

## COMPOSITE SHAPE MEMORY ALLOYS USED IN ENERGY DISSIPATION APPLICATIONS

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**Abstract:** Shape memory alloys exhibit through their martensitic transformation a high damping capacity that can be used in many applications. Microstructural and chemical analyses were made concerning a shape memory alloy based on copper that can be used as matrix material in a composite material for mechanical energy dissipation. Scanning electron microscope and X-ray analysis equipment were used to characterize some material properties.

**Keywords:** *shape memory alloys, damping capacity, martensite transformation*

### 1. Introduction

Shape memory alloys, because of their unique thermo-mechanical behavior, have developed considerable works towards the performance of intelligent materials and structures. Indeed, these alloys are particularly useful when large deformation and recovery of the shape is observed under a small rate of stress or temperature. These properties are attributed to the ability to undergo martensitic phase transformation. This approach presents the advantages to be easily incorporated in a structural computation. Shape memory alloys have the ability to modify both their shape and properties in response to the thermo-mechanical environment. They may be embedded into an inactive material to transform it into an active composite: by a suitable choice of their volume fraction, shape and alignments, they accomplish a specific function. Many applications can be profitably explored in aerospace structures, vibration control among others.

Actuation by shape memory alloys (SMAs) has generated considerable interest and some applications have been developed across a wide range of industries. Successful applications are still largely restricted to niche markets, although the extent of their applications is growing rapidly. Two factors seem to have restricted growth into other markets. These are the early dominance by the medical market, where small sections of low

temperature materials have been developed. This has partially led to the second limiting factor, which is the lack of availability of larger engineering sections and techniques. This second limitation is partially due to technical difficulties in scaling up of the materials and techniques, plus a lack of visibility of the benefits.

Nonetheless, impressive demonstrations of larger scale advanced actuator applications have been achieved, particularly in the aerospace industry. Applications within a gas turbine are an order of magnitude more difficult due to the more robust requirements and higher temperatures encountered [1]. Many research grants are in hand to investigate the opportunities for smart technologies to gas turbines, with SMAs attracting considerable interest. The opportunities for enhanced performance and cost reduction are generally obvious within the industry, but this must be achieved with realistic cost and reliability from the technologies.

In general, a high integrity, robust and stiff structure must be achieved. This has led to several programmes investigating larger structures and supporting technologies such as joining techniques. The control of noise pollution has become increasingly important in the aerospace industry. The generation and radiation of noise from aero-engines poses a problem of immense complexity. Over recent years, noise reduction has become a prime

requirement in the specification for next-generation propulsion systems.

Engine manufacturers are constantly investigating ways that will reduce the noise created by gas turbine engines. Commercial SMAs are usually available 'off the shelf' in the form of wires and thin strips. The SMA business is very much 'supply driven' and without major demands for large section SMAs, suppliers are reluctant to invest and develop the process technologies required to manufacture them. This has been a major factor hindering the advances in the alloy development and process technology of SMAs [2-4].

In this study a composite matrix material made of shape memory alloy based on copper is analyzed in martensitic state by microstructure and chemical composition points of view. Number of martensitic variants and grains dimensions influence the materials damping capacity through their boundaries dimensions and number so is important to analyze their characteristics [5-7].

## 2. Experimental details

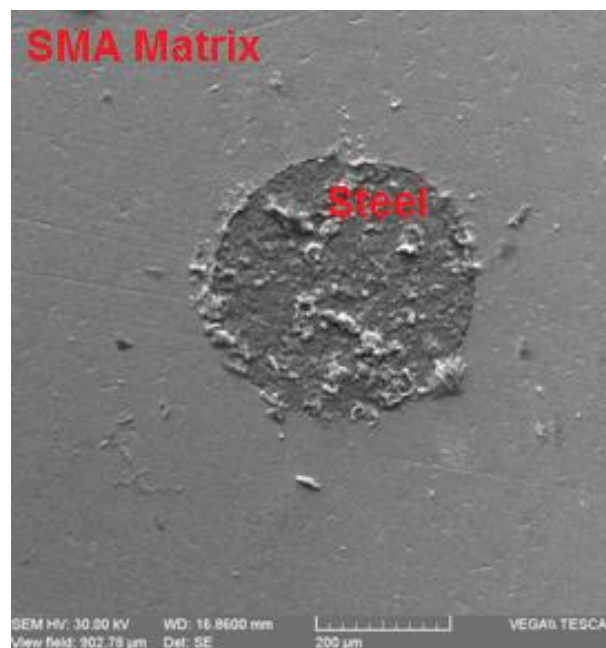
To obtain the alloy was used a laboratory furnace with graphite crucible using copper, zinc and aluminum high purity materials with reduce percentage of iron [8]. The heat treatments were realized on a laboratory

Vulcan furnace with controlled temperature variation [9].

