CuNi2Si1Ag0.8 – multi-components copper alloy with high strength and conductivity

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In order to meet the expectations of the global industry in such fields as: energy, heating, aviation, automotive, railway, Cu-Ni-Si-Ag alloys have been developed.

Precipitation hardening Cu-Ni-Si alloys are widely used as accessories in electrical devices, which must be characterized by increased strength obtained as a result of precipitation strengthening and are produced by cold working. In addition, Cu-Ni-Si alloys are characterized by electrical properties and excellent thermal conductivity. Strength and resistance to corrosion makes it widely used as construction elements of wind power plants, transformers and electric generators.

The addition of silver as well as the applied thermo-mechanical treatment increases strength properties and conductivity.

Heat and plastically by cold working treated CuNi2Si1Ag0.8 alloys were developed as part of the research. It was confirmed that silver with a mass concentration of 0.8% had a positive effect on changing the structure and properties of CuNi2Si alloys. The development of the alloy is the result of research performed in order to optimize the silver content and determine the parameters of heat treatment. In order to determine the structure (Fig.3) and properties of these alloys, the following tests were performed: scanning electron microscopy, X-ray analysis in micro-areas EDS, transmission electron microscopy (TEM). Thermal derivation analysis was also performed to find the relationship between the chemical composition, crystallization kinetics and structure.

A silver-modified Cu-Ni-Si alloy with the chemical composition given in Table 1 was used for the tests. Ingots were cast into thickwalled cylindrical cast iron molds. The alloy was prepared in an induction furnace. Alloying components were introduced into the heated crucible (600°C) and melted under a protective argon atmosphere. Argon was also fed to the stream during casting. The metal mold was preheated and the temperature during casting was 1150°C.

Supersaturation CuNi2Si1Ag0.8 alloys were performed at 770°C (the temperature was determined experimentally), cold deformed (with 50% crushing degree), and then aged at 500°C. The parameters of thermo-mechanical treatment are given on Fig 1a. On the other hand, CuNi2Si1Ag0.8 was determined experimentally as part of our own experiments (Fig.3). Heat treatment and cold plastic deformation were performed using a Gleeble 3800 thermo-mechanical simulator from DSI (Dynamic System Inc.) (Fig.1b). The Gleeble 3800 simulator is equipped with a direct resistance heating system that accurately maintains the desired temperature with an accuracy of ± 1°C. The use of the Gleeble simulator made it possible to perform heat treatment at a strictly defined temperature, and thus minimize errors that may occur during heating and direct cooling with a jet of water under pressure or compressed air during the process. A set of graphite and tantalum layers with a thickness of 0.1 mm was used and the contact surfaces of the sample, and additionally, the anvils were coated with nickel-based grease to protect the samples from joining the tungsten carbide anvil, improving the contact between the contact surfaces (which is very important in the case of resistance heating carried out in the simulator and consisting in the flow of current through the test sample), friction between the joint surface of the test sample and the surface of the tungsten carbide anvil.

The tests of Cu-Ni-Si alloys modified with Ag at the level of 0.8% mass showed that the addition of silver as well as the thermo-mechanical treatment on the Gleeble simulator causes an increase in hardness by 40% (the hardness of the thermo-mechanically treated CuNi2Si1 alloy is 150 HV, after adding silver it is 193 HV) (Fig.6). The conductivity for the thermo-mechanically treated Ag modified alloy is 18 Ms/m and is about 20% higher than for the non-modified alloy (Fig.6). Aging of the supersaturated and previously deformed CuNi2Si1Ag0.8 alloy causes precipitation of Ni_2Si phases (Fig.4;5). Modification of the chemical composition with silver at a concentration of 0.8% mass. causes an increase in hardness and an increase in conductivity (Fig.6). Segregated from the solution phases Ni_2S confirmed by TEM analysis occur in a longitudinal elongation-formed shape of a length of ca 500 nm, what influences the strengthening of the alloy due to similar size compared to the EBSD revealed grained /subgrained microstructure.

