ANALYSIS OF MECHANICAL AND ELECTRICAL PROPERTIES OF AN ALLOY AL-EC-0,7%SI MODIFIED WITH 0,26% TITANIUM

Djanir Travassos Brandão, djanir.brandao@yahoo.com.br
Emanuelle Sá Freitas, mmanufreitas@gmail.com
Alberto Luiz Mendes Macapuna, alberto_macapuna@yahoo.com.br
Kazuo Kamizono, kazuoak@terra.com.br
Hilton Túlio Costi, tulio@museu-goeldi.br
Prof. Dr. José Maria do Vale Quaresma, quaresma@fem.unicamp.br
Universidade Federal do Pará, Rua Augusto Corrêa, 01 - Guamá. CEP 66075-110. Caixa postal 479.

Abstract. *This study aims to examine the modification of the Al-EC-0, 7% Si content of 0.26% titanium, for the purpose of transmitting electric power distribution, analyzing their mechanical, electrics, heat resistance, and its macro and microstructure, varying the diameter of the wires. The League for the completion of related study was produced by solidification in metallic tube material and subsequently subjected to mechanical machining and rolling different diameters. The analysis was done by means of tensile test performed on a traction machine and electrical conductivity were evaluated by measuring the electrical resistance. Subsequently modified with titanium alloy was subjected to heat treatment and again evaluated for their mechanical characteristics and electrical heat resistance. The alloy was analyzed macro and micro structural and compared with the electrical and mechanical properties, in order to understand the cause for the results. With the experiment could influence the perception of a strong degree of plastic deformation in alloys, inferring experienced good results in the wires of the properties studied with decreasing diameters, especially for the 3 mm diameter.*

Keywords: *Aluminum Alloys; Mechanical Properties; Electrical Properties; Heat-Resistant Alloys;*

1. INTRODUCTION

The aluminum is the third most abundant element in Earth's crust, but it is the younger metal used in industrial scale, was first produced about 150 years (ABAL, 2010). Brazil has the third largest reserves of bauxite in the world and occupies the sixth place in the scale of production of primary aluminum, fifth and fourth in the export production of alumina.

In its pure state is a silvery metal that has as its main characteristics are lightness, malleability and ductility, although does not show great strength, however when other chemicals are added in its structure and subjected to adequate heat treatment, alloys Aluminum can be used for purposes requiring great strength. This metal has many industrial applications , this is due to the excellent properties and performances presented by the metal and its alloys. One such application occurs in the electrical industry, where it is used in wires and cables of various gauges used in the transport of electricity.

Most transmission systems for large distances is composed of airlines, which the use of aluminum conductors provides great savings in time and strength of supporting structures. In this type of large system, there is a solution for the use of aluminum alloys with superior mechanical properties or a combination of aluminum with steel to form the cables core in order to prevent the formation of the bend (FREITAS, 2010).

Observing this fact this paper analyzes the properties mechanical and electrical, and it makes a macro and microstructural analysis of samples of an aluminum alloy modified with 0.26% titanium, varying different diameters (4, 3.8, 2.7 and 3 mm) wires, with the goal which shows better performance for these properties and also examine the effect of plastic deformation in the alloys.

Al-Si alloys have excellent casting characteristics such as low flow and low shrinkage, and they have a third as dense as steel, copper and bronze. The Al-Ti alloys are part of a group of alloys classified as non-heat treatable, the mechanical properties of these alloys are improved with only cold working, which is explained due to low solubility of Ti in Al, because other alloys formed with elements that also have low solubility in Al exhibit this trend. Ti alloys is usually added in small amounts in order to refine the grain size.

According to Garcia (2009) in a comprehensive review of current manufacturing processes of metal parts and components shows that, except for articles produced by powder metallurgy techniques, all others are, at least once, by the solidification process. During this process the material undergoes very dynamic interactions that need to be properly audited, otherwise they can compromise the final product performance. The dynamics of the solidification process is what determines the microstructure, which in turn influence the properties of cast (Freitas, 2010).

It is known that the amount of voltage used to deform a material is related to the degree of difficulty of movement of the dislocations in the structure. Figure 1 is a comparison of some properties in relation to the degree of hardening and some heat treatments, it is observed that the electrical resistance and hardness increase as the degree of hardening.

