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Studies of selected properties of high-temperature superconducting tape 2G HTS SF series - the example: tape SF12050

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Materials

ABSTRACT

Purpose: In presented paper were characterized selected properties of high-temperature superconducting tape 2G HTS SF series - the example of the tape SF12050.

Design/methodology/approach: As part of the study smples of tape SF12050 were made. At first made to measure of chemical compsition and compared with manufacturer's information about that kind of tape. Second step of researcher were research about adhesion of the individual layers of SF12050. After then research was made about tensile strengtht what is the justification utility, as these tapes are subjected to tension at the time of their formation and winding on the transformer core.

Findings: As a result of research obtained information on the chemical composition, scratch resistance, adhesion of coating on the tape and about tensile strength. On the last step studies were conducted about critical currents - Ic.

Research limitations/implications: These results allow to identify the suitability of these tapes for use on a wide scale - in particular, the winding of the transformer cores.

Originality/value: On the basis of studies have demonstrated applications for which the tape may be used SF12050. Given its properties – scratch resistance and tensile strenght reistance, and information about critical current, was indicated best use of that tape for trnasformers production.

Keywords: High-temperature superconducting tape; SF12050; 2GT HTS FS

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1. Introduction

In 1986, superconductivity was discovered in a material temperature of about 30 K. Discovery was made by G. Bednorz and A. Müller. His phenomenon has become a driving force for many environments and for do interest in this problem and work within the framework of further research. Began to wonder how many opportunities gives superconductivity and how it can be used [1].

Within these issues, there has been significant progress in the design, manufacture and use of these materials. These materials have begun to be defined as HTS - High Temperature Superconducting) [2,3]. Materials LTS (Low Temperature Superconducting) required cooling with liquid helium, because were required the temperatures below 5 K. Unfortunately, this was associated with high costs and the risk of loss of the superconducting when generated too much heat. Materials HTS have raised the bar initially to 30 K. Currently produced materials that can operate at a temperature of 133 K and even 167 K. In many cases, these materials are produced under high pressure - about 60 GPa. The main interest in these materials, oscillating around electrical equipment [4], cables, energy storage devices that store energy by means of superconducting coils and current limiters [5,6]. In the electric machine, the use of these materials is focused on synchronous motors, linear motors and transformers [7].

2. Material and methodology

The experimental material in this article is the high-temperature superconducting 2G HTS tape of SF series. Tape is built on the principle of the composite and includes a substrate, a buffer layer, superconducting layer, and a coating. This coating is designed to protect the tape from: damage, the impact of external factors, which may cause a decline of ownership - current density flowing significant excess of a critical current or a rise in temperature above the critical temperature may cause damage to the tape or decrease its properties.

The aim of this study was to verify and confirm the chemical composition of the composite construction of the superconducting tape. For this purpose the scanning electron microscope JEOL JSM 6610LV with EDS chemical composition microanalyzer was used. Apparatus was used for linear measurements of chemical composition. Subsequently, studies were made on the adhesion of layers of tape. These studies were performed by scratch tester.

Studies on scratch tester were performed in triplicate. These studies rely on scratching the surface e.g. Rockwell's intender. These tests were allowed description friction force, depth of penetration and cohesion force. Studies were performed on 10 mm measuring section with increasing load 1-5 N, such forces were chosen because the thickness of the tape was 55 μm. In order to clearly express the results, these results were shown in the graphs: Fn - Normal Force - green colour, Ff - Frictional Force - pink colour, Pd - Penetration depth - dark blue colour. Changes in the coefficient of friction μ in the context of measurements are shown in separate graphs.

During the study scratch resistance of tape surface 2G HTS SF12050 take into account the value of the parameters scratching until breakthrough to the substrate.

In further studies measurements were performed of tensile strength, these tests were performed on the device 810 MTS produced by MTS. These tests make sense, because at the time tape winding of the transformer core, there is a possibility of different values of tensile stress. These stresses have an impact on the decline in performance characteristics. In the study, it was necessary to thickening of tape cross-section in place of the handle, because the tape holder fall out of the jaws of the testing machine, Fig. 15.

