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Zirconia – Yttria System for Manufacturing Ceramic Dental

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ABSTRACT

Zirconia-yttria oxide nano powder was prepared for ceramic dental industry Yttria (Y_2O_3). Magnesia oxide (MgO) nano powders were added to zirconia in different ratios to determine the best ratio as a stabilizer for zirconia. Alumina was added to (zirconia-yttria) system in different ratios. Dry pressure -dry pressing was used to prepare the specimens at a pressure of (2.5) tons, sintering at 1570°C. The physical tests were studied (apparent porosity, result in apparent porosity (0.05%), apparent density, result (6 gm/cm^3), and X-ray diffraction analysis were studying phases in the system. X-ray diffraction results showed that adding (Y_2O_3) at 3% is the best, as it obtained the highest percentage of tetragonal zirconia.

Keywords: Zirconia (ZrO_2), yttria (Y_2O_3), magnesia (MgO), alumina (Al_2O_3), ceramic dental, stabilizer

1. INTRODUCTION

Zirconia systems are widely and successfully used in the dental porcelain industry. Zirconia is one of the most important materials used in the dental industry due to its excellent mechanical properties and tooth-like color [1] zirconia-based dental materials are attractive to the general market. Due to their high bending strength, fracture toughness, biocompatibility, function, and affordability [2]. Due to the exceptional mechanical properties of ZrO_2, such as biocompatibility, high mechanical strength, and extremely high wear resistance, and friction, in dentistry, the use of ZrO_2 ceramics as a biomaterial for dental implants and crowns has increased dramatically [3]. At room temperature, zirconium dioxide (ZrO_2) is an oxide with a monoclinic crystal structure [4-5]. The most widely used phase in dentistry is the tetragon, which consists of three phases: monoclinic (M), cubic (C), and tetragonal (T) [6-7]. The problem of zirconia is the phase transitions, to solve this problem the stops (Cao, MgO, CeO_2, Y_2O_3) [8] are added, in small weight ratios to stop the phase transitions upon cooling after sintering from (T to M). Partially stable zirconia has a strong flexibility to temperature changes, making it suitable for application in high temperature environments. The monoclinic phase is tetragons generated at ambient temperature and after heating to 1170°C, tetragons are formed between 1170°C and 2370°C (and above 2370°C cubed) [20]. When cooled, the transition from tetrahedron (t) to monoclinic (m) phase leads to a significant increase in volume (4.5%). The tetragonal structure of zirconia alloys can be maintained at room temperature by adding Cao, MgO, Y_2O_3, or CeO_2. Phase transitions from T to M will be controlled [9-11]. To improve the situation and characteristics of the system, alumina (Al_2O_3) was added with different weight percentages (5%, 10%, 15%, and 20%).

The aim of this research is to prepare a (zirconia – yttria) system to preserve the tetragonal phase of zirconia after sintering by adding stops yttria (Y_2O_3), and alumina was added to improve the properties in general. Table 1 below lists the general properties of zirconia. These properties of zirconia have made wide applications in the present lives [13].

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Table 1 General properties of zirconia

Property	Amount
Color	white
Chemical composition	Zirconia, yttrium oxide 3 mol%
Density g/cm3	>6
Porosity%	<0.1
Hardiness HV	1200

2. EXPERIMENTAL PARTS

2.1 Materials

Nano-zirconia manufactured by a (fix anal, Hannover) German company was used. With a particular size of less than 45nm and a purity of 99.9%, the color of powder is pure white. Nano yttria (Y_2O_3) by a (sky spring), purity of 99.995% color of the powder is pure white and magnesia stabilizer by a German company with a particular size of 30-50 nm. Addition of the reinforcement material Nano Alumina manufactured by the company (sky spring), the purity of 99.9%, and binding ingredient was (polyvinyl alcohol).

2.2 Methods

- (Zirconia – yttria) system oxide nano powder was prepared according to the percentage listed in Table 2.
- (Zirconia- magnesia) system oxide nano powder was prepared according to the percentage listed in Table 2.
- The solution of the binder was prepared by dissolving vinyl alcohol in water according to the proportion (20ml:0.50g) using a magnetic stirrer..
- Specimens reinforced with Nano-alumina were prepared according to the percentage lists in Table 2.

