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Studying the Porosity Results of a Smart Alloy (CU-AL-NI) with Nano Copper Added and Comparing it with Other Additives

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ABSTRACT: This study compares the effects of adding copper nanoparticles to a shape memory alloy (83% Cu – 13% Al – 4% Ni) in terms of its porosity properties to another study that added Nano aluminum to the same alloy in the same proportions. Employing the same manufactured method. In exchange for decreasing the same percentage of the alloy's copper powder, the amounts of Nano-copper were altered. Nano-copper was added to the alloy in percentages of (0, 3, 5, 7, 9, and 11%). Before measuring the porosity, physical tests were conducted on the samples such as scanning electron microscopy and X-ray diffraction, to ensure the appearance of the martensite phase and the direction it takes, which has an impact on the studied property. The results of physical tests showed that the layer of martensite increased and appeared clearly when the nano-particles increased. The effect in the porosity of the alloy decreased, when copper nanoparticles increased, whereas the porosity of the first sample at (0%) Nano copper was (10.174), and when adding nano, the porosity of the last sample at a nano addition ratio of (11%) was (6.966), and comparing the examination results of this paper with previous research notice in both additions to the same alloy and same way of the samples manufacturing process. The porosity decreased, but the effect of adding nano aluminum on the porosity was greater than the effect of adding nano copper. The decrease in porosity compared to the first sample was due to the addition of nano-aluminum, which was more effective than the addition of nano-copper to the same alloy, as the percentage of decrease at the addition rate of (7%) nano-aluminum was (5.66%), and at the same rate, but with the addition of nano-copper, the percentage of decrease was (2.926%). The martensite appeared in one direction when copper nanoparticles were added, but it was multi-directional when nano aluminum was added.

KEYWORDS: Shape memory alloy; Powder metallurgy; Porosity test; Copper nanoparticles .

I. INTRODUCTION

Shape memory alloys (SMAs) are intelligent materials that can undergo the martensitic phase transformation when thermo mechanical loads are applied and can also return to their original form when heated above certain temperatures [1,2]. The shape memory effect was first discovered in 1930. The effect was observable in gold-cadmium alloys by a Swedish physicist, Arne Oland. Otsuka and Wayman discovered the pseudo-elastic characteristic of the Au-Cd alloys. Correspondingly, the shape memory influence was noted in substances such as aluminum, copper, and nickel in the 1950s. Wang and W Buehler investigated this influence in a NiTi alloy known as Nitinol. The first to find this Nitinol alloy was the American Navy Ordinance Laboratory. Since the 1980s, the lightweight and more versatile properties of Cu base alloy have made it useful in various compact structures. This approach was implemented to the shape memory material community in the 1990s [2].An austenite (A) parent phase and a martensite (M) produced phase undergo a phase transition that is the physical basis for "shape memory." This phase transition for SMAs is referred to as thermo elastic. It calls for a modification. Of crystalline lattice between phase martensite, sometimes referred to as the "low temperature" phase, and phase A, sometimes referred to as the "high temperature" phase. We refer to this alteration as a "martensitic transformation." It changes the austenite into "martensite variants" [3]. The primary feature responsible for the characteristics of shape memory alloys is the martensitic transformation, which begins with the transformation of austenite (high temperature phase) into martensite (low temperature phase). Additionally, this transformation is notable for being a diffusion less solid-state step that is demonstrated by nucleation and the formation pathway of the relative austenitic phase [4,5]. SMAs have a feature called the shape memory effect (SME) that makes thermo elastic martensitic transformation possible. When SMA is deformed during loading and unloading at temperatures lower than Mf, the shape memory effect takes place. These distorted alloys regain their original shape when heated to temperatures above Af, which causes the austenite phase to form. The cooling process causes the parent phase to change into the twined martensite (1 → 2). When the materials are loaded, inelastic strains and stress-induced de twinning may happen (2 → 3). Even after the unloaded process, the martensite phase remains in the same state as the de twinned structure with no recovered inelastic strains (3 → 4). Ultimately, the materials are heated above Af (4 → 1) in order to recover the inelastic

strains and return to their original shape [6]. As shown in "Fig 1."

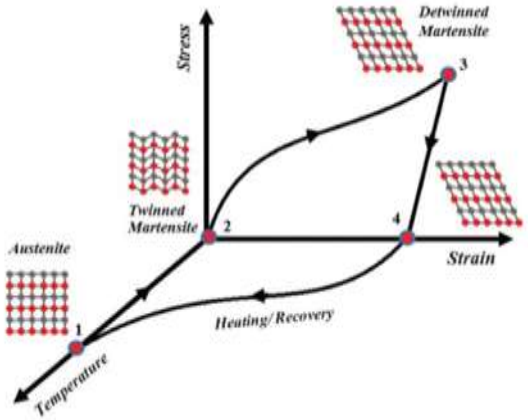


Fig. 1. diagram of stress-strain-temperature for the involved crystallographic changes during the phenomena of SME [6].

A variety of alloys, such as Au-Cd, In-Tl, Au-Cu, Fe-Pd, Fe-Pt, and others, show the shape-memory effect; however, only a small number of these alloys are employed in industry, primarily due to their high cost or poor qualities. There are only two types of alloys that are frequently utilized for applications: the NiTi category and the category of copper-based materials, which includes Cu-Zn, Cu-Al, Cu-Sn, Cu-Zn-Al, Cu-Al-Ni, Cu-Al-Be, and Cu-Al-Mn. [3]. In order to satisfy the needs of the application, the third element added to the binary and/or ternary is intended to change and regulate the transformation temperatures over a wide range. Generally speaking, alloys based on copper exhibit significantly less hysteresis than NiTi. The Cu-Zn-Al alloy is relatively inexpensive and easy to make making this alloy interesting in application [6]. The application of this (Cu-Al-Ni) SME in porous media actuators such membranes or filters, smart filtration systems, porous structures reinforcement, aerospace components or lightweight structural materials [7].

