ANALYSIS OF CHEMICAL COMPOSITION AND STUDY OF SURFACE TOPOGRAPHY OF NiMnGa ALLOY IN DELIVERY CONDITION

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Abstract: *The object of this work was an examination of the microstructure and mapping of chemical elements at the surface of NiMnGa. This material is distinguished by magnetostriction (even 6% of its length), shape memory and magnetocaloric effect. The sample was mounted and then examined with scanning electron microscope using detectors: SE , BSE and EDX (mapping). The structure on the obtained images can be defined as martensitic. The review of microcracks at the surface showed a non-chaotic distribution. The results of mapping of the chemical elements at the surface confirmed the uniform distribution of component.*

Key words: *SMART, surface topography, mapping, Heusler alloys.*

1. Introduction

NiMnGa alloy is a part of a group of SMART materials, which change their properties under the influence of a magnetic field. It mean that for specified signal it reacts in a appropriate manner. Materials with such properties found their application in industry, for example as generation sensors used to measure such parameters like: force, magnetic qualities and displacement.

The studied alloy is distinguished by magnetostriction, shape memory and magnetocaloric effect [6]. Magnetostriction occurs when the material changes its dimensions under the influence of a magnetic field. Magnetostriction is commonly connected with Terfenol-D, but the magnitude of reaction is much smaller than for NiMnGa alloy – it is only 0,24% in volume. According to many articles [1-5] about NiMnGa, under the influence of magnetic field with magnetic induction 1÷2T, the alloy can elongate even by 6%. However, the domain rotation effect appears in both materials [3]. Dimensional changes generate a force which in future could be useful in the implementation of small movements. Such use of the material reaction could be applied in actuators, as it was earlier done with Terfenol-D.

2. Objectives

All characteristic qualities of the studied alloy are closely related to its internal structure and chemical composition. The object of the study was an analysis of the material without any earlier temperature

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treatment after the purchase. Depending on the crystalline form (monocrystal or polycrystal) and work temperature or various mechanical construction of the actuator, different results of alloy characteristic would be obtained. Studied samples were monocrystal slabs (information provided by the supplier - AdaptaMat). To analyze the microstructure of the alloy, the material was studied using scanning electron microscope. In the future, the obtained results could lead to the most optimum utilization of the alloy in various applications, such as actuators.

3. Material and Methods

Figure 1 depicts one of the studied samples of dimensions 20x3x2mm.

3.1. Sample preparation

To create images on scanning electron microscope, the sample of NiMnGa alloy was mounted with conductive resin and its surface was repeatedly etched using Nital.

Fig. 1. *Image of the sample*

3.2. Structure review of the alloy using SEM

Figures 2-3 depict the images of the surface of the sample which were obtained using SEM.

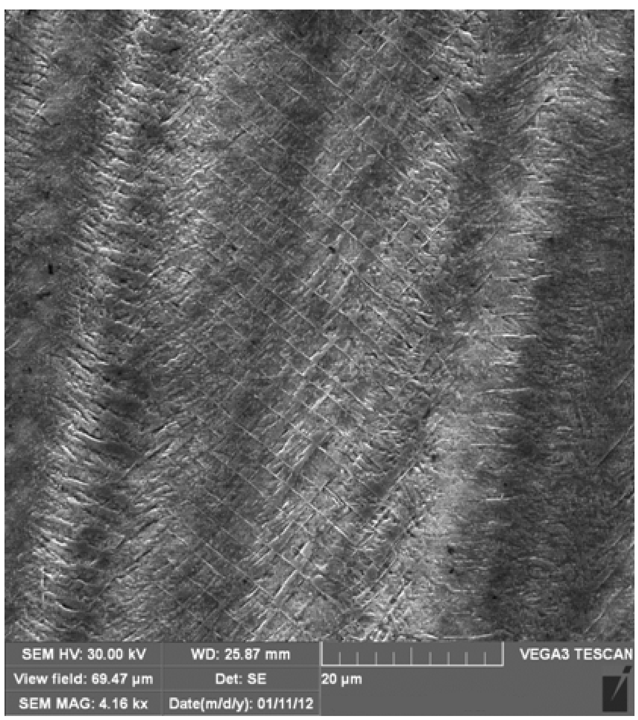

Fig. 2. *Microscopic image of surface topography of NiMnGa alloy. Martensitic type structure. Etched: Nital; SEM*