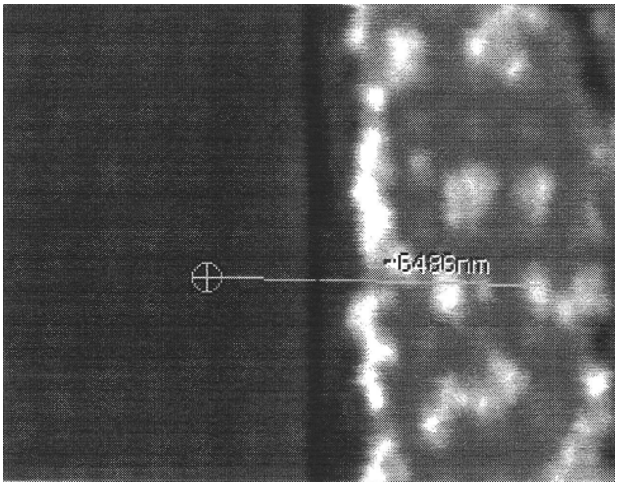

Fig. 1. Random place where the measurement was performed for the chemical decomposition of the superconducting tape SF12050, zoom x 1000

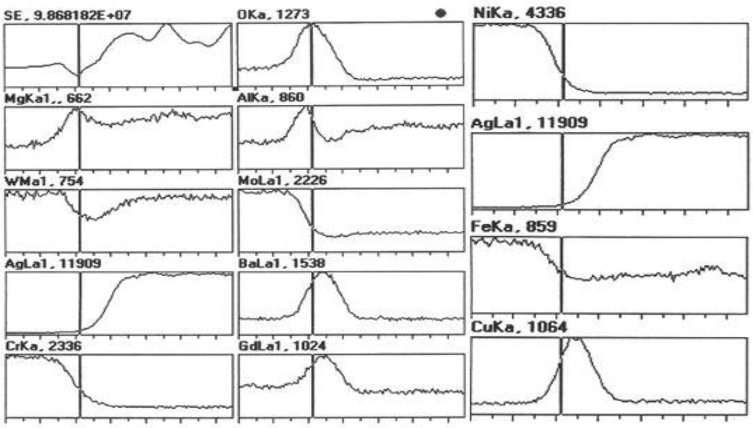

Fig. 2. The linear distribution of the concentration of elements made for superconducting tape SF12050

As a last conducted a study that aimed to determine the critical current Ic tapes. In order to perform that study, measuring system was used (Fig. 21). In order to solder the tape into the system, was used a low melting mixture of tin and Wood alloy (melting temperature - 66-72°C), rosin and flux. The current system was built from the source of three-phase current HP 6681A with a maximum intensity constant current output 580 A (accuracy of current regulation 0,5 A) and output voltage in the range of 0-8 V. Readability of designated critical currents using HP 6681A in range 0-580 A equal 15-311 mA.

Voltage measuring system was equipped with a highly sensitive digital nanowoltometer - Keithley 182 having a measurement accuracy of 1 nV.

Determine the chemical composition was held at the measuring section 6,486 μm (Fig. 1). On the basis of the study obtained linear distribution of element concentrations for the test tape (Fig. 2).

The composition of high-temperature superconducting tape 2G HTS series SF was confirmed by the characteristic spectrum (Fig. 3). Information from this study are shown in Tab. 1.

In order to verify and the full degree of the analysis of the chemical composition of the substrate tape conducted the same study (Fig. 4) and the results recorded in tabular form Tab. 2.

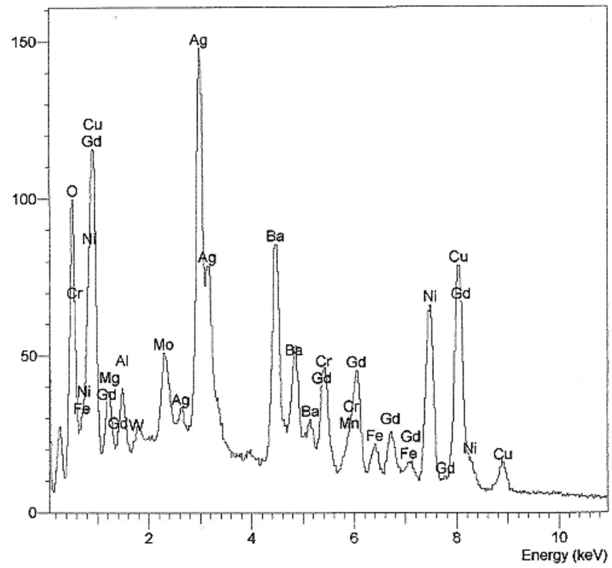

Fig. 3. Characteristic spectrum the chemical composition of superconducting tape SF12050

