Sintering Additives Effects on the Microstructure and Electrical Behavior of Yttrium Oxide Ceramic Composites

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Abstract

Ceramics type Yttrium oxide with Silicon carbide. were selected to investigate its sintered density, microstructure and electrical properties, after adding V_2O_5, of 100 nm grain size. Different weight percentages ranging from (0.01,0.02,0.03 and 0.04) were used. Dry milling applied for twelve hours. The pelletized samples were sintered at atmospheric of static air and at sintering temperature 1400 ˚C, for three hours. The crustal structure test shoes the phase which is yttrium silicon carbide Scanning electron microscopy, scan sintered microstructure. Samples after sintering were electrically investigated by measuring its capacitance, dielectric constant and their results showed increasing after added V_2O_5 particles at the combination Yttrium oxide 80 Wt.% -Silicon carbide 20 Wt.% with 0.04 V_2O_5 Wt.%.

Key Words: Yttria, Silicon Carbide, Vanadia, Dielectric Constant, Electrical Capacity.

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Introduction

Each composite materials having two or more materials with strong boned gives a material have better performance than its components. Matrix yttria can be modified, silicon carbide can be used as a filler material (G. Magnani, 2014), (R.N. Rao, 2008). Yttrium oxide attract many investigators, to study and develop its electrical features like dielectric constant, electrical strength and current leakage (G.Tong, 2010).

Yttrium oxide, most stable oxide can be used with metal as coated protection material and often also used with zirconia to Stabilized it (Y-S -Z).Yttria characteristics as ceramics that are not found in other materials. Its excellent mechanical properties and high thermal stability, erosion, and chemical resistance, low electrical conductivity.>Some scientists make their interest about the sintering behaviour of yttria, jianhua Tong et al, mentioned the powder activity from 600 ˚C to 1350 ˚C, while Marlowe and Wildwer study the densification from 670 to 1600 ˚C. Yttrium oxide a and Silicon carbide as a ceramic are brittle and their strength is to less than that of other metal carbides, from that, silicon carbide under large mechanical stress or shock crack propagation can move until fracture cause, (Hue, 1997). Another restricted in uses of SiC its difficult to be produced in any required shapes especially for component design for selected application. And to have a dens silicon carbide additives should be used and suitable with selected applied load (Fukushima, 2009). This behavior reflect the covalent bonding between silicon and carbon atoms.

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The sintering enhancement to produce silicon carbide with compact atoms are alumina Yttrium oxide (Y_2O_3) and boron oxide (B_2O_3). Vanadium oxide is used as a catalyst in many industrial chemical reactions. It is also used in some applications, like optical laser, crystals, alloys, ceramics and in energy saving materials, (H. Liong, 2014).

The current investigation aimed to improve the microstructure and electrical behavior for yttrium oxide after adding silicon carbide and vanadium oxide.

Experimental Work

Pellets, Yttrium Oxide – Silicon Carbide with V_2O_5

Yttrium oxide and silicon carbide of 60 µm, powder form, was pelletized to have a grain ceramic compact. SiC were added and dry mixed with the matrix yttrium oxide by weight percentage of 5 to 20 and for eight hours. The sintering was done at atmospheric air, the temperatures used were (800,100,1200, and 1400)˚C, respectively. Y_2O_3 80 Wt.% - SiC 20 Wt.%, was selected. The vanadium pent oxide of 100 nm, grain size was used to be added in the weight percentage (0.01,0.02,0,03 and 0.04). The fabricated pellets were sintered at 1400 ˚C.