This paper will study the effect of adding Copper nanoparticles on the martensite layer and the porosity of (Cu – Al- Ni) shape memory alloy and compare previous research in which the same work methodology was followed regarding the manufacturing process and the tests conducted on the manufactured samples. In the last study, nano aluminum was added, in weight percentage (0, 3, 5, 7, 10, 15)% to (83% Cu-13%Al- 4%Ni) SMA, and its effect on the physical and mechanical properties of the alloy was studied. Among these properties inspected is porosity test. The samples were manufactured using the powder metallurgy technique. The pressing of the samples was in one direction, and the sintering temperature was 850 degrees Celsius. Thermal treatments were carried out on them, represented by quenching and aging processes. The results showed the porosity decreases when the percentage of nano aluminum increases Much research has been conducted to study the effect of adding nano elements to the (Cu-Al-Ni) SMA and their effect on porosity [8].

The effects of Ta additions on the microstructure and characteristics of Cu-Al-Ni shape memory alloys. the powders of Cu-Al-Ni-x Ta SMAs (x is 1.0, 2.0, and 3.0 wt.%) were prepared by powder metallurgy A field emission-scanning electron microscope (FE-SEM) energy-dispersive spectroscopy (EDS) , X-ray diffraction were used to examine the samples. The results show the addition of Ta, the porosity density and grain size decreased; the lowest porosity and smallest grain size were found in pre alloyed Cu-Al-Ni following the addition of 2.0 weight percent Ta [9].

The Effect of (Al-Ni) & (Cu-Ni) Concentrations Ratios on the Hardness and Porosity of Ternary (Cu-Al-Ni) Smart Alloys. Samples of (Cu-Al-Ni) smart alloys were created using a vacuum system and powder metallurgy. Five weight percentages of ternary (Cu-Al-Ni) smart alloys, Cu-Ni and Al-Ni, were chosen for this experimental setup. Using a digital Vickers micro-hardness tester, an X-ray diffraction device (XRD), an optical microscopic device, a scanning electron microscope (SEM), and porosity testing, the Vickers micro-hardness and porosity properties of these alloys were investigated. The analysis's findings demonstrated that alloy lead's hardness and porosity automatically increase as Al and Ni concentrations rise; however, an increase in Al ratio has a greater impact than an increase in Ni ratio. S5 (82.4%Cu, 14%Al, 3.6%Ni) is the best smart alloy; this is especially true for applications like self-lubricant application, as it yields the highest porosity (6.853% by volume) and of the five samples examined [10].

The effects of incorporating carbon nanotubes (CNTs) into shape memory alloy (SMA) were investigated. The percentages of carbon nanotube addition were 0, 0.5, 1, 2, and 2.5 percent about to the copper ratio (83% Cu, 13% Al, 4% Ni). Powder metallurgy (PM) was used in the manufacturing of the samples. The findings demonstrated that raising the concentration of carbon nanotubes (CNTs) to 2.5% increased the hardness by the same amount of CNTs. The porosity increases with increasing concentrations (0, 0.5, 1, 2) % [11].

The effects of vanadium element on the mechanical properties, microstructure, and shape memory effect of Cu-13.0 Al-4.0Ni-xV (x = 0.5, 1.0, and 2.0) (wt.%) high-temperature shape memory alloy. The findings indicate that the Cu-13.0Al-4.0Ni-xV alloys have a dual-phase morphology, with the (Al, Cu,Ni)V3 phase and 18R martensite making up the majority of the morphology. Vanadium is added and this considerably reduces the grain size. The solid solution strengthening and grain refinement of Cu-13.0Al-4.0Ni-xV alloys and the porosity reduced. also improve their mechanical properties. For Cu-13.0Al-4.0Ni-0.5 V alloy, a shape memory effect of 5.8% can be achieved when the pre-strain is 10% [12].

The influence of Mg addition on the mechanical properties of (Cu-Al-Ni) SMAs. The alloy (Cu 83%-Al 13%-Ni 4%) that was made by adding magnesium with a content of (0.25, 0.5, 0.75, 1.0, 1.25%)% as a volumetric ratio derived from the copper percentage were made by powder metallurgy [13]. The result show The apparent and the true porosity and the water

absorption decrease by decreasing the volume fraction of Magnesium [14].

The effect of adding Al_2O_3 Nanoparticles on the mechanical. Using powder metallurgy, the AL_2O_3 nanoparticle was added in (3,5,8) weight percent to the Cu-Ni/Al2O3 nano composite samples. As the concentration of Al_2O_3 increased, The porosity percentage increased from 3.7% in the Cu-Ni matrix to 10.8% in the Cu-Ni-8%Al2O3 Nano composite [15].

The effect aluminum nanoparticles on the mechanical properties of memory-shaped alloys (Cu-Al-Ni) SMA aluminum nanoparticle was add in weight percentage 3,5,7,10,15 wt% to(Cu-Al-Ni)alloy samples are manufacture using powder metallurgy Vickers micro-hardness testing was performed. The results show In the porosity test of the samples under study, the rise in the percentage of nanoparticle addition decreases the porosity [16].

This paper will study the effect of adding Copper nanoparticles on the martensite layer and the porosity of (Cu-Al-Ni) shape memory alloy and compare previous research in which the same work methodology was followed regarding the manufacturing process and the tests conducted on the manufactured samples. In the last study, nano aluminum was added, in weight percentage (0,3,5,7,10,15)% to (83%Cu-13%Al- 4%Ni) SMA, and its effect on the physical and mechanical properties of the alloy was studied. Among these properties inspected is the porosity test. The samples were manufactured using the powder metallurgy technique. The pressing of the samples was in one direction at pressure (650 Mpa), and the sintering temperature was (850ºC). Thermal treatments were carried out on them, represented by quenching and aging processes. The results showed the porosity decreases when the percentage of nano aluminum increases [16].