Chemical composition was determined through spark spectrometry analysis using Foundry Master equipment (for matrix and reinforcement elements chemical analysis) and EDAX analysis as well for matrix study. In this study different EDAX software applications were used to determine the chemical variation of the elements on Line Point mode with automatic or element list considerations. Microstructures of the composite matrix were obtained with a scanning electron microscope (SEM) LMH II by Vega Tescan brand using a secondary electrons (SE) detector to characterize the matrix in martensitic state details.

## 3. Experimental results

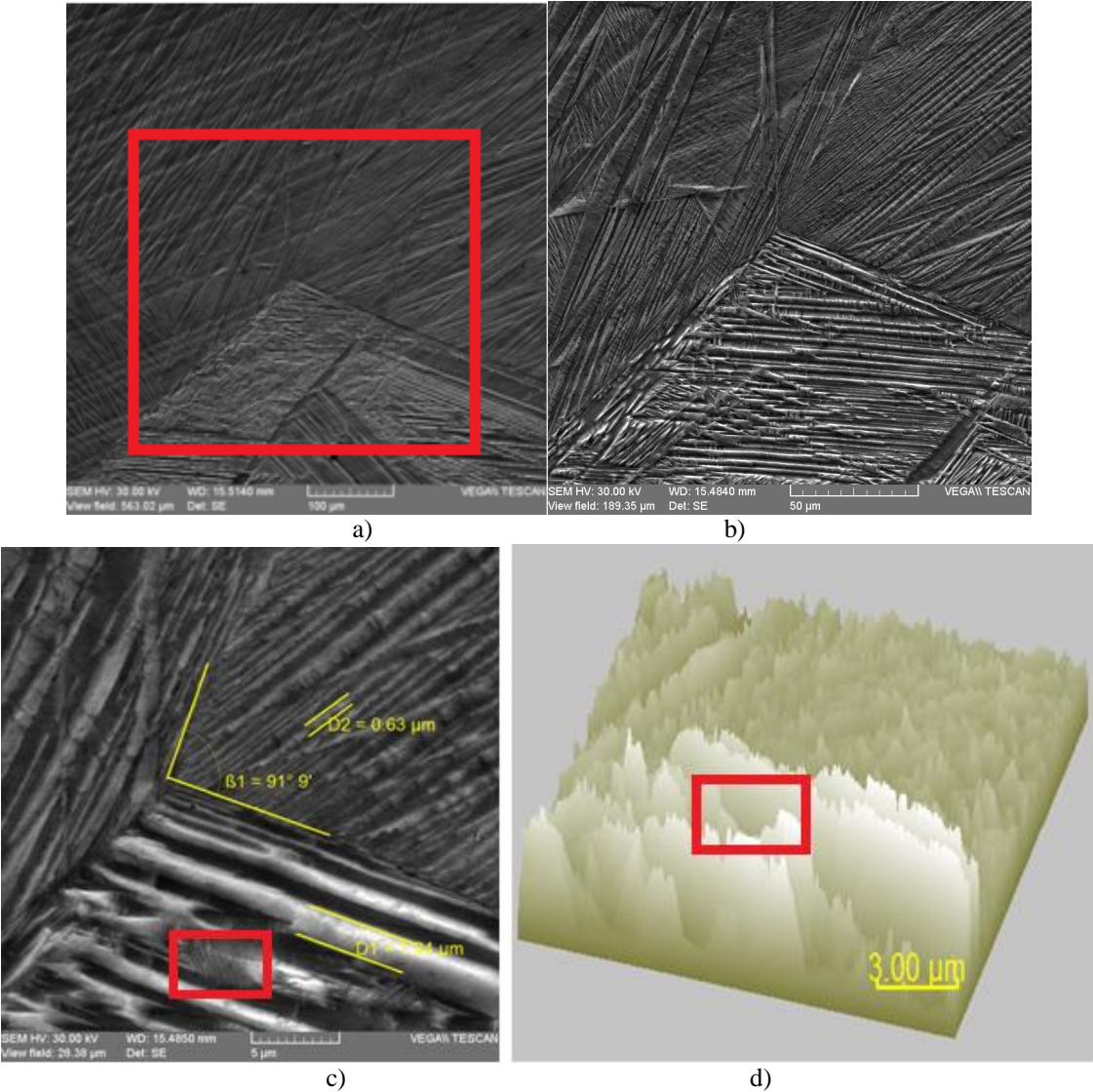
Microstructural and chemical investigations were carried out to analyze a shape memory alloy based on copper used as matrix material in a composite. SEM microstructure of the composite surface is presented in figure 1 at a 500x image amplification. Composite material is made of a shape memory alloy as matrix and an arch material (steel) reinforced in metallic matrix. Analyses concerning some interface phenomena were done [10] presenting a nice combination of the materials and a diffusion made layer between SMA and steel materials.



