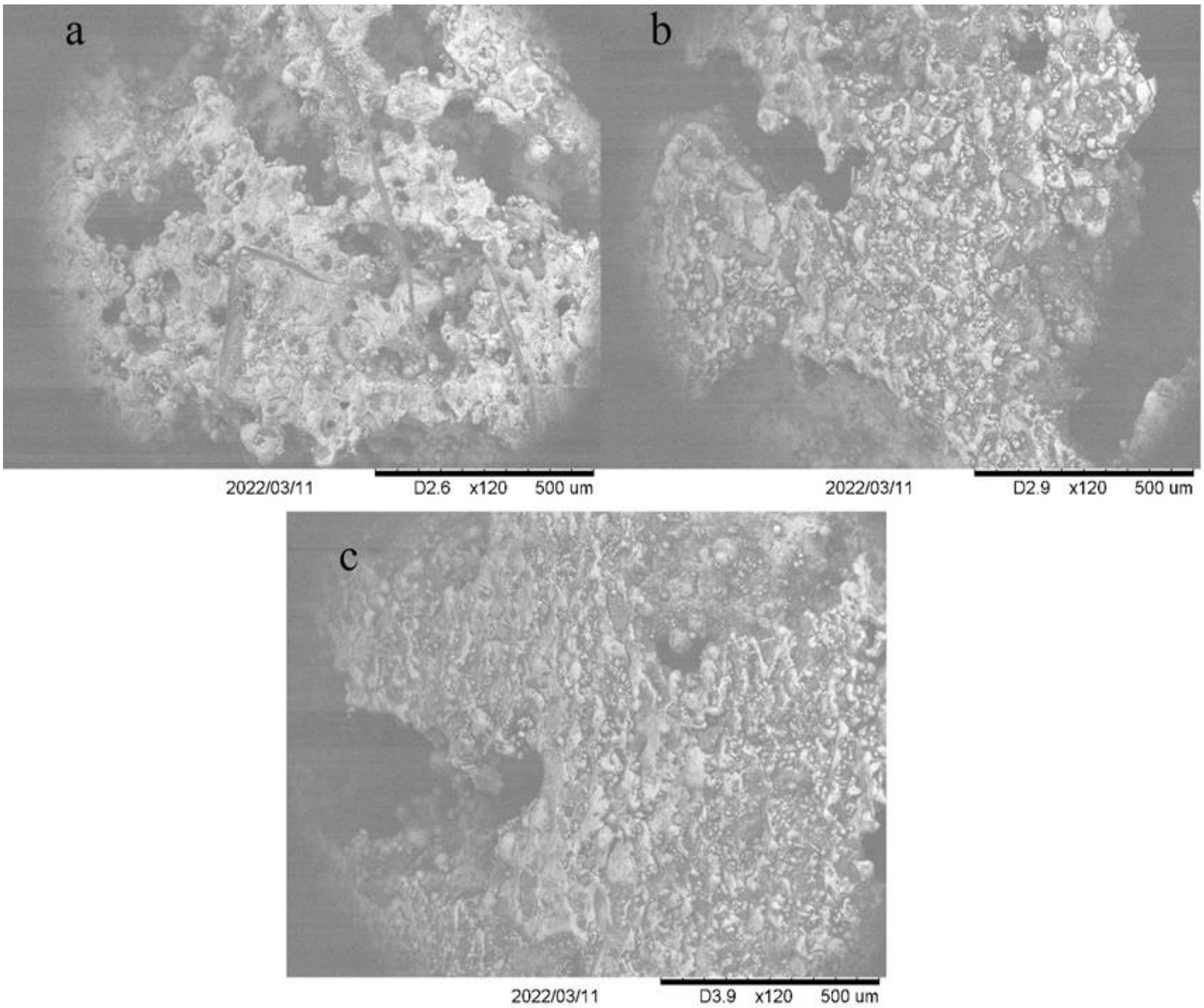

Fig. 2. The microstructure of the lateral surface of the Ni-Ti alloy:
a. Not treated by ultrasound sample;
b. Ultrasound treated for 30 minutes samples;
c. Ultrasound treated for 120 minutes sample

As can be seen from the image of the sample cross-section microstructure (Fig. 3), the pore size of the not ultrasound treated sample is 60–70 µm on average, while the pores of the ultrasound-treated sample became longer, and their width increased to 150 µm.