II. THE MATERIALS AND METHODOLOGY USED

MATERIALS

The alloy consisted of 83% copper, 13% aluminum, and 4% nickel powders with copper nanoparticles added. After the powders and nanoparticles were prepared, they were tested using energy-dispersive X-ray (EDX) (AXIA thermo scientific) and scanning electron microscopy (SEM) (3000 X Magnification ratio) to ensure the metal purity and particles shape. "Table I" lists the powders used in this paper and their parameters.

Table I. Powder Used In Prepare Alloy

Materials	Purity	Particle shape	Particles size	Origen
Copper (Cu)	97.6	Spherical	425mesh	USA
Aluminum (Al)	96.4	Acicular	250 mesh	England
Nickel (NI)	98.8	Spongy	200 mesh	China
Copper nano particles	98.1	Spherical	10-30 nm	China

Methodology

Powder metallurgy (PM) was used to manufacture the samples in this study. Twelve smart alloys (83% Cu-13% Al-4% Ni) with dimensions of (11) mm in diameter and (5) mm in length were manufactured, with the concentrations varying based on the percentage of copper nanoparticles added (0, 3, 5, 7, 9, and 11) %. "TABLE II" displays the weight percentage of powders and nanoparticles in grams and the nano-add ratio. Two samples were produced from each weight and addition.t

TABLE II.The weight percentage of powder

NO OF SAMPLE	CU gm.	NI gm.	AL gm.	NANO RATIO %	NANO ADD gm.
CSD1	2.49	0.39	0.12	0	0
CSD2	2.4153	0.39	0.12	3	0.0747
CSD3	2.3655	0.39	0.12	5	0.1245
CSD4	2.3157	0.39	0.12	7	0.1743
CSD5	2.2659	0.39	0.12	9	0.2241
CSD6	2.2161	0.39	0.12	11	0.2739

Three steps make up powder metallurgy: mixing, compacting, and sintering. to achieve the best mixing performance, the powder is first mixed using a horizontal mixing device for six hours at a speed of (71) rpm at room temperature after the percentage weight has been weighed using a sensitive balance (KW-3018 series 3 Digit), to achieve optimal mixing with 1% acetone of the volume of mixing powder for lubrication and to avoid segregation due to varying densities of the alloying elements, the powder is placed in a glass container at 40% of its volume. The samples were compressed in the second stage using an electric press machine (MEGA KPD-50E) with punches and dies. The samples were compressed in two directions. The samples are shaped like discs and have dimensions and weights of (11) mm in diameter, (5) mm in length, and (3) g. They were pressed at workshop temperature (18º C), and the pressure was (650) MPa. Twelve minutes was the critical time for pressing the disc sample, and two minutes was the holding time. A holding time was established before removing the sample from the mold in to stop it from springing back. To lessen friction between the powder particles and the mold walls, an oiler with a density of (0.88) g/cm³ was utilized.

Heat Treatment

After pressing of the samples, the third stage was the sintering process performed for the samples. This purpose aims to strengthen the samples and obtain the austenite phase. The samples are placed in the electric furnace (MTICR GSL 1600 X), in the combustion chamber with both ends of the chamber closed with high-temperature insulating materials. The furnace has an insulation system using argon inert gas. The benefit of the buffer gas that it prevents oxidation of the samples during the sintering process and expels the gases emitted during the process, which in turn leads to damage to the samples. The sintering process is performed in two stages. The first stage was heating the samples from room temperature to(500 C) at a heat rate (15 C/min) for one hour and then raising the temperature to (850 C) at a rate of (7 C/min) for five hours and then letting the samples cool down in the furnace, as shown in "Fig 2".

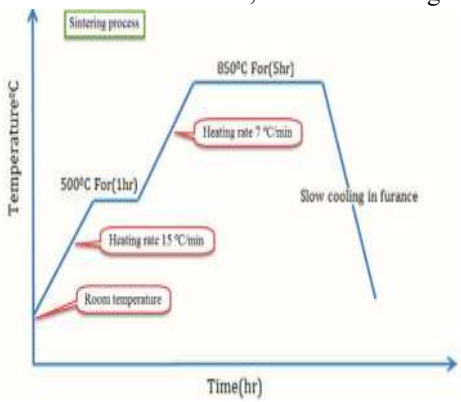


Fig. 2. Thermal cycle of sintering process.

After the manufacturing of the sample was completed, heat treatment was performed. The purpose of this process is to get on the martensitic phase and stabilize this phase. Heat treatment was conducted in two stages. The first stage (quenching) was heating the samples from room temperature to (800ºC) at a rate (of 15º C/min) for one hour and then cooling the sample rapidly in ice water. This stage was conducted to get the martensite phase. The second stage (Aging) was heating the sample from room temperature to (100º C) at a rate of (20º C/min) for two hours to stabilize the martensite phase, as shown in "Fig 3". And "Fig 4".