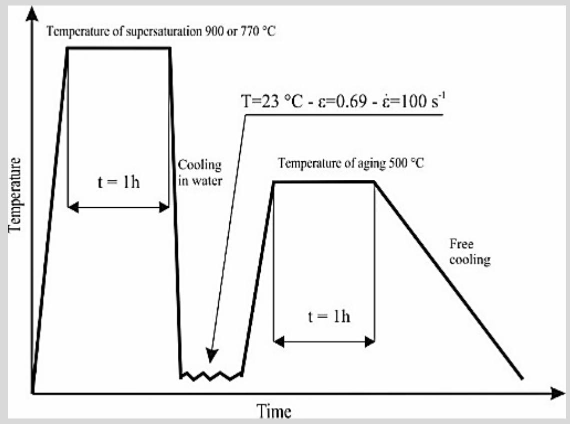

Figure 1a. The parameters of thermo-mechanical treatment

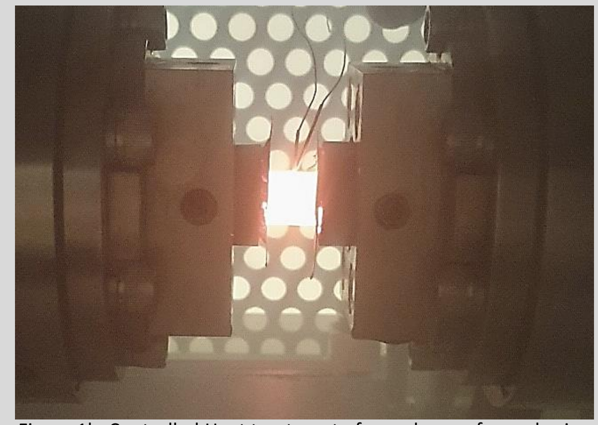

Figure 1b. Controlled Heat treatment of samples performed using a Gleeble 3800 simulator

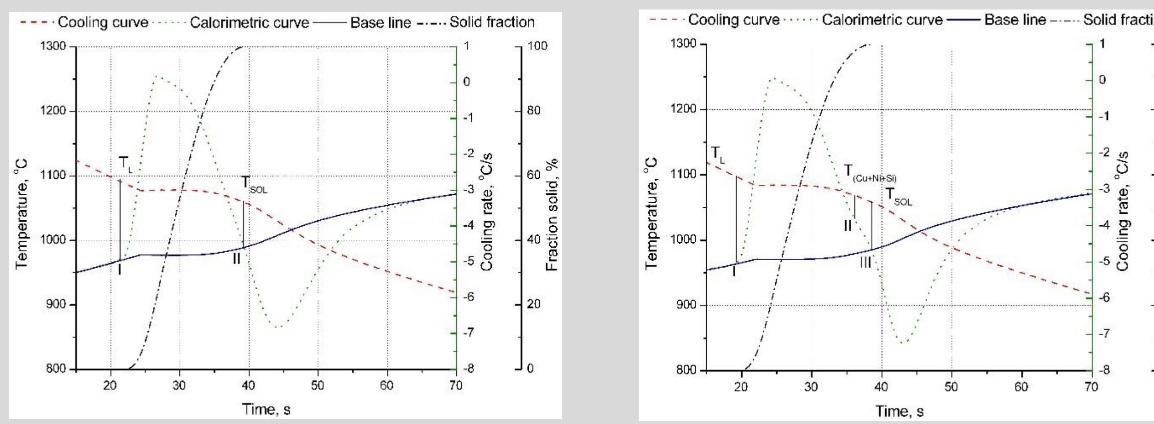

Figure 2. Cooling and derivative curves and solid fraction during the crystallization of the particular compounds for Cu-Ni-Si and Cu-Ni-Si-Ag alloys.