**Figure 1:** SEM microscopy of a composite material with a shape memory alloy matrix

Microstructure of a shape memory alloy used as matrix material in a metal-metal composite material is analyzed in figure 2. SEM microscopy presented in figure 2 were realized with a SE (secondary electrons) detector at a 30 kV alimentation tension lamp and different image amplifications like 500x in

a), 1000x in b) and 10000x in c). Using the Tescan Software 3D analyzes of the martensite variants was done based on the electrons analyzed from de sample.



**Figure 2:** Microstructural analyze of a shape memory alloy based on copper used as matrix in a composite material in martensite state a) grains intersection b) detail of grains intersection from a) with martensite variants type c) geometrical and dimensional characteristics of martensite variants d) 3D image of area selected in c) for martensitic variants characterization

Martensite microstructure of the copper based shape memory alloy propose for the matrix material has different types of variants like plates or V shape with different kind of dimensions between 2 or 3 μm to 50 to 100 nm. Secondary martensite variants appear as

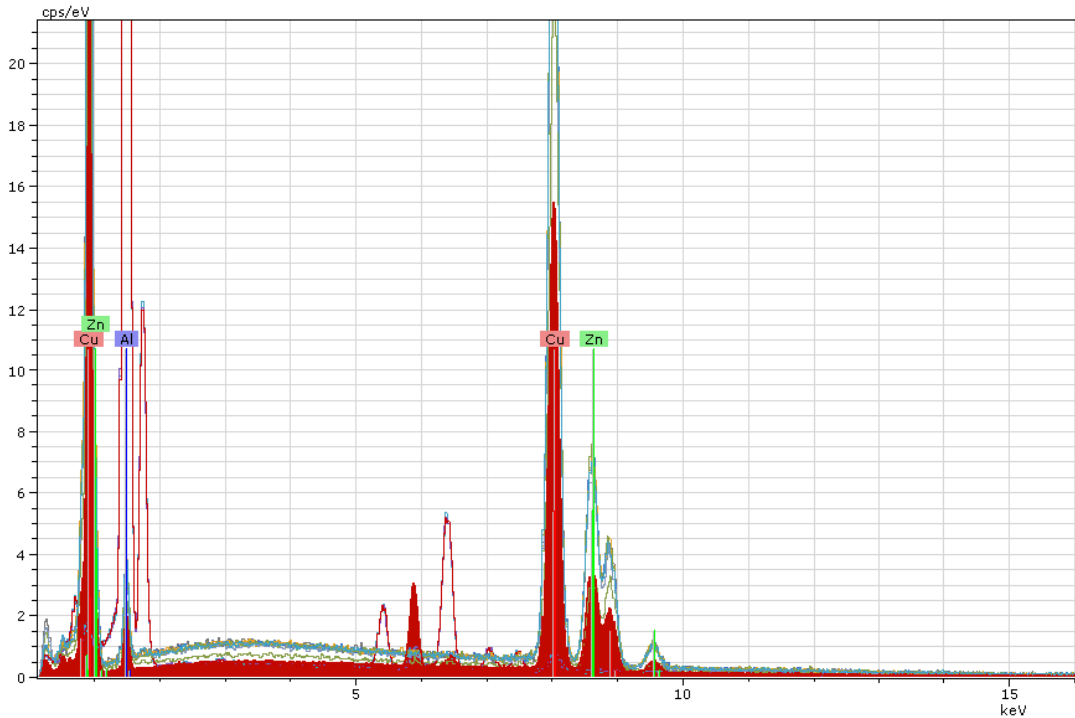
well in the microstructure, marked with red line in figure 2 c), having nanometric dimensions and being formed between big martensite variants. Different grains contain different orientation variants of martensite, presented in figure 2 c), parts of them

orientated at 90 degree. The 3 D representation of figure 2 c) present three different types of variants not only as shape and orientation but as high as well.

Chemical investigations of the matrix shape memory alloys were done on different areas of 4 mm<sup>2</sup> from the material surface and chemical

composition results (ten different areas) being averaged in table 1.

Spectral energies characteristics to shape memory alloy analyzed are presented in figure 3 with two energy connections for copper and zinc and a single characteristic energy for aluminum.