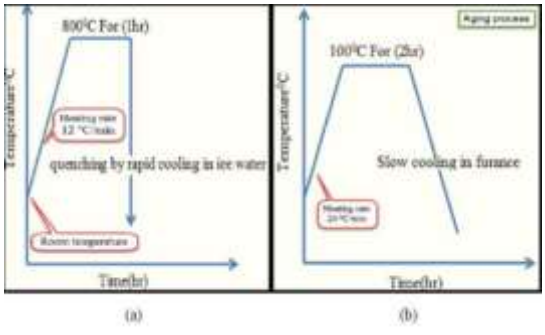


Fig 3. Thermal cycle of heat treatment (a) quenching process (b) Ageing proceed

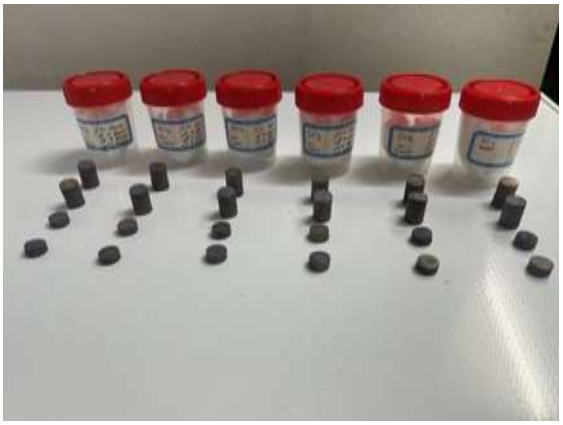


Fig. 3. Samples after heat treatment.

Grinding and polishing was done after heat treatment to prepare the samples for testing grinding was done using a grinding device (KHUTM-ROTOR) with two types of grinding paper with water. The first type was waterproof aluminum oxide paper (100,400, 600, 2500), and the second type was waterproof silicon carbide paper (220, 600, 1000, 2500) to get rid of scratches and correct the sample's face. The polishing process was carried out using a polishing device (KHUTM-ROTOR) with cloth paper and diamond paste, and polishing liquid to eliminate very fine surface scratches on the samples.

III. PHYSICAL AND MECHANICAL TESTS

The following physical tests were performed on the manufactured samples to identify the phase that is responsible for the creation reliability of this kind of alloy:

- Scanning Electron Microscopy: This test was used to show the layers of martensite after heat treatment.
- XRD X-ray diffraction: This test was used to confirm the existence of the martensite phase.
- Porosity test: The three-digit sensitive balance (type KERN 770) was used for this test. The porosity test was conducted on a sample that measured 11 mm in diameter and 5 mm in thickness. The sample was put through three stages of testing: first, it was measured the mass of samples in the air; second, it was measured after being submerged in distilled water for 24 hours at 20 C, giving it a density of 0.9984 g/cm^3; and finally, it was immersed in oil, which has a density of 0.88 g/cm^3, in a sealed glass container under vacuum pressure for 30 minutes and then measured the mass of the samples and the porosity was calculated according to equation (1) [17].
- $P = \frac{B-A}{B-F} \times Dw \times 100\%$ .....(1)
- A = mass in air of oil-free sample, gm.
- B = mass of oil-impregnated sample, gm.
- F = mass of oil impregnated specimen in water with mass of wire tarred, gm.
- D w = density of distilled water at the immersion temperature.
- D oil = density of the oil, 0.88 gm/cm3.

The porosity test was done on twelve samples divided into two groups, and two readings were performed for each sample and then the average was taken between every two samples as shown in "TABLE III"

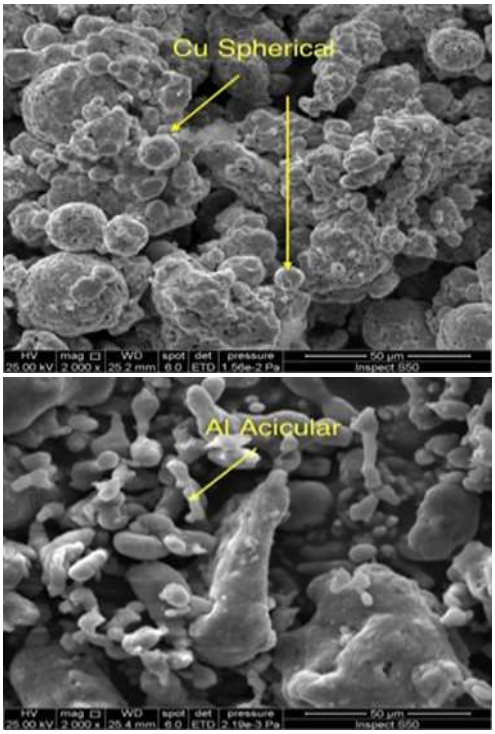
TABLE III the results of porosity test

Sample	W In air	W In water	W In oil	Porosity	Average
CSD1	2.512	2.029	2.563	10.949	10.174
	2.206	1.806	2.243	9.40	
CSD2	2.221	1.785	2.262	9.912	9.080
	2.400	1.966	2.438	9.096	
CSD3	2.474	2.048	2.500	7.535	8.295
	2.161	1.745	2.198	9.054	
CSD4	2.412	1.951	2.445	7.338	7.248
	2.411	1.947	2.442	7.159	
CSD5	2.683	2.197	2.711	6.255	7.176
	2.554	2.063	2.592	8.098	
CSD6	2.261	1.854	2.284	6.059	6.966
	2.248	1.883	2.279	7.874	

IV. RESULT AND DISCUSSION

Before discussing the results of the porosity test, some physical tests were conducted, and the results:

- It has been demonstrated through testing with SEM to look at particle shapes that powders come in a various forms. The copper particles were shaped (spherical), while the aluminum particles were (Acicular), the shape of the nickel particles was (spongy), and the copper nano particles were (spherical). Because of their different shapes, the raw materials' particles interact better, increasing their bonding force and decreasing voids and porosity, as shown in "Fig 5".