Specimens were formed by semi-dry pressing method binder was added to all the specimens. Then formed by a mold and pressed by a hydraulic press under a pressure of 2.5 tons. At list, it was sintered in an electrical furnace at 1570°C. Materials were added according to the proportions listed in Table 2. Materials were added according to pedigree lists in Table 2.

Table 2 Symbols and code for (Zirconia – yttria) system

Matrix	Sample Code	Addition
zirconia	1	0%
Yttria	2	3%
Al_2O_3	3	5%
Al_2O_3	4	10%
Al_2O_3	5	15%
Al_2O_3	A	20%
MgO	B	3%

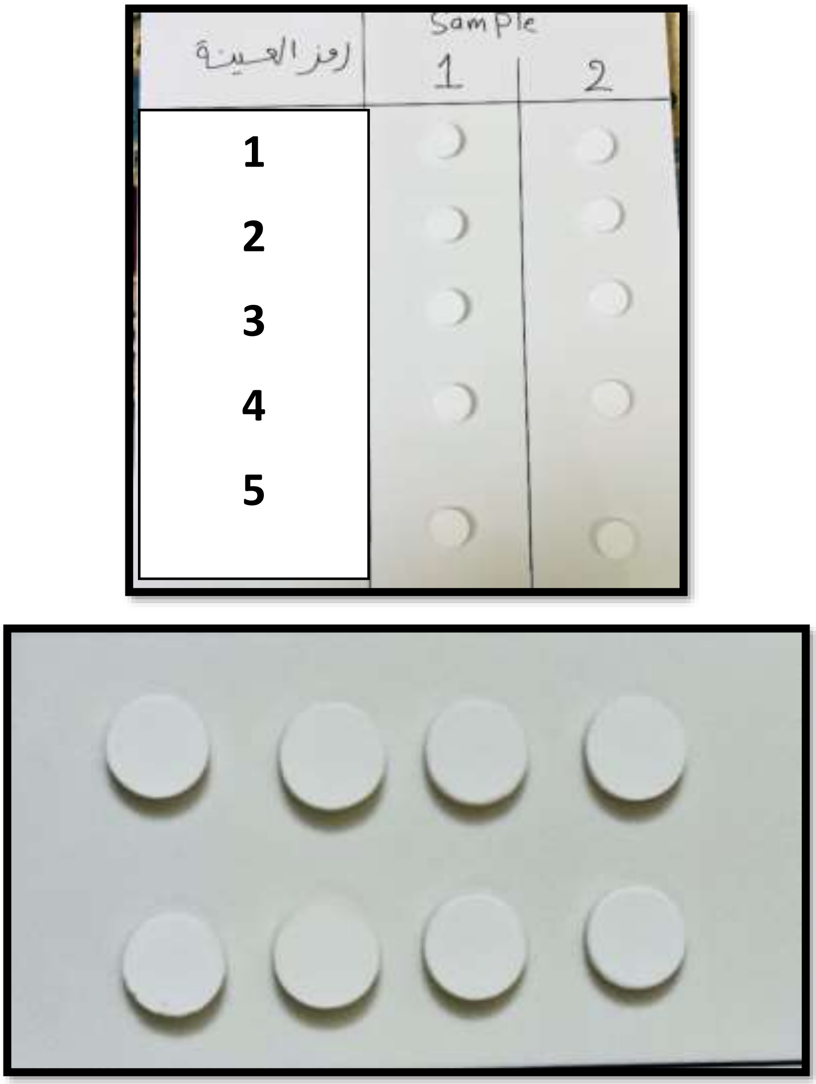

Figure 1. Specimen of zirconia.

2.3 Archimedes Method

Apparent density, water absorption, and apparent porosity, where Archimedes method was used to compute it. To remove water that has become trapped in the pores, a dry specimen weighing (Wd) was immersed in water for thirty minutes After that, the specimens were cooled to room temperature and weighed to determine the weights of being infiltrated with water (Ws) and being immersed in water (Ws) (Wn).

$$(A.D) = \frac{Wd}{Ws-Wn} \times D \tag{1}$$

$$(A.p)\% = \frac{Ws-Wd}{Ws-Wn} \times 100 \tag{2}$$

$$(W.S)\% = \frac{ws-wd}{wd} \times 100 \tag{3}$$

Where: W_d is weight of the dry spaceman. W_s is weight of a spaceman being infiltrated with water. W_n is weight of a spaceman being immersed in water.