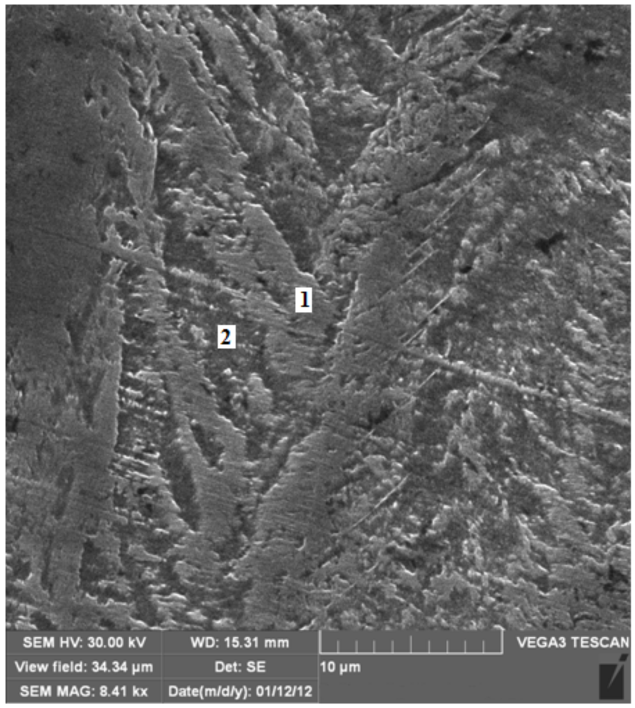

Fig. 3. *Enlarged image of microstructure of the surface of NiMnGa alloy; (1 – martensitic area, 2- retained austenite); Etched: Nital; SEM*

Figure 2 depicts the banding in the material connected with its structure. Figure 3 presents an enlarged image for a more accurate analysis.

On the basis of the observations of the structures depicted in Figures 2-3, a banded martensitic structure with retained austenite in spaces between the plates was assumed [1].

3.3. Review of microcracks at the surface of the sample using SEM

Figure 4 depicts microcracks at the surface of sample. The microcracks might have been formed due to inadequate mechanical loads and the method of preparation of the sample before the examination.

It is clearly visible that the cracks are not chaotic, they are mutually perpendicular. They occur in strictly specified directions.

3.4. Mapping of chemical elements at the surface of the alloy

Table 1 presents the percentages of chemical elements: Ni (nickel), Mn (manganese), Ga (gallium). Figure 5 depicts the mapping of chemical elements at the surface of the sample, which is superimposed on the image of the microstructure. The examination was carried out using Energy-dispersive X-ray spectroscopy (EDX) on a scanning electron microscope.