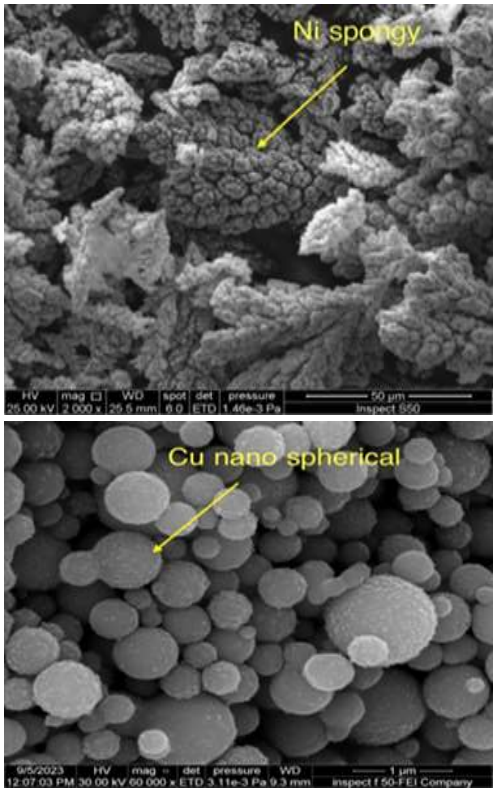
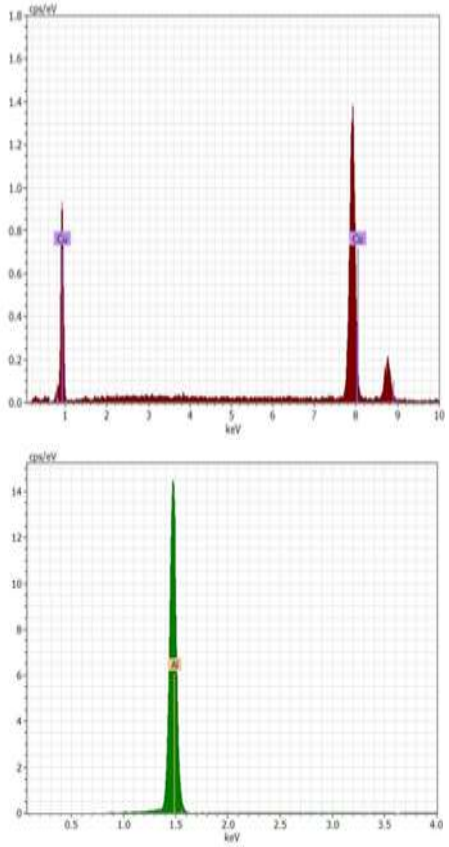


Fig. 4. SEM for Raw Materials (Cu , Al , Ni , Cu Nano Particles).

2. The results of the tests using EDX to determine the purity of the raw materials were having Cu (97.6), Al (96.4), and Ni (98.8), and Cu nanoparticles (98.1), as shown in "Fig 6". Which is good purity can be in the manufacturing process of the samples.



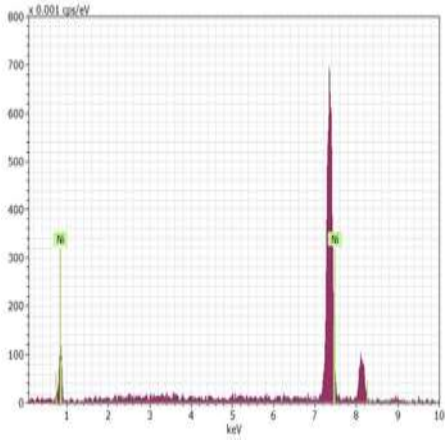
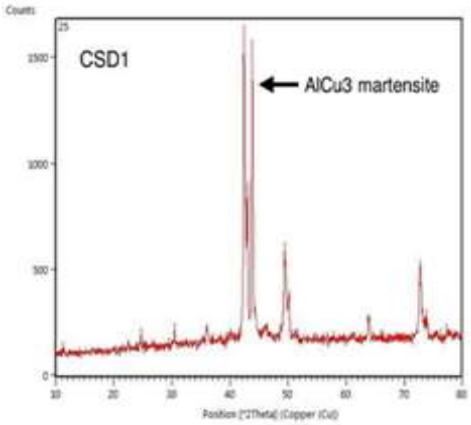
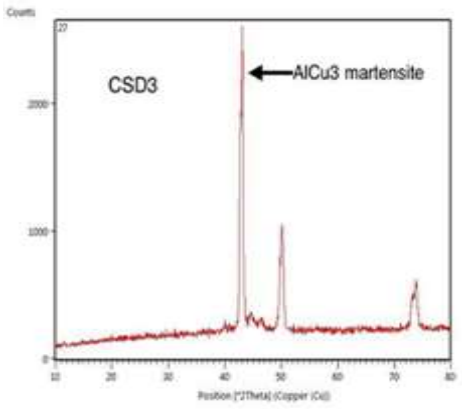
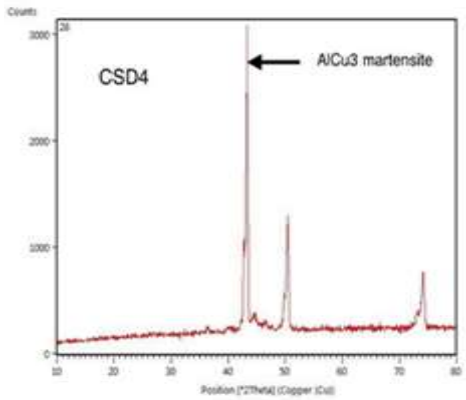


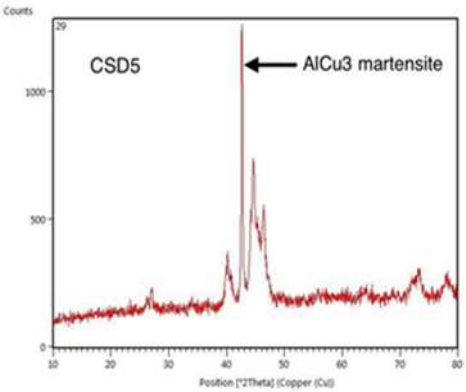
Fig. 5. EDX image for Raw Materials

- According to data analysis, the martensitic phase (AlCu3) is present in the samples, after comparing the XRD test results with standard peaks and test equipment tables. The sintering, quenching, and aging processes successfully produced the martensite phase in every sample used in this experimental work. The martensitic phase is the primary factor causing shape recovery, and it developed in all of the study samples. The analysis of each sample shows that the crystalline microstructure of the martensitic phase is the same in all of them. Since every sample is present in the phase (AlCu3), as shown in "Fig 7".