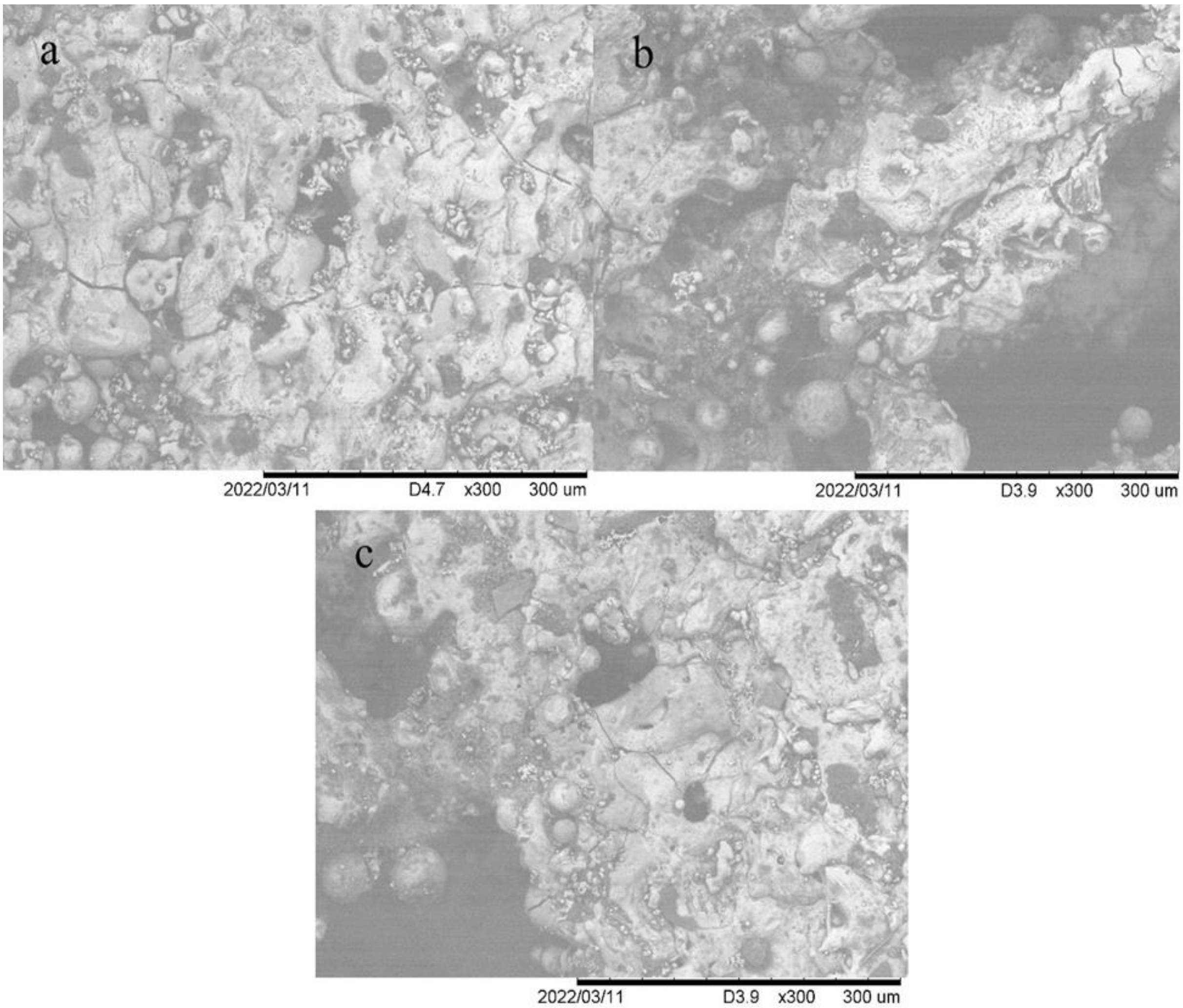

Fig. 3. The microstructure of the cross-section of the Ni-Ti alloy:
a. not treated by ultrasound sample;
b. Ultrasound treated for 30 minutes sample;
c. Ultrasound treated for 120 minutes sample

Energy dispersive X-ray spectroscopy (EDS) of not treated samples is shown in Figure 4, and the measurements results of the chemical composition are shown in Table 1.