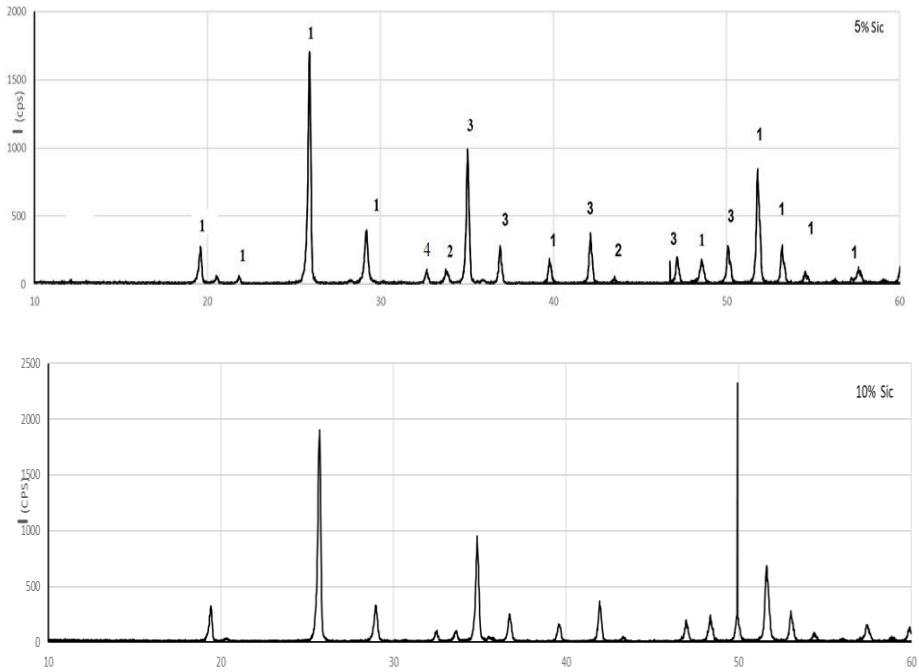
Samples Characterization

The compacted specimens were calculated its density when applied different temperature, standard technique was used by the ASTM C29/C29M-17a. The crustal structure identification was done through, x-ray diffraction technique, the selected scan were (20-75) tow theta degree. SEM test done to study the microstructure of composites ceramics after adding the V_2O_5 Nano particles. The dielectric and capacitance were measured after sintering according to the ASTM D2149-13.

Results and Discussions

Crystal Structure

From x-ray diffraction pattern after sintering p, figure 1, shows the major intensity number 1,its yttria structure, (T.T. Issa, 2014), and the second phase is number3 - Y_5Si_3 (Card No. 00-038-0794). While SiC phase was marked by No.2[8], for all sintering temperature. At 1200 ˚C and1400 ˚C, SiC phase (Tarik, 2015), marked by No.4, (T.T. Issa, 2016), Y_5Si_3e, was completed its formation at temperature 1400 ˚C, for all compositions, showed increased intensity as silicon carbide weight percentage increased.