Table 1
The chemical composition of superconducting tape SF12050

Element	Type of study	% mass	% atomic
O K	EDS	34.77	72.32
Mg K	EDS	1.19	1.62
Al K	EDS	1.29	1.59
Cr K	EDS	2.56	1.64
Mn K	EDS	0.58	0.35
Fe K	EDS	1.08	0.64
Ni K	EDS	8.97	5.08
Cu K	EDS	13.70	7.17
Mo L	EDS	2.70	0.93
Ag L	EDS	13.55	4.18
Ba L	EDS	10.92	2.65
Gd L	EDS	8.03	1.70
W M	EDS	0.67	0.12

Table 2
The chemical composition of the substrate superconducting tape SF12050

Element	Type of study	% mass	% atomic
Cr K	EDS	14.97	18.25
Mn K	EDS	0.53	0.61
Fe K	EDS	5.17	5.87
Co K	EDS	1.22	1.31
Ni K	EDS	56.90	61.45
Mo L	EDS	16.43	10.86
W M	EDS	4.79	1.65

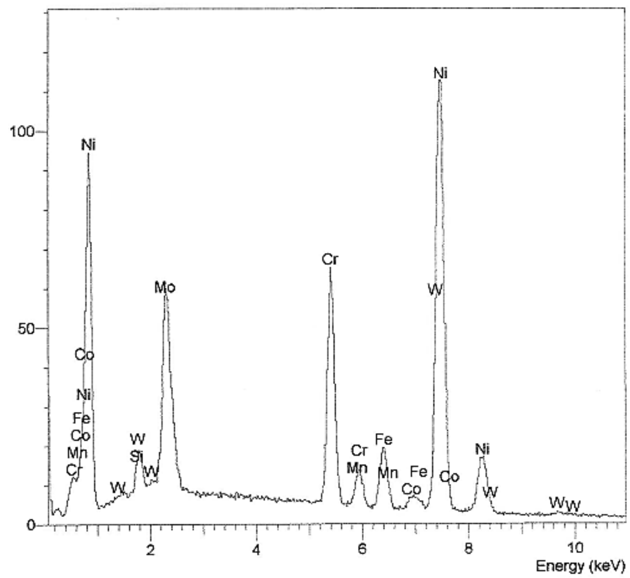

Fig. 4. Characteristic spectrum the chemical composition of the substrate superconducting tape SF12050

3. Results

After determining the chemical composition of the tape has been carried out a study on adhesion layers which are components of high-temperature superconducting tape SF12050. These studies were performed in triplicate.

For the first trial the normal force was equal 1-5 N. The strength gain was 0.3 N/min., feed speed of the indenter 0.75 mm/min. At the time of the penetration depth was 3.6 µm On the other hand the normal force was 1.9 N. The coefficient of friction for selected parameters was scratching during insertion equal 0.3-0.075.

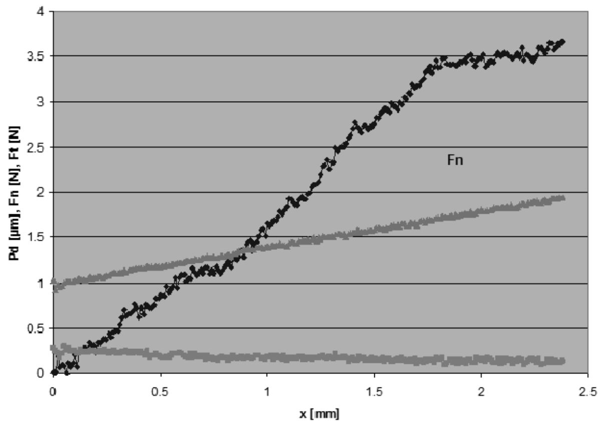

Fig. 5. Parameters showing the process of scratching the surface the superconducting tape SF 12050 load increasing 1-5 N for growth 0.3 N/min - first measurement