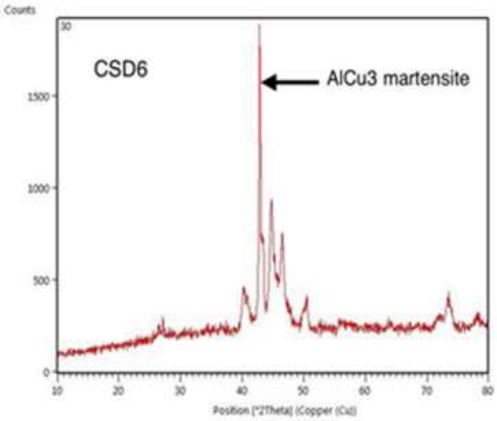
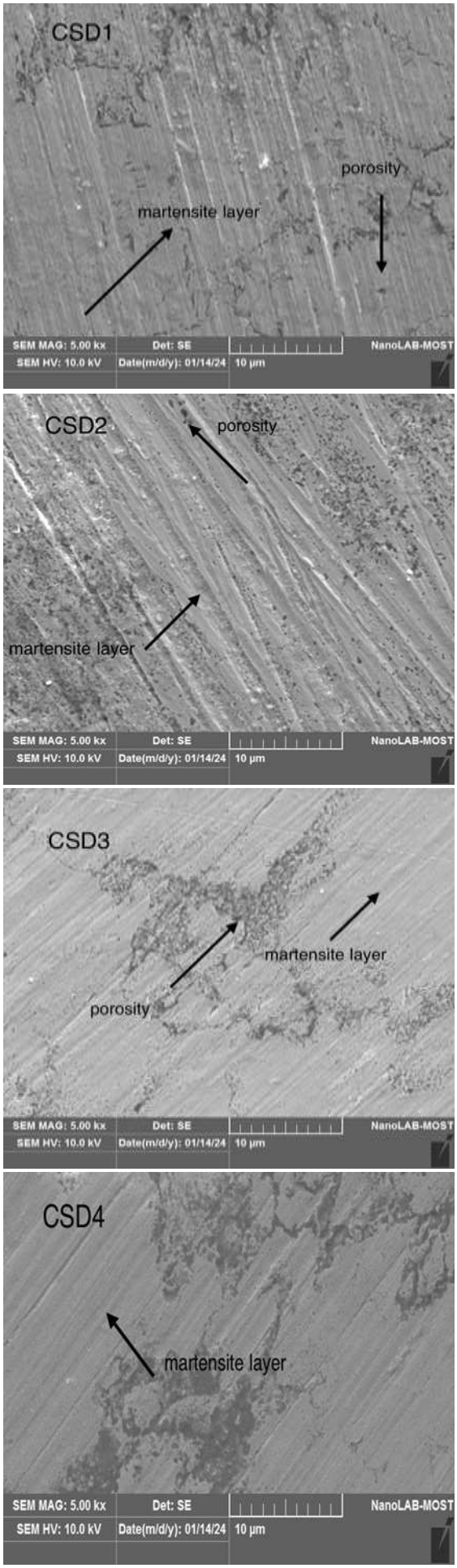


Fig. 6. Results of XRD Test for Manufacturing Samples

The tests finding using scanning electron microscopy, were examined the sample's structure following heat treatment (quenching and aging) and to determine its martensite phase. The CSD6 sample, which has a percentage of 11% nano adding, has been found to have a higher and more distinct layer of martensite than the base sample, CSD1, which has a percentage of 0% nano-adding. In a similar way, the CSD2, CSD3, CSD4, and CSD5 samples have all shown increased in martensite layers compared to the base sample, CSD. It can be said that a higher percentage of nano addition results in a higher martensite layer, as shown in "Fig 8".