2.4 X-ray Diffraction

Shimadzu-6000 X-ray Diffractometer with graphite monochromatic and copper anode for K radiation. At a wavelength of 0.154 nm, the X-ray tube was operated at 40kV and the 30mAhe scanning range is 20.0000 - 70.0000 degrees with a step size of 0.02° and 0.10 seconds each step.

3. RESULTS AND DISCUSSION

Apparent porosity is one of the most important characteristics that must be controlled during manufacture of ceramic dental from ceramic materials because of its great impact on the work of the ceramic dental and the period of use since presence of pores means penetration of saliva and fluids inside ceramic dental body. This is not a good factor because it is a medium for bacterial growth. It is best to manufacture porcelain teeth that have less porosity in the phases of the sintering (cooling and heating) process of zirconia, a phase shift from tetragonal (t) to monoclinic (m) phase was achieved characterized by a significant increase in grain size (~4.5%), polymorphism, which occurs during cooling. The change in size leads to a catastrophic failure in the limits of flexibility and fracture, which results in cracks and defects in the teeth without oxides, and this, is consistent with [14]. To stop this transformation, (Y_2O_3 and MgO) were added as breakpoints to partially stop the transformation, zirconia systems were converted to zirconia partially stopped temperature regime, particle size, fine material, overall structure, and the concentration of stabilizing oxides all play a role in the T to M conversion. [15-16]. The apparent porosity decreases by adding (Y_2O_3, MgO) to zirconia systems because these added particles are nanoparticles and thus contribute to filling the zirconia voids, thus reducing the porosity and this is a good behavior and suitable for the previously mentioned side effects of pores. The comparison of addition of (Y_2O_3, MgO) showed that Y_2O_3 is better and more efficient than magnesia, as it showed lower porosity. (Y_2O_3, MgO) addition effect on the apparent porosity as shown in Figure 2.

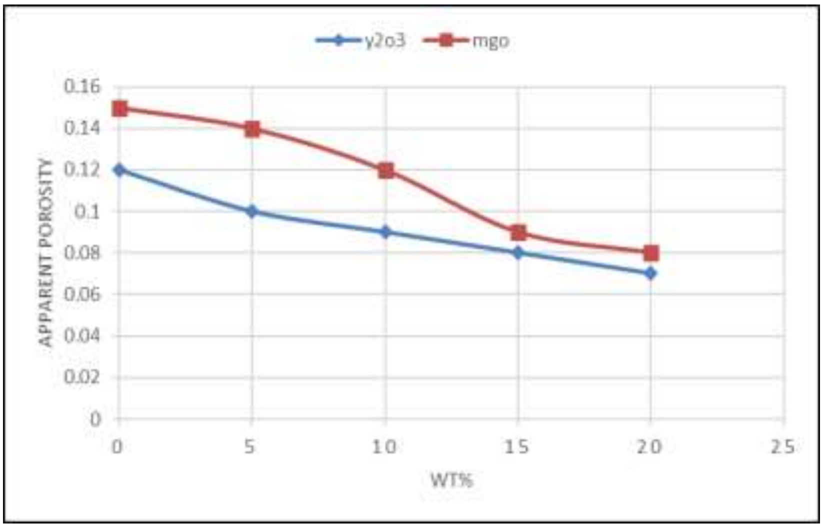

Figure 2. Effect of (Y_2O_3, MgO) addition on the apparent porosity of zirconia systems.

Figure 3 shows the effect of adding Al_2O_3 on the apparent porosity. From Figure 3, alumina has been added to improve the general properties and lead to a decrease in porosity. Since alumina was added as nanoparticles filling the pores and voids, we obtained a decrease in the apparent porosity. These results are consistent with [17-19].