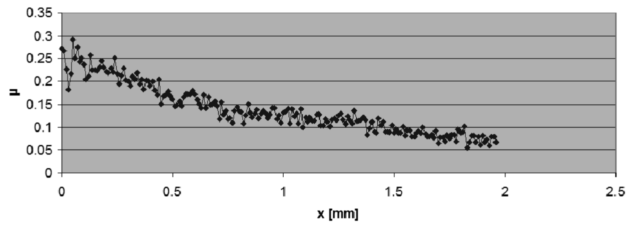

Fig. 6. Changes in the value of the coefficient of friction recorded during surface scratches the tape SF12050 - first measurement

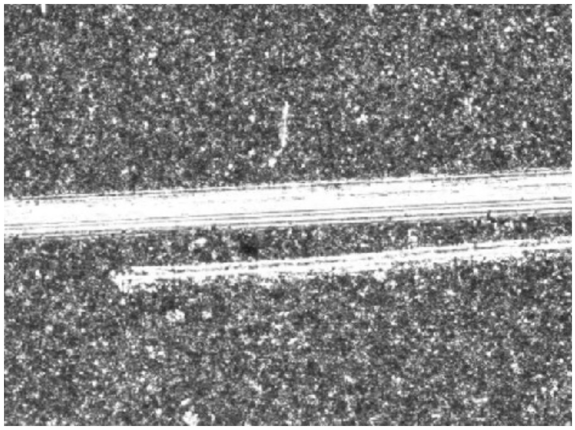

Fig. 7. Microscope image of surface scratches the superconducting tape SF12050 (load increasing 1-5 N for 0.3 N/min) - first measurement

For the first trial the normal force was equal 1-5 N. The strength gain was 0.5 N/min. Feed speed of the indenter 1.25 mm/min. At the time of the penetration depth was 5.6 µm. On the other hand the normal force was 1.6 N. The coefficient of friction for the selected parameter has a clear declines in the depth of penetration 2, 4 and 5 µm.

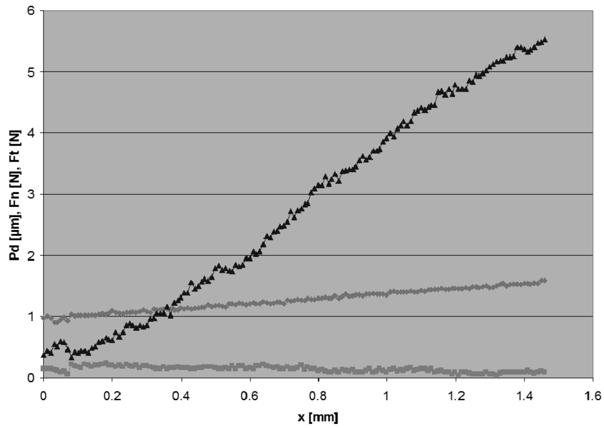

Fig. 8. Parameters showing the process of scratching the surface the superconducting tape SF 12050 load increasing 1-5 N for growth 0.5 N/min - second measurement

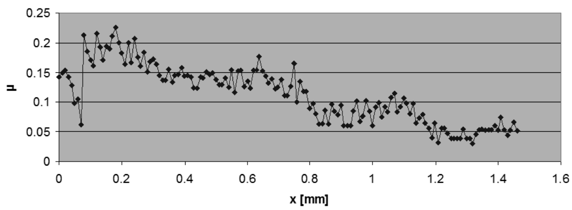

Fig. 9. Changes in the value of the coefficient of friction recorded during surface scratches the tape SF12050 - second measurement