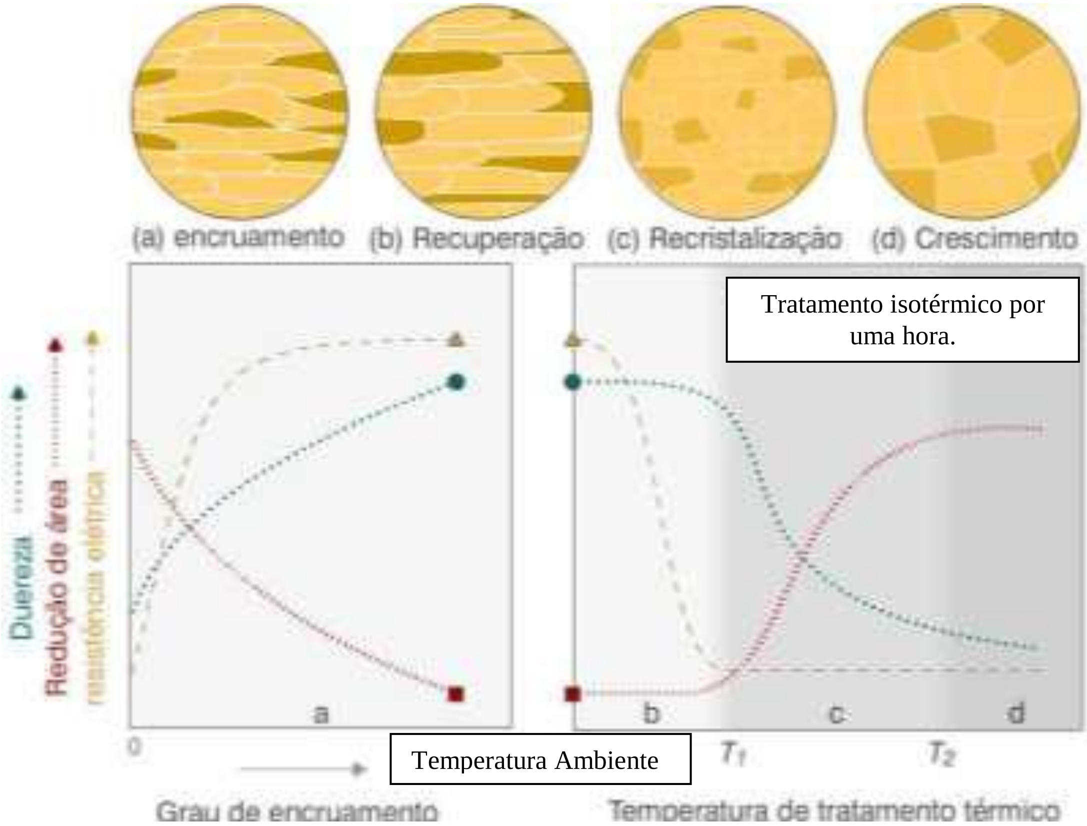

Figure 1 - Schematic comparison of the effect of cold working and heat treatment of metals (CIENCIADOSMATERIAIS, 2011).

According to Novikov (1994), recovery annealing is a heat treatment of metal or alloy deformed. In this annealing process is the key to recovery. A material to be deformed, suffers from the hardening process that results in the accumulation of internal stresses at a given degree of deformation is necessary to alleviate these tensions so that the material does not undergo fracture, in this circumstance is used to recover heat treatment and according SANTOS (2006) in recovering the little variation in strength and hardness.

2. MATERIALS AND METHODS

The casting and solidification of alloys begins with the cutting of aluminum ingots and other elements to form the alloy, in this case, the titanium. Then the materials were weighing and introduced into the crucible of silicon carbide with 3.5 liters of volume, which was painted internally with a solution of kaolin to prevent the adherence of a considerable amount of material and preheated for 20 minutes at a temperature of 150 ° C to remove moisture.