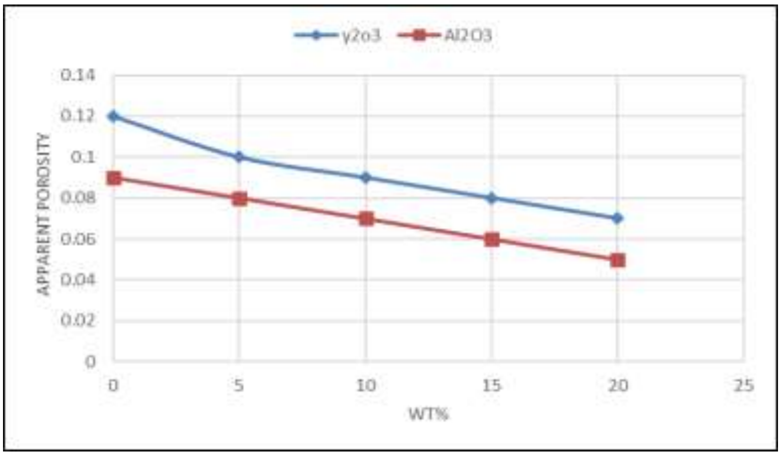

Figure 3. Effect of (Al_2O_3) addition on the apparent porosity of (zirconia -yttria) systems.

Figure 4 shows the effect of nano-oxide powder of (zirconia-yttria) and (zirconia-magnesia) systems on water absorption. From Figure 4 there is a decrease in water absorption with the addition of (Y_2O_3, MgO) because it is directly related to the apparent porosity, as it represents the amount of water or fluid that enters the ceramic body through the open pores. Therefore, the lower the porosity, as a result, the water absorption decreases, as it decreases with the addition of (Y_2O_3, MgO) as breakpoints, agreeing with [20-21]. Figure 5 shows the effect of Al_2O_3 adding on (zirconia -yttria) system. From Figure 5 we notice a decrease in the absorbance ratio by adding Nano-alumina, meaning that it behaved the same as the apparent porosity.

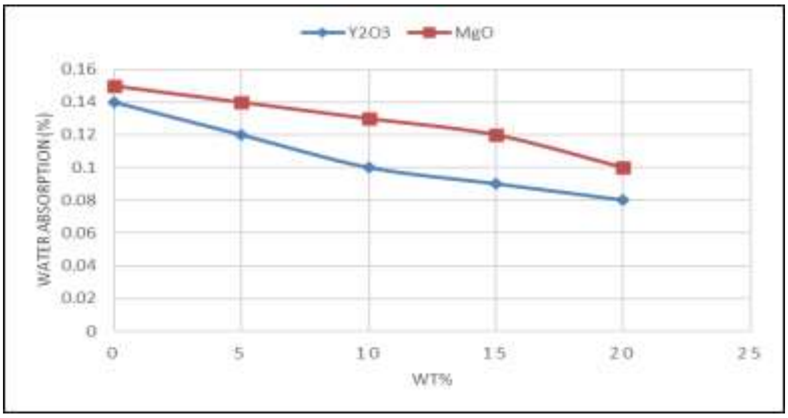

Figure 4. Effect of (Y_2O_3, MgO) addition on the water absorption for zirconia systems.

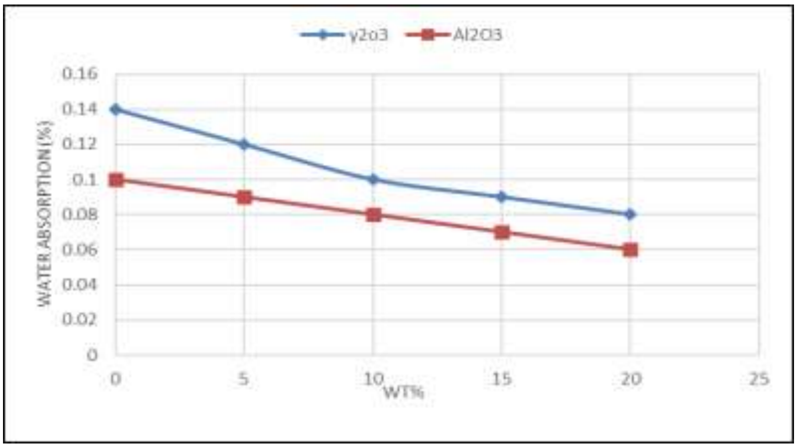

Figure 5. Effect of (Al_2O_3) addition on the water absorption for (zirconia -yttria) systems.