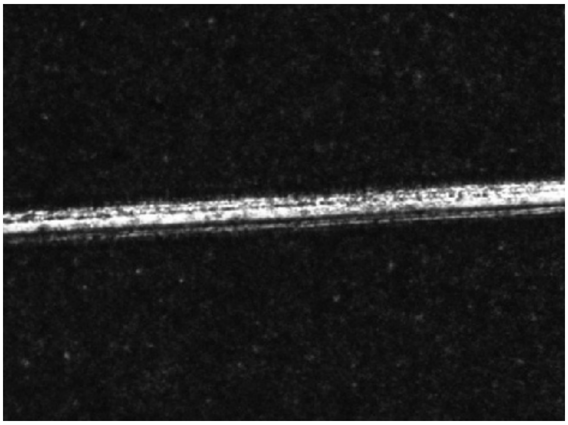

Fig. 10. Microscope image of surface scratches the superconducting tape SF12050 (load increasing 1-5 N for 0.5 N/min) - second measurement

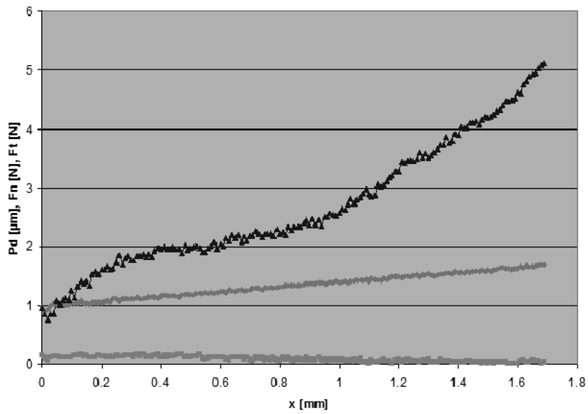

Fig. 11. Parameters showing the process of scratching the surface the superconducting tape SF 12050 load increasing 1-5 N for growth 0.25 N/min - third measurement

For the third trial the normal force was equal 1-5 N. The strength gain was 0.25 N/min. Feed speed of the indenter 0.63 mm/min. At the time of the penetration depth was 5.1 μm. On the other hand the normal force was 1.7 N. The coefficient of friction for selected parameters with the depth of penetration 2 μm decreased from 0.15 to 0.1 where the puncture of silver layer was observed.

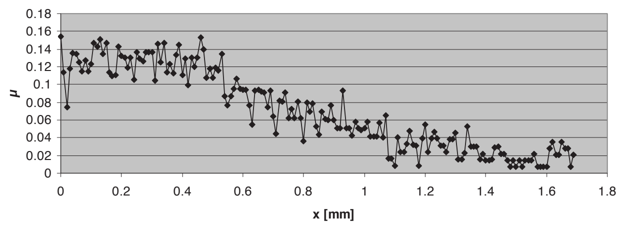

Fig. 12. Changes in the value of the coefficient of friction recorded during surface scratches the tape SF12050 - third measurement

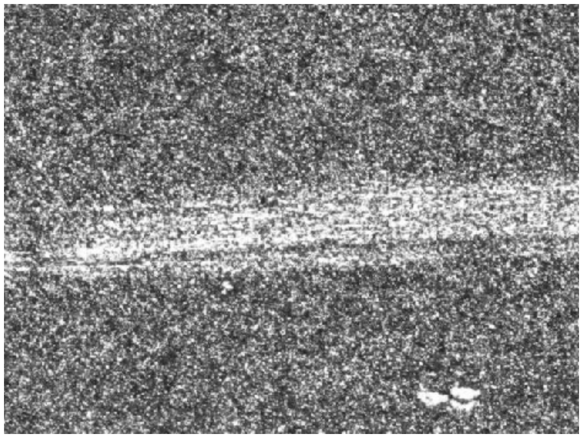

Fig. 13. Microscope image of surface scratches the superconducting tape SF12050 (load increasing 1-5 N for 0.25 N/min) - third measurement