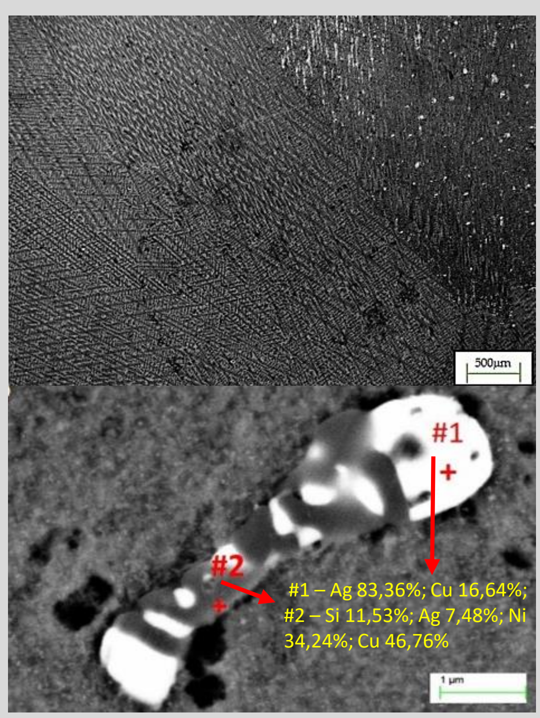

Figure 3. Structure of CuNi2Si1Ag0,8 alloy: initial state

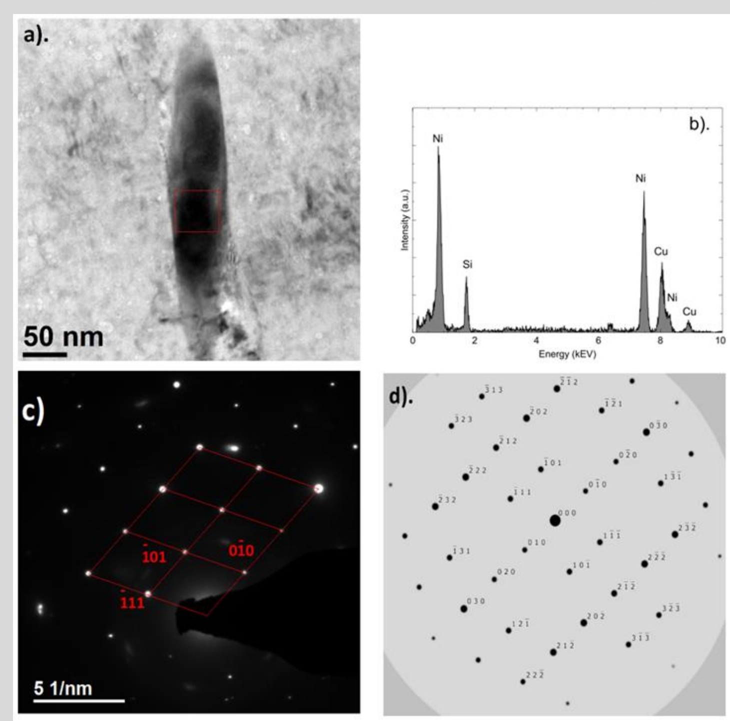

Figure 4. Ni_2S particle embedded in the substrate material: (a) TEM image, (b) EDS spectrum obtained for area indicated at a).; (c) SAED electron diffraction and (d) computer simulation of the electron diffraction of the of Ni_2S in the [101]

Table 1. Chemical composition of the copper alloys

Sample description	Elements as compounds of the modelled Cu casts
Cu-Ni-Si	Cu, Ni (up to 2%mas concentration), Si (up to 1 % concentration),
Cu-Ni-Si-Ag	Cu, Ni (up to 2%mas concentration), Si (up to 1 % concentration), Ag (up to 0,8% mas. concentration),

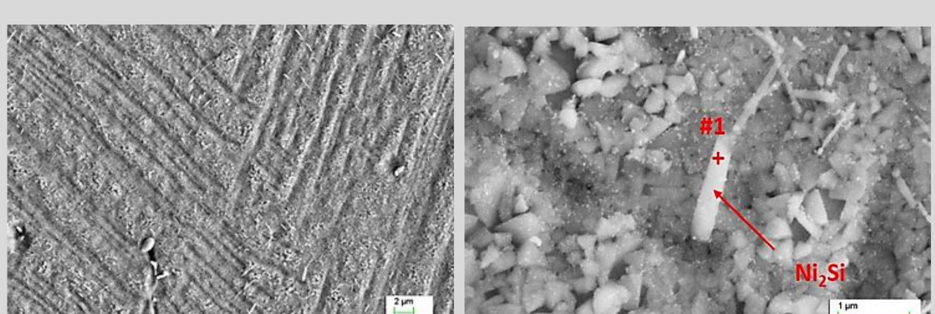

Figure 5. Structure of CuNi2Si1Ag0,8 alloy after thermo-mechanical treatment

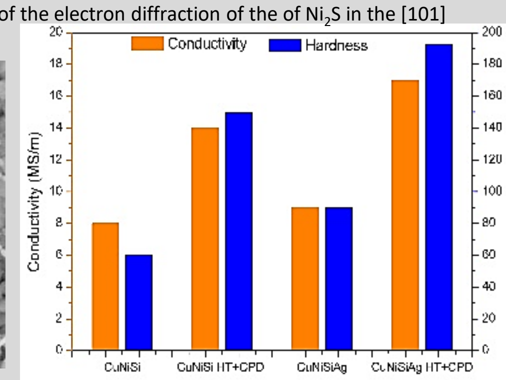

Figure 6.Hardness and conductivity of Cu-2Ni-1Si and Cu-2Ni-1Si-0,8Ag alloys (HT+CPD - after heat treatment and cold plastic deformation)

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