Figure 6 shows the effect of nano-oxide powder of the (zirconia-yttria) and (zirconia-magnesia) systems on the bulk density. Figure 6 shows bulk density as a critical feature of dental ceramic materials because it is both proportional to and inversely proportional to apparent porosity. As the porosity decreases, the density increases. If the tooth has a high density and is devoid of pores, then this is its prolonged use and the absence of bacteria and this is a very important factors those otherwise causes' diseases of biological contamination. Figure 7 shows the effect of adding Nano-alumina to zirconia systems. From Figure 7 apparent density increases with adding Al_2O_3 since it is a nanoparticle and sets at the voids between zirconia practical and alumina it has a high density.

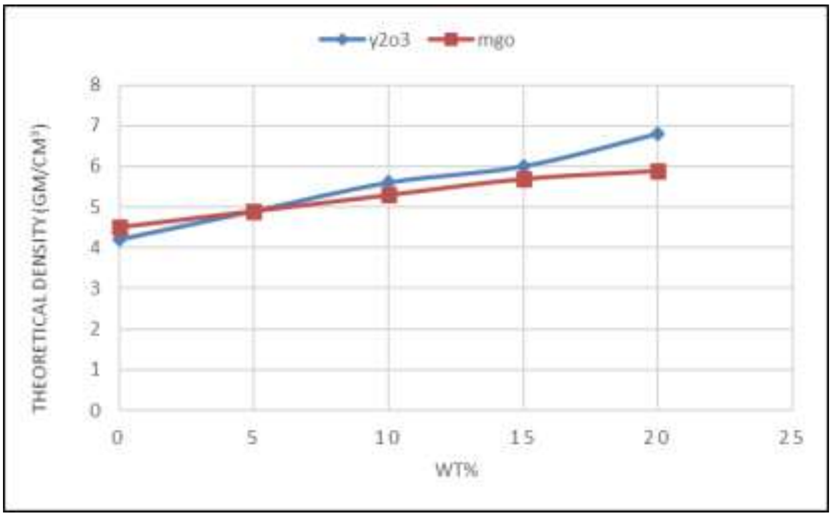

Figure 6. Effect of (Y_2O_3, MgO) addition on the apparent density of zirconia system.

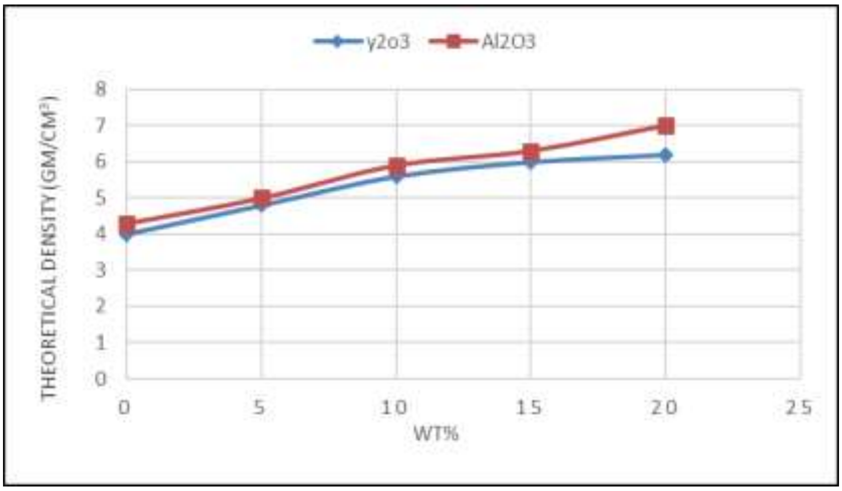

Figure 7. Effect of (Al_2O_3) addition on the apparent density for (zirconia -yttria) system.