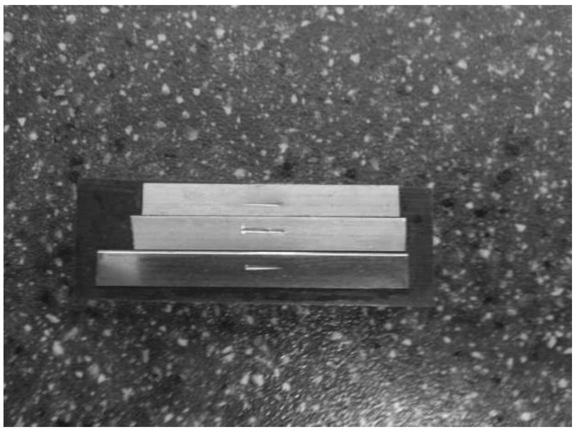

Fig. 14. Macroscopic picture of a sample in the form of tapes on the surface after the scratch process

As a result of tests it was found that the loading force interrupt the continuity between the components of the superconducting tape - for the tape SF12050 is equal 1.7 N. The next step was to carry out research on of tensile strength the superconducting of the tape SF12050. The length of the samples was used 175 mm. In addition, the tape has been bold in a place holder, by virtue of the fact that fared the jaws. Diagrams which are the result of the tests are shown in Figs. 16-18.

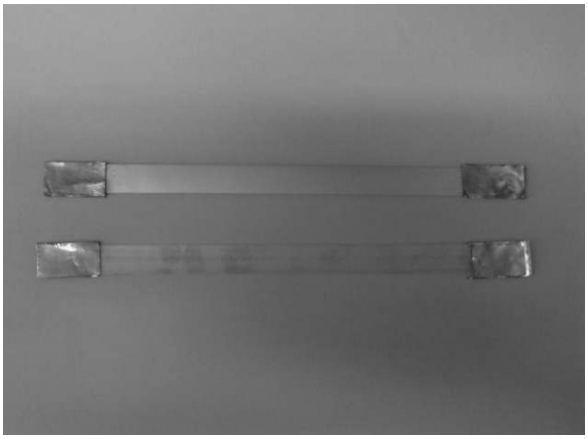

Fig. 15. Superconducting Tapes prepared for testing SF12050

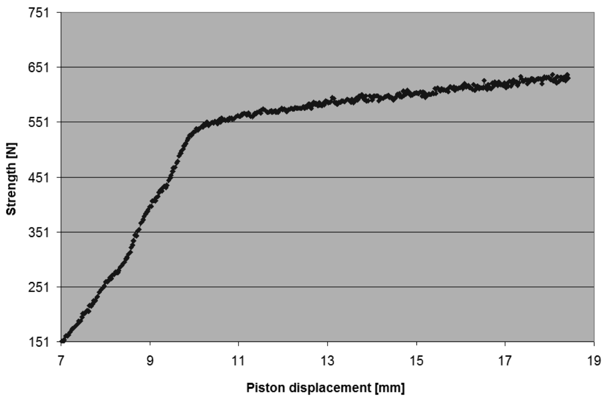

Fig. 16. Chart stretching the tape SF12050 first measurement

In the context of the tests were calculated average tensile strength for high-temperature superconducting tapes SF12050. Average values was 956.04 MPa. The standard deviation for the test set of samples was 58.29 MPa, what is the equivalent 6.1%. Section after stretching tape was presented on Figs. 19 and Fig. 20 was presented photography of turn of tape formed after stretching SF12050 made using scanning electron microscopy SEM.