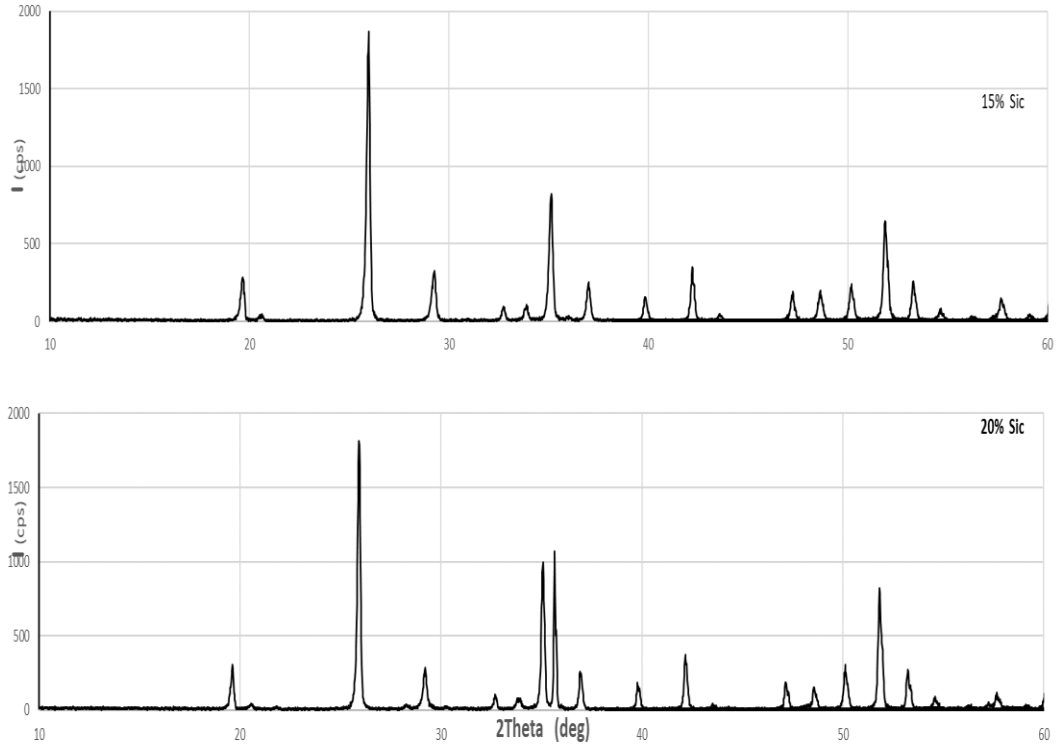


Figure 1. X-ray diffraction pattern for the (Yettria- SiC–V_2O_5) Wt.%, number.1 (Yttrium oxide), number.2 (Silicon carbide), number.3 (Y_5Si_3), number.4 (Silicon oxide).

The best results were identified in the combination Y_2O_3 80 Wt.% with SiC 20Wt.%. For that and to improve its electrical properties, the catalyst V_2O_5, was used. After adding the V_2O_5 Nano particles to the desired combination Y_2O_3 80 Wt-SiC20Wt.% and sintered at 1400 ˚C for 3hours,the crustal structure doesn't shows any changing in its pattern, that's because of the high stable situation notes in the combination. Figure 2, the sintered density reflect the increasing indicated for all combinations. At the added five weight percentage from SiC the first initial stage was noticed. And the intermediate sintering step noticed at the silicon carbide of 10,15 weight percent respectively. At the sintering temperature (1350- 1400) ˚C, the results were improved for the composition Y_2O_3 80 Wt.% with SiC 20Wt.%, having its maximum value 2.569 (gm./cm3), equal to (47) TD% and (53%) porosity, which indicate the sintering in its 3rd stage. Sintered density was increased this is resulted by the acceptable homogeneity between yttrium oxide and SiC, that improve the powder activity of the Yttrium oxide (G. Manani, 2014) (Ulrike, 2004) and the existing of SiO2, (Saito , 1988) as melted phase.

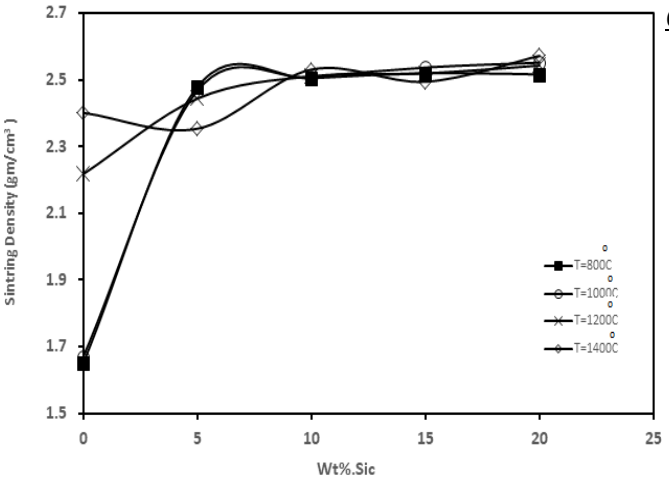


Figure 2. Density after sintering for the combination (Yttrium oxide with added Silicon carbide) sintered at different temperatures at atmospheric air.

From sintering temperature 1200 ˚C, the scanning electron micrograph, figure 3 which shows the Silicon oxide represent liquid phase, (Ruchi, 2015).