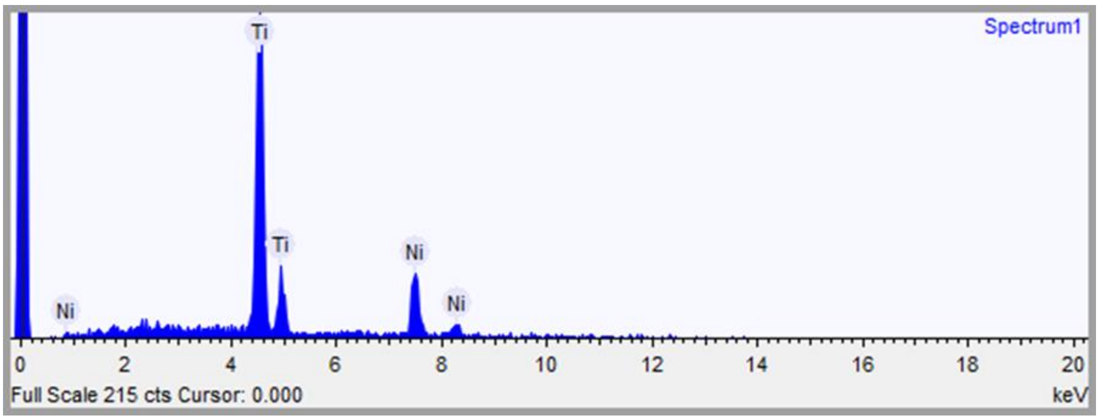

Fig. 4. EDS of not activated by ultrasound samples

In this sample, only the elements Ni and Ti were found, indicating the absence of other impurities. Volumetric weight is Ti57.7% and Ni42.3%.

Table 1. The composition of the Ni-Ti alloy not treated by ultrasound

Element	Weight, %
Ti	57.7
Ni	42.3

EDS of samples treated by ultrasound for 120 minutes is shown in Figure 5, and the measurements results of the chemical composition are in Table 2.

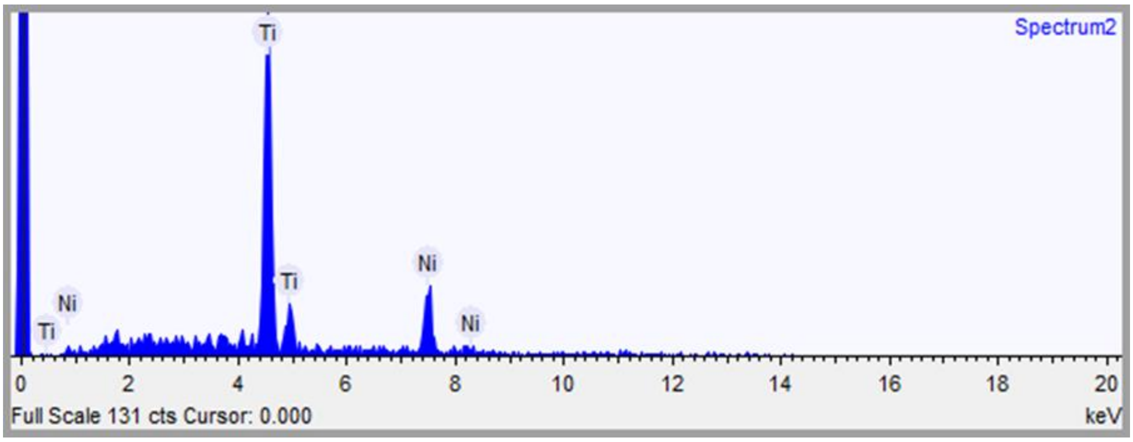

Fig. 5. EDS of samples treated by ultrasound for 120 min

Table 2. The composition of the Ni-Ti alloy treated by ultrasound for 120 min

Element	Weight %
Ti	60.3
Ni	39.7

In this sample, only the elements Ni and Ti were found, indicating the absence of other impurities. Volumetric weights are Ti60.3% and Ni39.7%.

Table 3. The hardness of Ni-Ti alloy

Sample	t - Duration of ultrasound treatment, min	d - Diameter of the depression	Hardness
A	0	6.9 mm	34.1 HB
B	15	6.12 mm	43.4 HB
C	30	5.23 mm	63.7 HB
D	120	4.5 mm	86.8 HB

The hardness of the not treated sample is 34.1 HB, while the sample treated for 120 min is 86.8 HB.

Conclusions. A shape memory Ni-Ti alloy with a porous structure was obtained by the method of self-propagating high-temperature synthesis with ultrasound preactivation.

The influence of the ultrasound preactivation time duration of component metals on the microstructure and hardness of the porous Ni-Ti shape memory alloys has been studied.

The porosity of the side surface of the not treated samples averaged 150 μm, and the pore size of the samples treated with ultrasound became longer and wider, i.e., microstructure has changed. Also, the size of the pores in the cross-section of the microstructure of the not treated samples was on average 60-70 μm, the porosity of the ultrasound-activated samples was longer and the width increased to about 150 μm.

The experimental data analysis showed that the hardness of the shape memory Ni-Ti alloy with a porous structure increases as the time of ultrasound preactivation increases.

Acknowledgments. This research was carried out within the framework of the joint Fundamental Research Project ShuKhtB-2021/02 of The Mongolian Foundation for Science and Technology and The Belarusian Republican Foundation for Fundamental Research. The researchers would like to thank The Mongolian Foundation for Science and Technology and The Belarusian Republican Foundation for Fundamental Research for their financial support.

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