The fusion happened in a furnace type muffle brand BRASIMET at a temperature of 790 ° C after the complete melting of the material the crucible was removed from the oven and is then made a homogenization of the molten metal by means of a manual agitation with a spatula steel. Subsequently the solution was added to argon in order to remove gases and impurities that could cause solidification defects, it was formed on the surface then a layer of slag, which was separated by steel trowel. Then it was carried out the leak at a temperature values between 730 and 750 C with the same material made a sample which call control sample to be carried out chemical analysis in a mass spectrometer, this knowledge becomes important due to strong influence that the content of alloying elements on mechanical properties.

Figure 2 – [a] Fumace type muffle [b] Added to argon.

The mold used in the leakage was "U" type, it made of steel, it painted inside with a solution of kaolin, used in painting the crucible. The leakage occurs in a conventional way, to fill the mold by molten metal is by gravity, after solidification the mold is removed by hand. The specimen of the mold leaving a U-shaped with a diameter of 22 mm which is then machined to 18.5 mm, this step takes advantage to remove some of solidification defects such as pipe. Then the material is deformed by cold rolling mill in a reversible electric two-high to achieve the desired diameter for the present analysis: 4.0, 3.8, 3.0, 2.7 mm.

The heat resistivity test was held in the furnace type muffle following the specifications of COPEL (Companhia Paranaense de Energia) featuring alloys such as heat resistant when they have no loss at its maximum tensile strength higher than 10% when subjected to a temperature of 230 º C for one hour. Electrical characterization was performed using multiohmímetro (Kelvin Bridge) MEGABRAS MPK-2000 model which measures the electrical resistivity of the material, the specimens used had 60 cm for all diameters.

Figure 3 – [a] Multiohmímetro MEGABRÁS model MPK-2000 [b] Rolling two-high mill.

The tensile test was performed on the machine model IKCL1 KRATOS-USB attached to a microcomputer with a data acquisition system, tests were carried out to compare the values of tensile strength limit (LRT) were obtained from each diameter (4.0, 3.8, 3.0, 2, 7) and for the specimens with and without heat resistivity test.

To study the macrostructure was withdrawn shortly after the leakage in a sample cross section and subjected to the process of metallography, then chemically attacked by Poulton solution [12ml HCl (Conc.), 6 ml HNO3 (Conc.) 1 ml HF (48%), 1 ml H2O]. This step aims to reveal the size and orientation of grains.

Figure 4 – [a]Machine KRATOS model IKCL1-USB [b] Data Acquisition System..

The study of the microstructure is performed from the topography of the fractures and the transversal and longitudinal sections, resulting from the tensile test and analyzed with SEM (Scanning Electron Microscope), which were also embedded with resin and sanded and polished, both sanding and polishing were performed on a polishing machine.

Figure 5 - Scanning Electron Microscope

3. RESULTS AND DISCUSSION

The methodology above aimed achieves the presented objectives. As described early, this work was based on the alloy Al – 0,7%Si, modified with 0,26% Ti, which was submitted to the entire process of mechanical, electrical, structural e thermo resistance characterization, in order to study applications on power transmission cables (type Tx and Dx). Four diameters were investigated (4,0 ; 3,8 ; 3,0 ; 2,7 mm); The results obtained were compared so that the most efficient diameter could be find.

The macroscopic structure was revealed after the samples were etched by the chemical solution Poulton. At this stage, the structure of the basis alloy modified with 0,26% of Ti was compared with the structure of the basis alloy, without adding any other chemical element. As one can see in Figures 5 and 6, the addition of Ti causes refining on the grain size, which was already expected.

Figure 6 - Macrostructures of the base alloy without additional and modified with Ti content of 0.26%.

The SEM microscopic analysis allow us observe in great detail the grain contours of the alloys studied. In the same way, we can state that the structure does not present precipitates of Al_2Ti, suggesting that the Ti might be retained on the alloy as a solid solution, or on the form of “Dispersoides” with nanometric dimensions observed only with the aid of powerful Transmission Electronic Microscopes (FREITAS, 2009). It is possible to identificate the presence of a complex structure known as “Escrita Chinesa”.