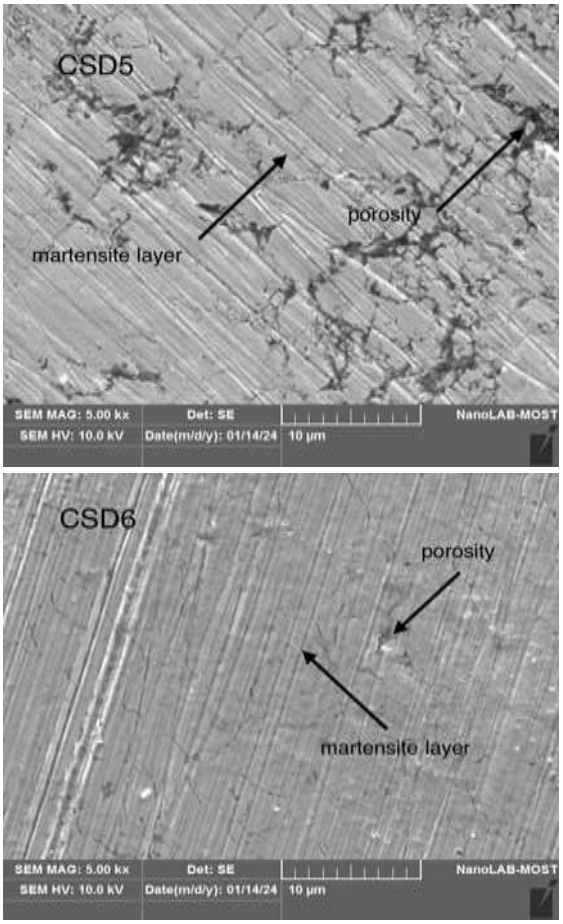


Fig. 7. Results of SEM Test for Manufacturing Sample

"TABLE III" and "Fig 9" show the results of the samples' porosity tests. Twelve samples were used for the test, divided into two groups, and the average sample was chosen from each pair of samples. The porosity measurement showed a decline as (CU) increased. The average porosity of (CSD1) is (10.174), it is the highest value. While it decreased by (1.09%), as the average value (9.08) for the second sample (Sd2), The third sample (CSD3) declined from the base sample (CSD1) by (1.88%), the fourth sample declined by (2.93%) from (CSD1), the fifth sample (CSD5) declined by (2.99%) from the base sample and finally, last sample declined by (3.2%) from the base sample, as shown in"TABLE IV" The curve's analysis showed that porosity decreases as copper nanoparticales concentration rises. This is because copper nanoparticles fill the atoms' spaces in the base alloy, reducing the amount of pores between them.

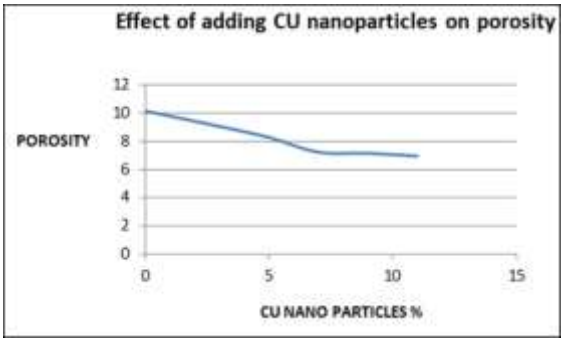
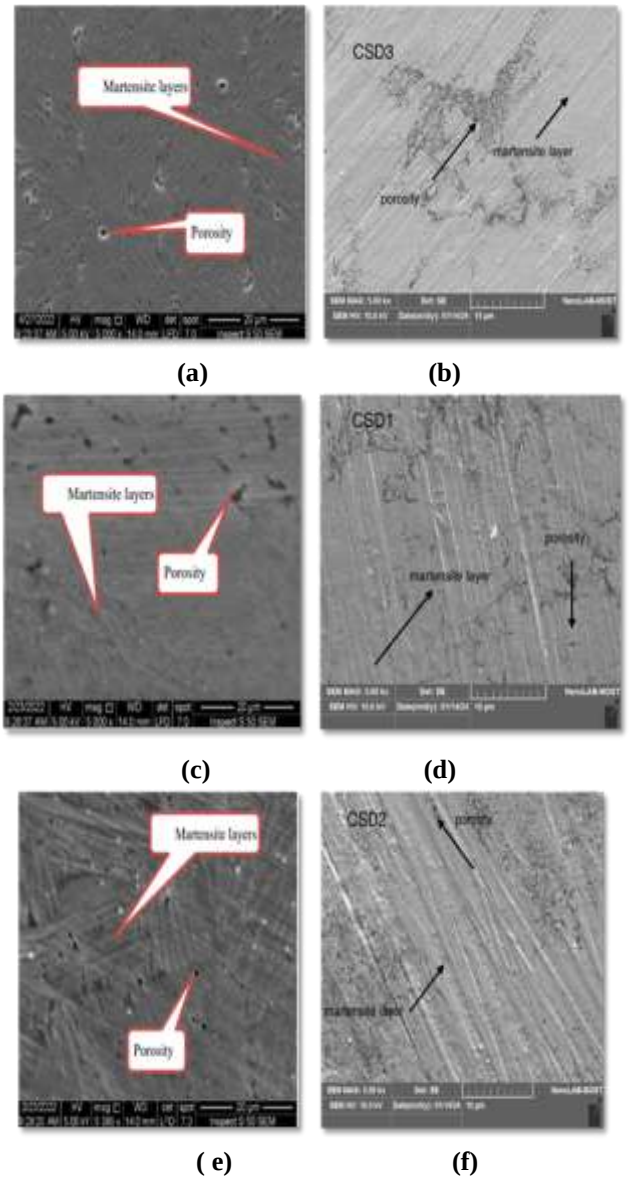


Fig. 8. effect adding copper nanoparticles on porosity

TABLE IV The amount decline in porosiry over base sample

Sample No	The amount decline in porosity over base sample
CSD1	1.09%
CSD2	1.88%
CSD3	2.93%
CSD4	2.99%
CSD5	3.2%

- When comparing the current study with earlier studies that used the same methodology and the same ratio addition of nano (0, 3, 5, 7) %, but added aluminum instead of copper [15], it was found that the effect of nano copper on the martin site layer was more appearant. The layers were in one direction, unlike the martensite layer, when aluminum was added the layers appeared less clear than when copper nano particles was added. The martensite layers were in several directions, as shown in "Fig 10".



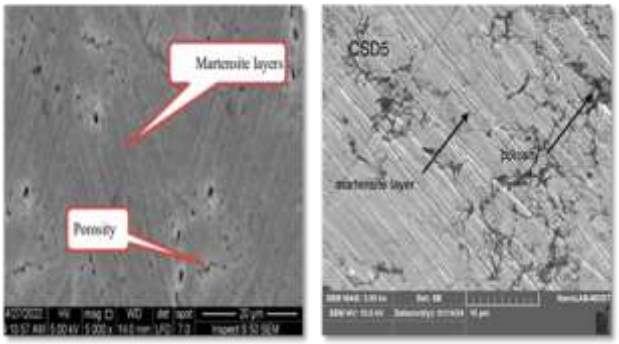


Fig. 9. Comparison in Martensite Layer Between Al Nano Add & Cu Nano Add to Cu-Al-Ni SMA

(a) Martensite Layer with 0%Al nano [15].
(b) Martensite Layer with 0% Cu nano.
(C) Martensite Layer with 3%Al nano [15].
(d) Martensite Layer with 3% Cu nano.
(e) Martensite Layer with 5%Al nano [15].
(f) Martensite Layer with 5% Cu nano.
(g) Martensite Layer with 7% Al nano [15].
(h) Martensite Layer with 7% Cu nano.