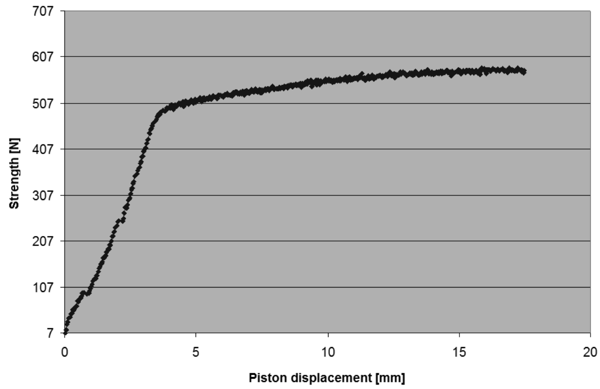

Fig. 17. Chart stretching the tape SF12050 second measurement

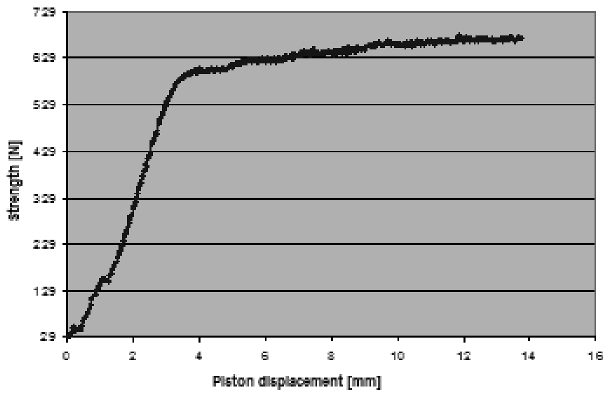

Fig. 18. Chart stretching the tape SF12050 third measurement

For fractures were detected areas of both brittle and ductile. Base material - a substrate, is clearly ductile this is reasonable the fact that it has a load bearing. While the other layer as a buffer, silver and superconducting show fragility. Fragments of the fragile components of tape SF12050 have a regular shape. In the section of the substrate was observed opening which the footsteps of the separation and the bands characteristic of the turn of the plastic, which arose as a result of the applied tensile stress.
Subsequently, studies were performed related to the critical current Ic Tape. The measuring system used to study these currents was shown in Fig. 21. Thanks to research results were obtained in the form of graphs of current voltage superconducting tapes in the series SF12050 studied at liquid nitrogen temperature Fig. 22 [8].