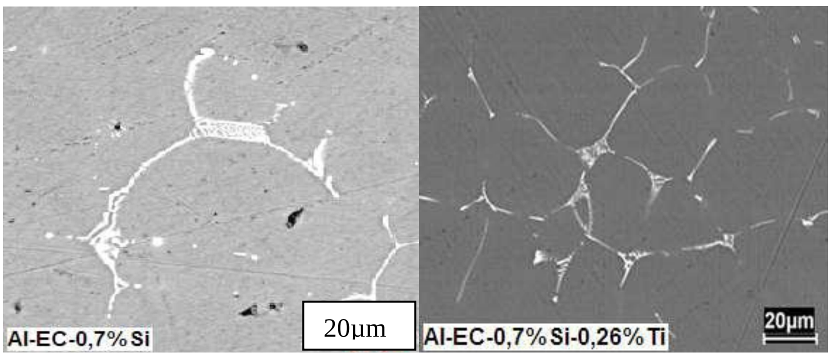

Figura 7 - Micrography of transverse cutting

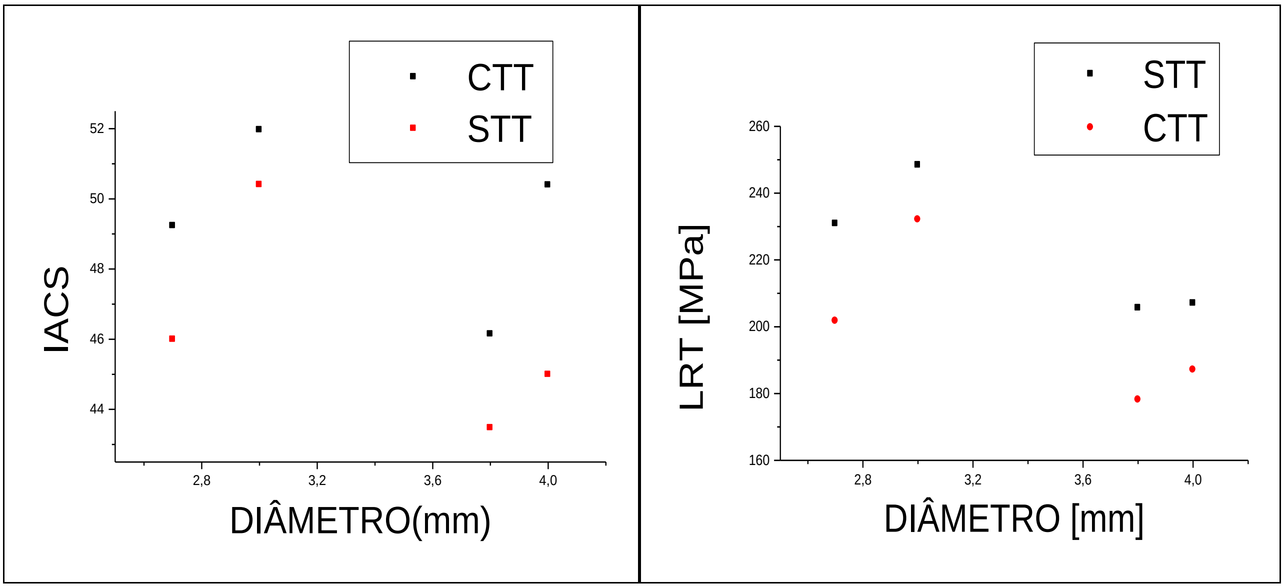

Figure 8.1 – Graph comparing the values of IACS in function of diameters of specimens STT (Without Heat Treatment) and CTT (Heat treatment). Figura 8.2 – Graph comparing the values of LRT in function of diameters of specimens STT (Without Heat Treatment) and CTT (Heat treatment).

The electrical characterization was evaluated by IACS degree, which compares the electrical conductivity of a material with the correspondent conductivity of copper. Analyzing the graphics, we can state that the smaller the diameter, the smaller is the IACS, with exception to the sample of 3 mm, which presented the best results on this parameter. This phenomenon can be explained by the dynamic recovery, which consists on a recovery after plastic deformation without the sample being submitted to a great elevation of temperature. The tension applied inducing plastic deformation is summed to the tensions acting between the discordance. In such way, the effects of the recovery can be observed at low temperatures. In regarding to the thermo resistivity test, it was observed that the material presented a better conductivity after submitted to the heat treatment, what suggests that the temperature used triggered the recovery phenomenon, explaining the high conductivity values to smaller diameters.