Compared to earlier research that used the same working principle and added percentages of nanomaterial, with a difference in the additive, it has been observed that adding nano aluminum to the same alloy results in a decrease in porosity with increasing nano percentages. According to the current study, we observe a decrease in porosity with an increase in the percentage of nanoparticles when we add nano copper material to the same alloy. Nevertheless, adding aluminum nanoparticles reduces porosity more effectively than adding copper nanoparticles. As shown in "TABLE V" and "TABLE VI".

TABLE V Results of previous reserch [16].

Nano addition	Porosity
0%	21.140
3%	19.827
5%	19.01
7%	15.476

TABLE VI Results of current reserch

Nano addition	Porosity
0%	10.174
3%	9.080
5%	8.295
7%	7.248

When comparing the amount of decreasing the porosity over the base materials for the same nano addition between previous and current research, it has been noticed that the decrease in porosity due to the AL nano addition is more effective than CU nano addition for the same percentage. At (3%) Al nano adds, the reduction in porosity is (1.313%) over the base sample, and it was higher than Cu nano adds at the same percentage (1.09

%). This is the same for the rest of the addition ratio as shown in "TABLE VII", "TABLE VIII", and "Fig 11".

TABLE VII previouse reserch [15]

Nano addition	The amount of reduction in porosity over base samplte
3%	1.313
5%	2.13
7%	5.66

TABLE VIII currecnt reserch

Nano addition	The amount of reduction in porosity over base samplte
3%	1.09
5%	1.87
7%	2.926

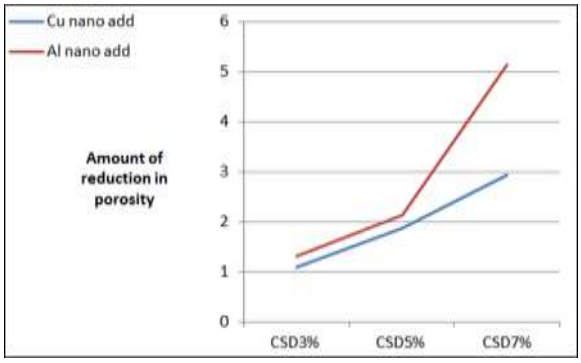


Fig. 10. A chart Show The Comparison Between the Amount of reduction in porosity for the Previous Research AL Nano Add [ ] and Current Research Cu Nano Add

The research was confronted with several obstacles, such as the expense of the raw materials, manufacturing process and testing procedures because of the scarcity of testing and manufacturing equipment.

Future researchers can benefit from this research by adding different nanomaterials to the same alloy, using the same manufacturing method, conducting other tests such as hardness testing or shape memory testing, comparing the results with previous research, and using statistical methods for the results.

V. CONCLUSIONS

- According to physical tests, an increase in the percentage of copper nanoparticles leads to a corresponding increase in the martensite layer. This phase, which is thought to have a higher hardness than other structural phases, consequently reduces porosity.
- The particles of the raw materials interact better because of their varied shapes, which increases their bonding force and decreases voids and porosity.
- The porosity test of the samples under study shows the increase in the percentage of nanoparticle addition led to a decrease the porosity, where its value for the first sample without Nano addition is (10.174), while a decrease in porosity for the sixth sample with 11 % Nano addition reached the minimum value (7.248).
- By comparing the current research (addition of nano-copper) and other research (nano-aluminum addition). It has been noted that adding nano-copper to the (Cu-Al-Ni) SMA causes the martensite layers to appear more clearly than when nano-aluminum is added to the same alloy. Additionally, the direction of the martensite layers is more regular and directed when adding nano-copper than when adding nano-aluminum, as opposed to the martensite layers being in different directions.
- When the current study was compared to earlier studies that used the same addition process, sample manufacturing techniques, and addition weight ratios, the additive material was different. It has been observed that porosity decreases with increasing nano percentage for nano-aluminum added to (Cu-Al-Ni) SMA. Also the porosity decreases with increasing nano percentage for nano-copper added to the same alloy. However, adding Al nanoparticles has more significant impact on reducing the alloy's porosity than adding Cu nanoparticles.
- The important contribution to modern application of (Cu-Al-Ni) SMAs in porous forms in biomedical implants, actuators in aerospace or micro devices, vibration damping in strictures or equipment, advance filters.
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VI. ABBERVIATIONS

SMAs	Shap memory alloys.
PM	Powder metallurgy.
A	Austenite phase.
M	Martensite phase.
SME	Shape memory effect.
MF	Martensite finish temperature.
AF	Austenite finish temperature
FE-SEM	Filed emission scaning electron micro scope .
SEM	Scaning electron microscope
EDS	Eenrgy dispersiv microscope
EDX	Eenergy dispersive x-ray
XRD	X-ray diffraction
MESH	Count the number of openings in one linear inch of screen .
R.P.M	Revolusions per minute .
P	Porosity test .

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AUTHOR'S CONTRIBUTIONS

All authors read and approved the final manuscript.

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AVAILABILITY OF DATA AND MATERIALS

The dataset used and/or analyzed during the current study are available from the corresponding author on reasonable request.

DECLARATIONS

Competing interests

The authors declare that they have no competing interests.

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