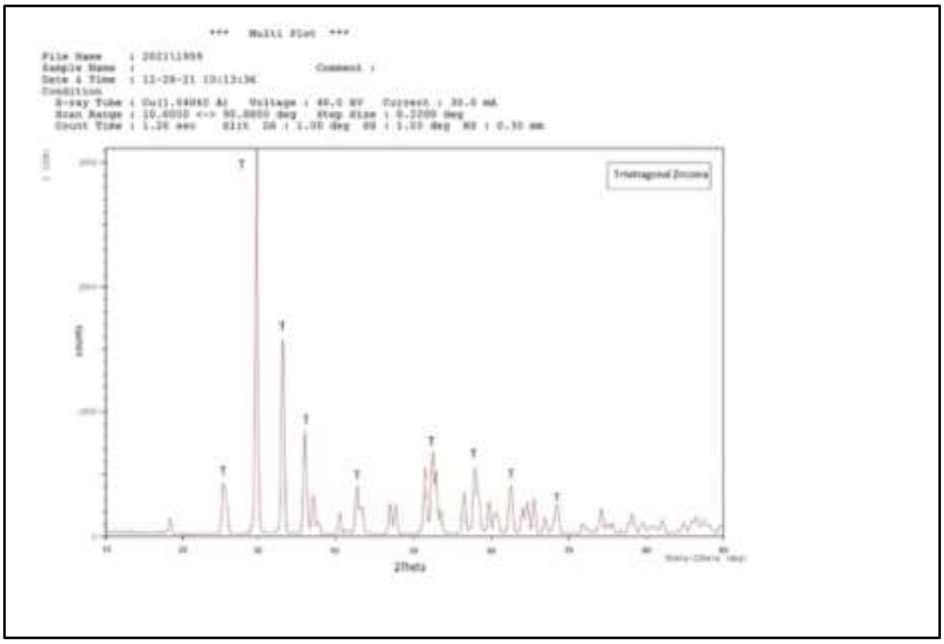

Figure 8. XRD phase pattern of ZrO_2 powder.

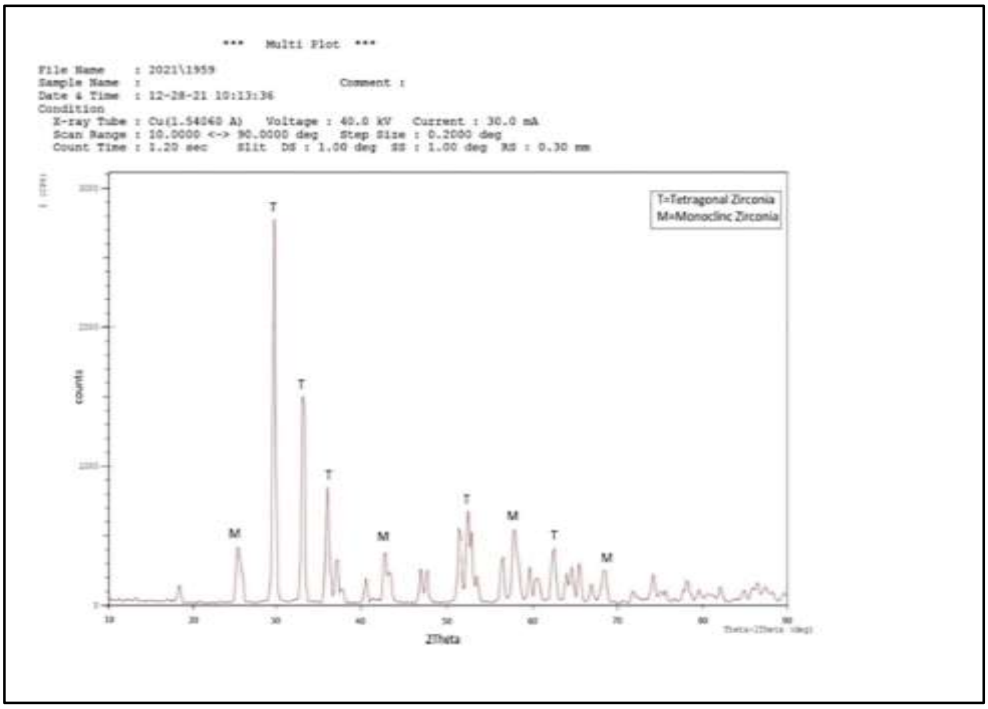

Figure 9. XRD phase pattern ZrO_2 powder sintering at 1570°C.