The analysis of mechanical properties was done by collecting the values of LRT, relevant to the application of the alloy studied. Observing data from graphs presented it is clear that the LRT grows as it decreases the diameter, and better results for 3 mm, this fact explained by the increased density of dislocations in the material structure, a phenomenon known as work hardening, that this does not happen, because it occurs only increased LRT crossing diameter 3.8 to 3.0.

Protocol according COPEL alloys used for transmission of electric energy should not lose 10% of LRT after undergoing the test heat resistivity. The graph below that the wire meets this requirement is better than 3 mm in diameter, 4 mm is very close to 10%, about 9.6%, which is considered unsatisfactory.

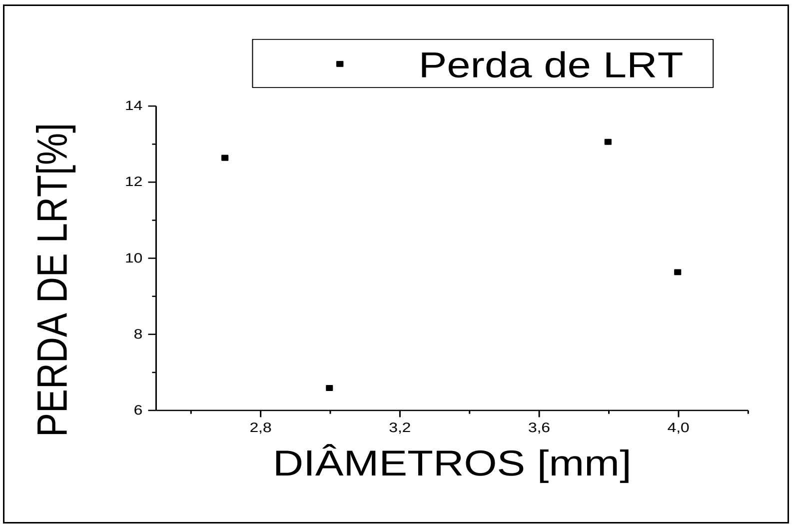

Figure 9 – Graph of loss, in percentage, LRT specimens with their respective diameters after thermal treatment.

It can be verified that the white particles, identified here as "Iron Lines", tend to decrease in size, intensity and spread in the sections observed as the degree of deformation increases. This trend seems to follow the appearance of the fracture that presents "Dimples" (microcavity) with smaller diameters.