**Figure 3:** Spectral energy distributions of elements from composite material matrix

In table 1 weight and atomic percentages of the component elements are presented having a 72.84 % wt of copper, 20.42 % wt of zinc and 6.73 % wt aluminum. Atomic percentages

present a 67.11 contribution of copper, 18.29 % zinc and 14.597% aluminum that are combined as CuZn, Cu<sub>5</sub>Al<sub>9</sub> and Cu<sub>5</sub>Zn<sub>8</sub> formations [11].

**Table 1** Chemical composition of matrix material consisting of a shape memory alloy

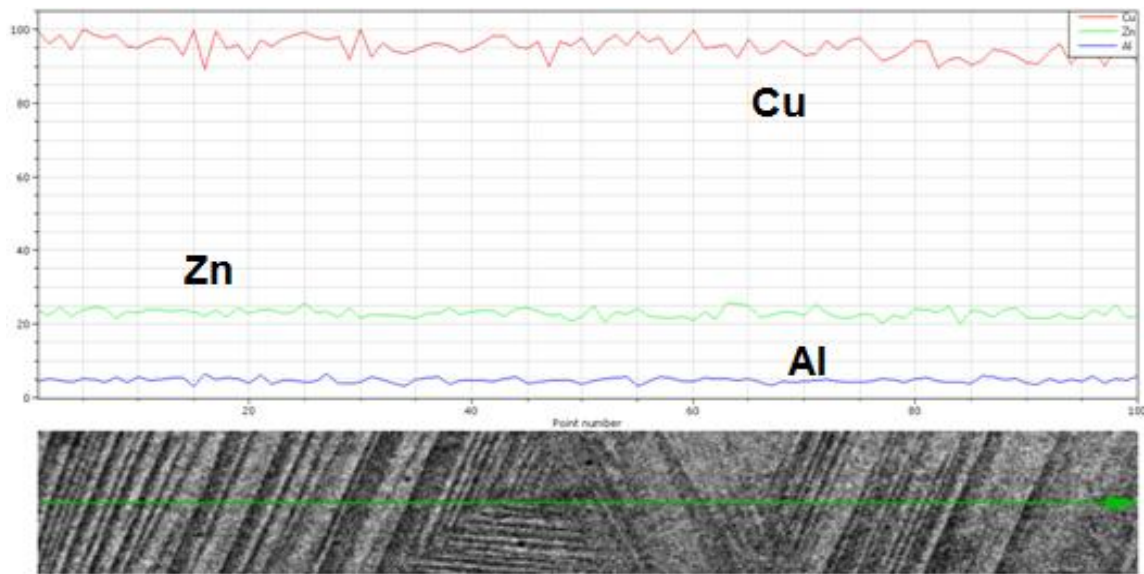
Element	AN	series	Net	[wt.%]	[norm. wt.%]	[norm. at.%]	Error in %
Copper	29	K-series	77223	64,25326	72,84393	67,11193	1,617906
Zinc	30	K-series	18388	18,01927	20,42844	18,2902	0,487459
Aluminum	13	K-series	3272	5,934216	6,727622	14,59787	0,360829
			Sum:	88,20674	100	100	

In figure 4 distributions of chemical elements copper, zinc and aluminum on a 100 μm line are presented and can be considered that the material homogeneity is very good exhibiting nice properties on entire material mass. Following the diagram from figure 4 can be observe a smoother behavior distribution of copper on the smaller martensite variants and bigger variations of all elements in the other

parts of the material. Having a smoother homogeneity shape memory alloys can be better controlled in practical applications. Shape memory alloys exhibit a nice damping capacity due through martensitic transformation that can be used in dissipation applications. Reinforcement of a shape memory alloy to increase their strength and helping the shape



memory recovery represent a goal of the researchers in this field.



**Figure 4:** Chemical elements distribution on a 100  $\mu\text{m}$  line of a shape memory alloy based on copper

Energy dissipation in shape memory alloys from mechanical to thermal is made especially on boundaries matrix between grains and martensitic variants. Modifying the grains number and dimensions and the variants shape, dimension and number can improve damping capacity of the material.

#### 4. Conclusions

A shape memory alloy based on copper was obtained through classical melting methods and analyze by Microstructural and chemical points of view.

The material is proposed for a damping composite having a high dissipation capacity in martensitic transformation domain of mechanical energy in thermal energy. Grain boundaries and martensite variants support most of the energy dissipation so is very important to control the material microstructure.

Showing different martensite variants and various dimensions the material present a good potential for damping composite metallic materials.

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