Figures 8 and 9 show X-ray diffraction of zirconia before and after sintering at 1570°C, respectively. From the above figures, it is clear that zirconia before sintering consists of only a tetragonal phase, but after sintering and as a result of cooling, phase transitions of zirconia occurred and part of it turned into a monoclinic phase, and this phase is mechanically and biologically weak, so yttria and magnesia were added as stopping points for phase transitions, As shown in Figures 10, 11 and this corresponds to [13,22].

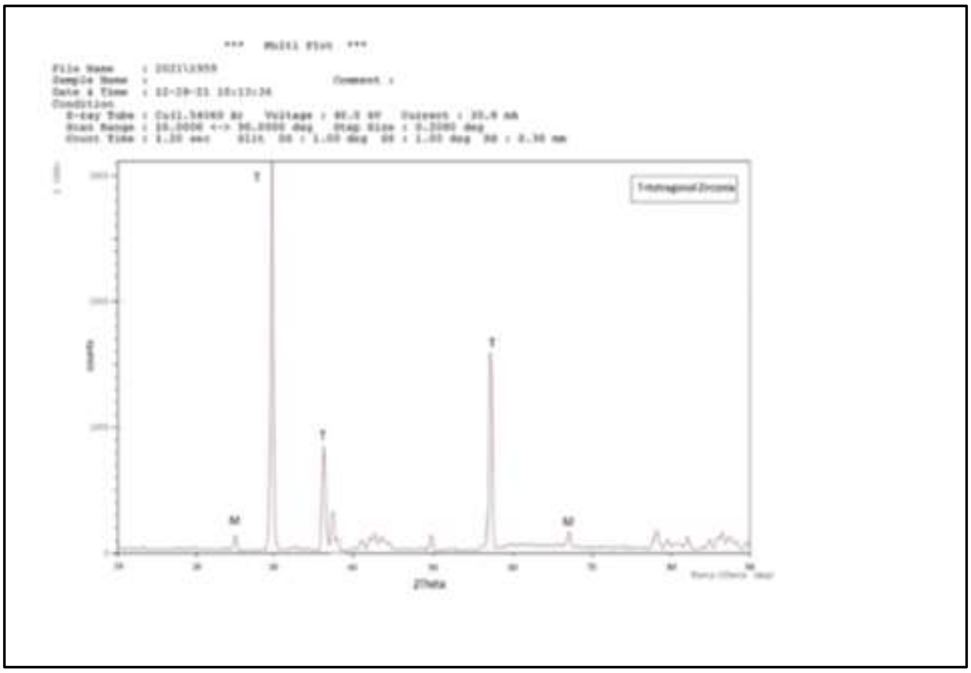

Figure 10. XRD pattern of ZrO_2 doped with Y_2O_3 sintered at 1570°C.

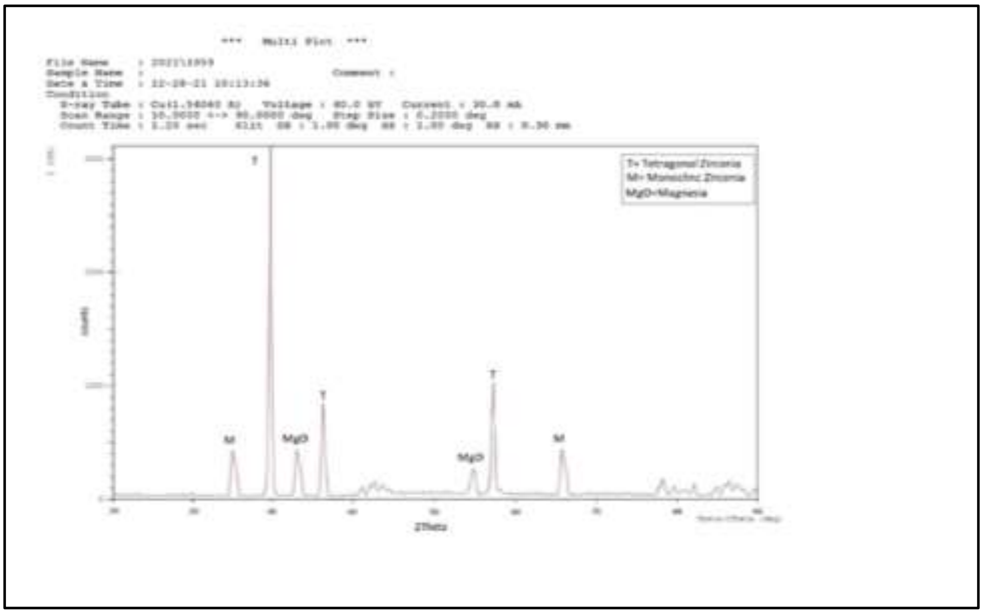

Figure 11. XRD pattern of ZrO_2 doped with MgO sintered at 1570°C.