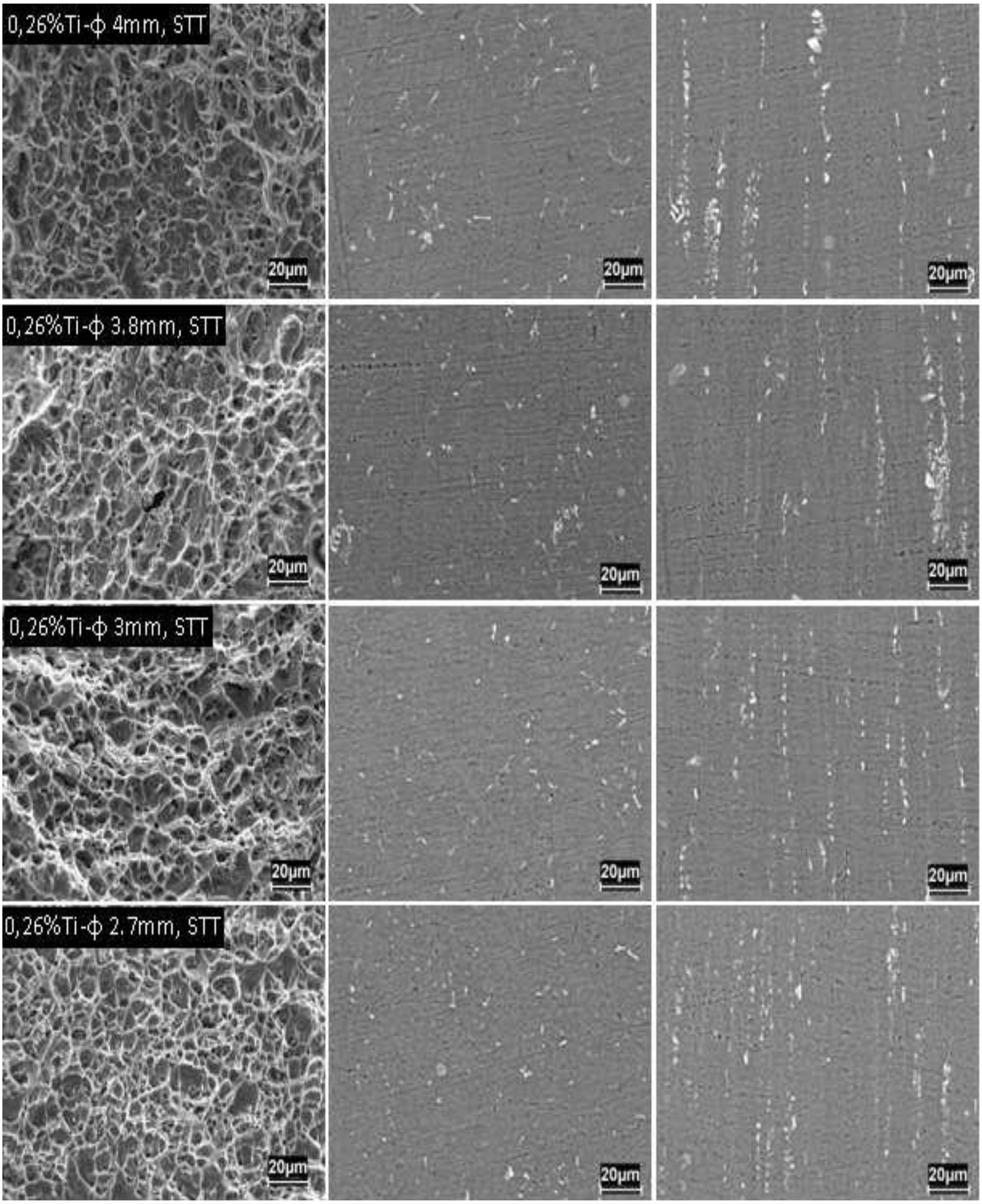

Figure 10 - Topography of the fracture and cuttings: transverse and longitudinal section of Al-alloys EC-0, 7% Si-0, 26% Ti, respectively, for diameters [4.0, 3.8, 3.0 and 2.7] mm, Without heat treatment.