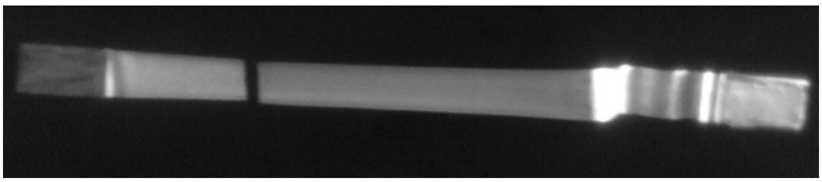

Fig. 19. Tape SF12050 after stretching

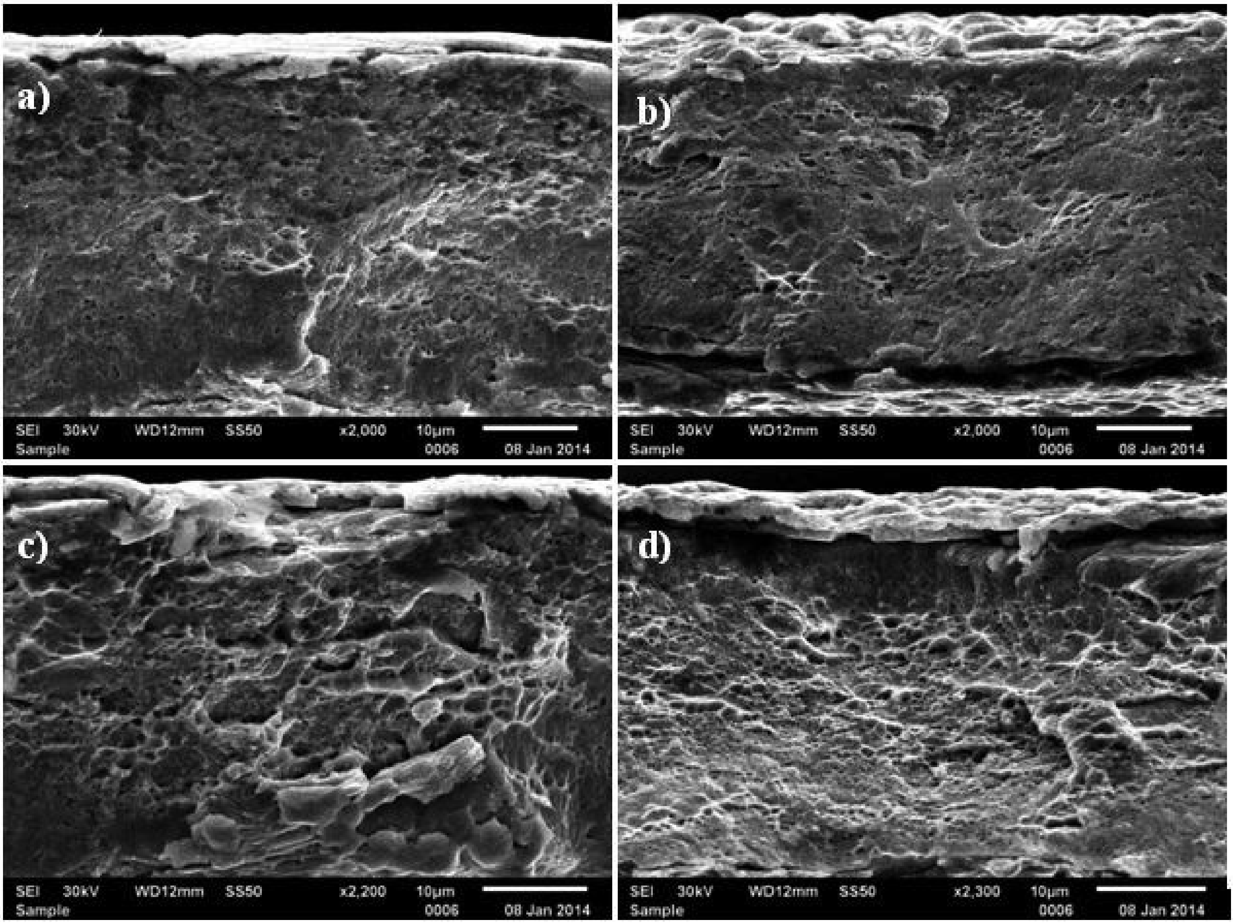

Fig. 20. Photos breakthroughs tape SF12050 after stretching SEM, zoom: a, b) 2000x, c) 2200x, d) 2300x

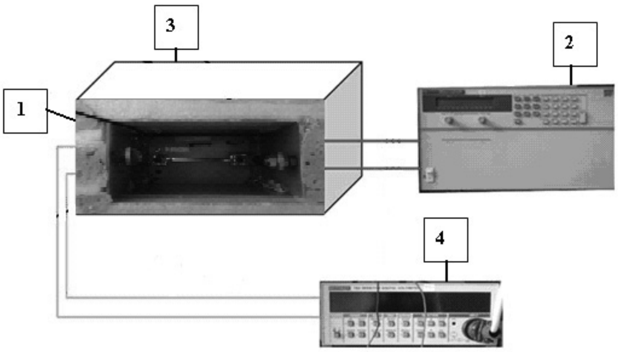

Fig. 21. A system for measuring the critical current Ic in a superconductor: 1-sample, 2-source of current, 3- cryostat, 4- nano-voltmeter

Superconducting tapes are used, among others. the transformer windings. They are formed into a final shape. The research provided information that the critical current tape SF12050 is high and equal 285 A, while being the thinnest 55 µm.

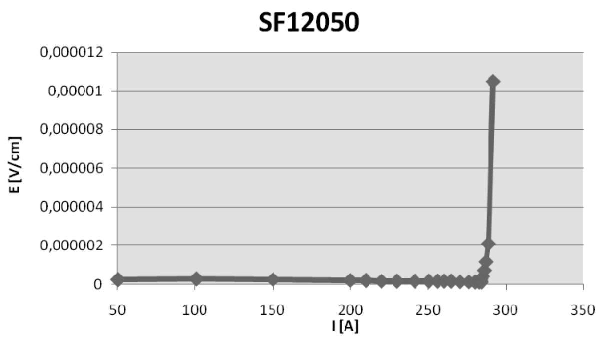

Fig. 22. Current-voltage characteristics the superconducting tape in a series of SF12050 tested at liquid nitrogen temperature

4. Conclusions

As part of the study achieved a number of results concerning various properties of high-temperature superconducting tape 2G HTS SF12050. The results clearly show that the best use of the tapes should be at the production of the windings on the cores of transformers. For such a use for the results of face bending strength and the contiguity of layers, which is a greater resistance to scratching. In addition, there is an issue of high critical currents Ic. Taking into account this information, it is clear that the best place to use these tapes are transformers

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