Percentage of chemical elements Table 1

Chemical element	Percentage [wt%]
Ni	46.40
Mn	28.60
Ga	23.39
Other	1.61

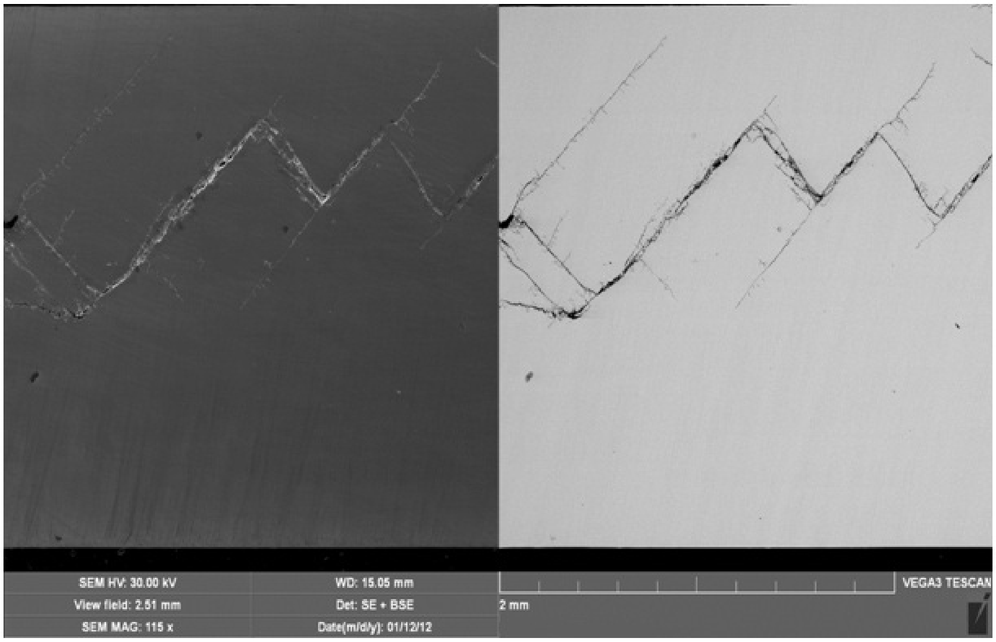

Fig. 4. *Microscopic image of microcracks at the surface of NiMnGa alloy; SEM*

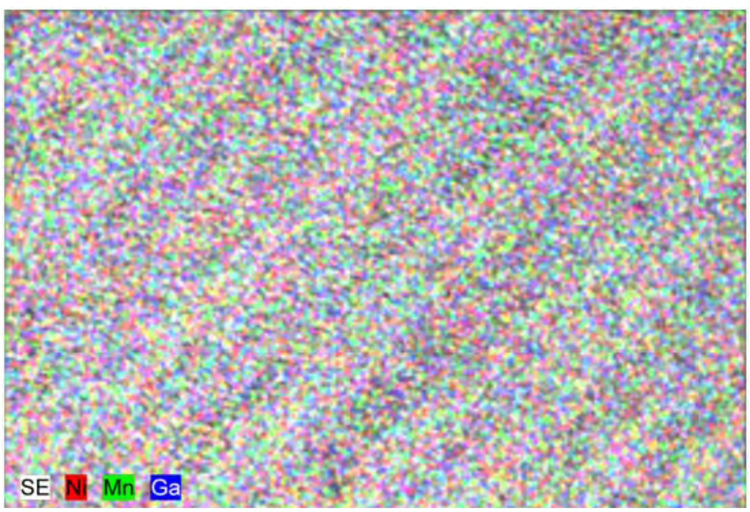

Fig. 5. *Surface element distribution (Ni, Mn, Ga) superimposed on the microstructure image (mapping) (image created on Wroclaw University of Environmental and Life Sciences)*

The elements listed as “Other” in Table 1 are a result of detector sensitivity and the method of preparation of the sample, e.g. using a conductive resin.

After the examination of mapping of chemical elements, a uniform distribution of ingredients at the surface was determined. Furthermore, no relationship was found between the images of microstructure and chemical distribution.

4. Results and Discussions

On the basis of Figures 2-3, a banded martensitic structure with retained austenite was assumed. A martensitic transformation has taken place, which is probably a result of deformations of the sample. It is supposed that this transformation was not completed as indicated by retained austenite. It can be concluded that the influence of mechanical loads can cause changes in structure, especially in dislocation structure, which may lead to material damage.

Figure 4 depicts microcracks at the surface developed during the deformation of the material. It is possible that the alloy structure contains privileged planes in which the atomic bonds are broken first. These places in the structure have a lower resistance to force acting upon it, which leads to creating a microcrack.

The non-chaotic distribution of microcracks suggests that the direction of the applied force is very important for the studied material. Thus, any noncollinearities in the construction or any vibrations occurring during the exploitation of the device may lead to irreversible material damage and in consequence the destruction of the actuator.

The percentages of each component in the alloy suggested that the material is a good example of so-called Heusler alloys. The stoichiometric formula of the alloy is close to Ni_2MnGa. On the basis of mapping no relationship was found between the images of microstructure and the element distribution. The distribution of elements is uniform on the surface of the sample, there are no concentrations of the elements, which suggest a lack of imperfections in the structure and a correctness of its production.

5. Conclusions

The materials microstructure, possibility of occurrence of the microcracks during the mechanical loads and the percentage composition of chemical elements along with the mapping of their distribution was determined. The examination showed that the most important problem during the utilization of the material is an appropriate mounting in the construction of the actuator. It is caused by the possibility of occurrence of microcracks inside the alloys structure, which may lead to irreversible material damage. The material is a part of group called Heusler alloys. The nickel percentage, being twice the percentage of manganese and gallium, leads to the best possible cohesion of the three components.

Surface topography suggests that probably as a consequence of strain the material underwent a martensitic transformation. Possibly also the magnetic field has a very strong influence on the structure of the studied alloy. In the future, NiMnGa will work as a magnetostrictive actuator and the knowledge about its interaction with a magnetic field will be very useful.

Acknowledgement

Studies of mapping of chemical elements at the surface of NiMnGa were made with help of Krzysztof Kaliński from Wrocław University of Environmental and Life Sciences

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