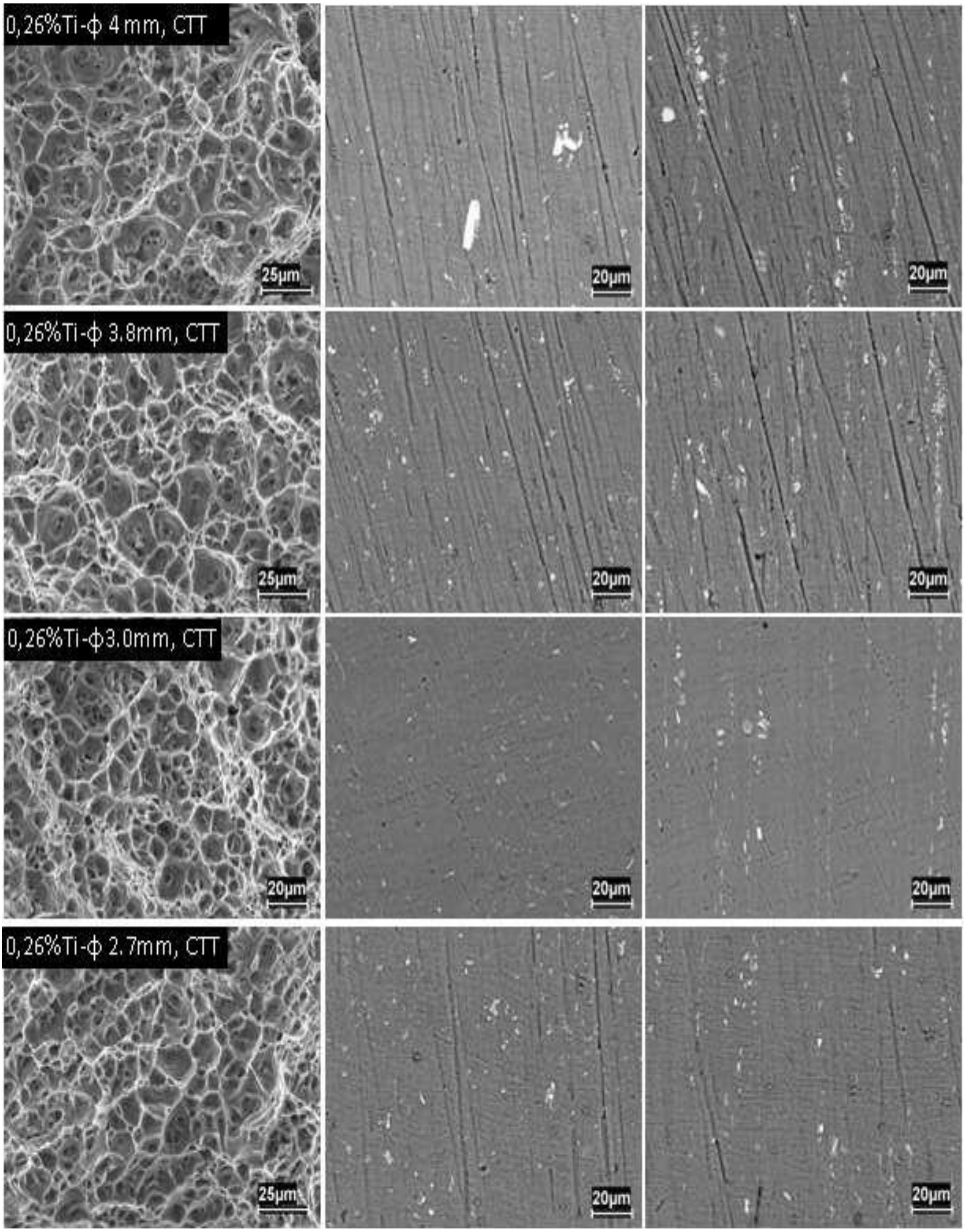

Figure 11 - Topography of the fracture and cuttings: transverse and longitudinal section of Al-alloys EC-0, 7% Si-0, 26% Ti, respectively, for diameters [4.0, 3.8, 3.0 and 2.7] mm, heat treatment.

It is likely that the intense multiplication of new anchor points of disagreement, because of the intensity of plastic deformation, inhibit the movement of these. The variation in the size of "Dimples" is governed by the reduction of area and nearest second phase particles, movement of dislocations and displacements of the grain boundaries. Elements that promote the nucleation, growth and coalescence of "Dimples "

4. CONCLUSION

Through the results it is possible to conclude first, observing the gross structure, the titanium has a great capacity to refine the grain. Second, there is a tendency to decrease in value of IACS, as the increasing degree of plastic deformation, in other words, smaller diameters tend to have lower levels of IACS, except in the deformation of the diameter 3.8 to 3 mm which possibly have been increased by the phenomenon of dynamic recovery, the results obtained after the thermotolerance test were higher, which is explained by the fact that during the heat treatment the material was still recovering.

The diameter of 3 mm also performed better on the mechanical strength and heat resistivity test, though all suffer a decrease in LRT after heat treatment, which should have annihilated the discrepancies in the accumulated strain which explains the fall of LRT, the diameter of 3 mm was the only one that fit the standards for cables Copel.

In the microstructural analysis, it is noteworthy that during the plastic deformation occurs dynamic recovery which tends to decrease the intensity of the dislocation tangle (Freitas, 2010), by analyzing the specimens without heat treatment can be concluded that the major modifier of the size of dimples is the degree of deformation. The heat treatment of 1h at a temperature of 230 ° resulted in the recovery static, where you can see in figure 11, dimples larger when compared to figure 10.

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