In Figure 10 and 11, the addition of Y_2O_3 is better than MgO because of the tetragonal and monoclinic phase is shown in X-ray analysis. The highest is quaternary phase and the lowest is monophasic, and this is consistent with [23]. To strengthen the zirconia - yttria (Nano-oxide powder system, alumina nanoparticles were added, and Figure 12 shows the X-ray diffraction results by adding Al_2O_3.

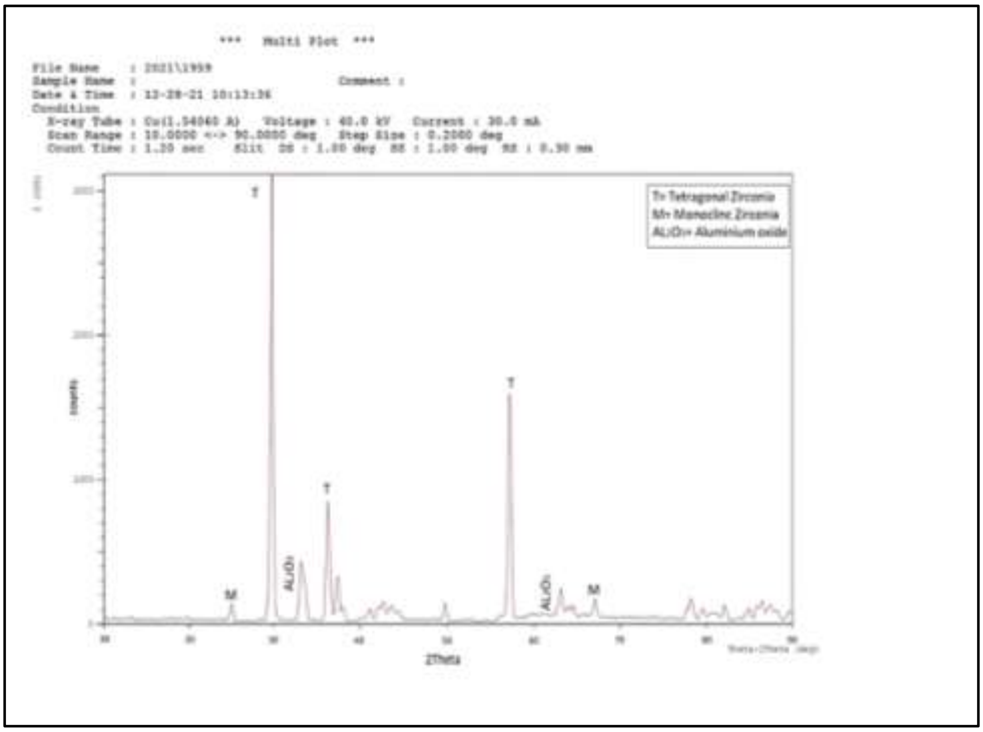

Figure 12. XRD pattern of the Al_2O_3.

It appears from the previous figure:

- Zirconia tetragonal phase is the main phase and appeared in a high proportion
- Monoclinic phase appeared at a very low ratio, and this is the aim of this research.
- The appearance of alumina's hexagonal (corundum) phase in a good proportion to strengthen. Thus, (zirconia -yttria- alumina) system oxide Nano powder was prepared.

4. CONCLUSION

- The problem of zirconia phase transition must be stopped.
- Phase transitions are stopped by adding nano-oxide powder (Y2O3 or MgO).
- It is preferred to add yttria according to the results of X-ray diffraction, where the highest percentage of the quadrangular phase appeared.
- The lowest apparent porosity was obtained when 3% yttria nano oxide powder was added, as the porosity was close to zero.

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