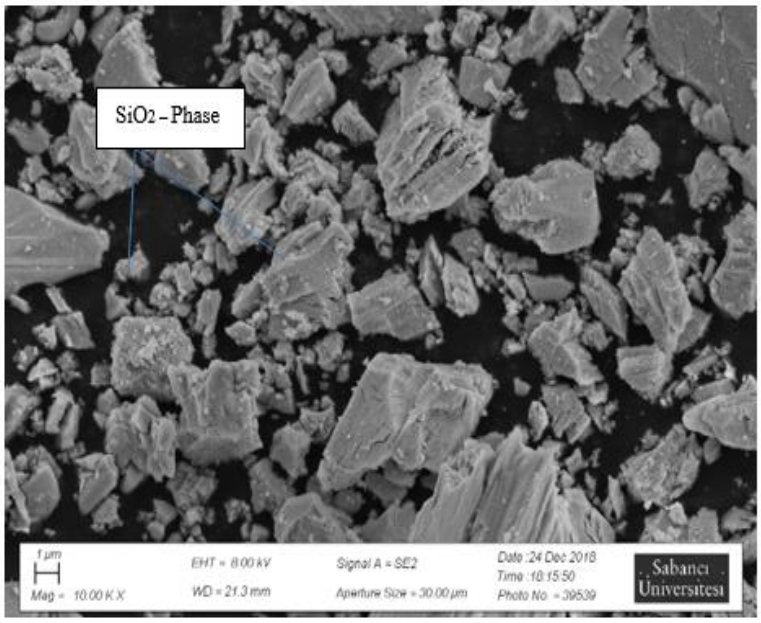


Figure 3. Scanning electron micrograph for the composites ceramic (Yttrium oxide with added Silicon carbide), sintered at 1200 ˚C at atmospheric air for three hours.

While the sintered density reflect reducing in its behavior after adding the V_2O_5 Nano particles, as shown in figure 4. The decreasing in its value is due to the porosity created by oxygen diffusivity (J. Ihle, 2005) showing lowest value of (39.5)TD% of (60.5) porosity, at the composition (Yttrium oxide 80 Wt.% - Silicon carbide 20 Wt%. with added V_2O_5 0.04 Wt.%).

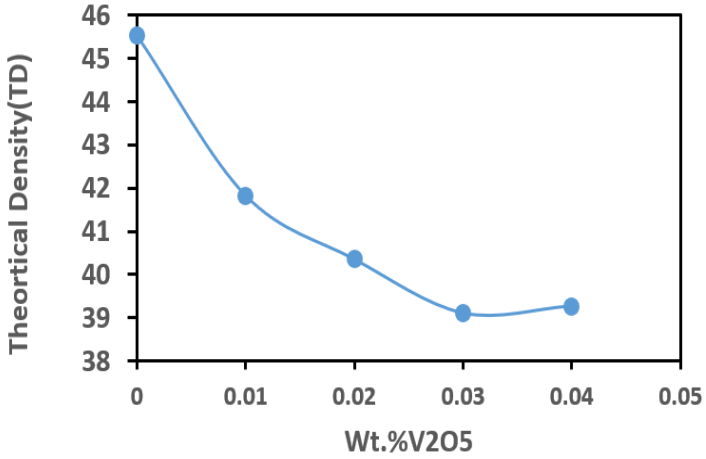
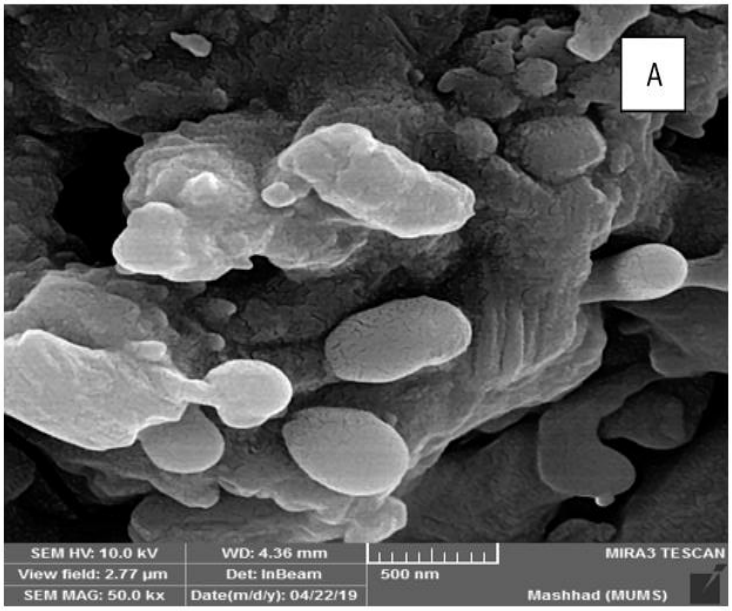


Figure 4. The theoretical density for the composites ceramic, Yttrium oxide with added Silicon carbide with V_2O_5 Wt.%, sintered at 1400 ˚C at atmospheric air for three hours.

That's can be also detected by the SEM, micrographs showing the microstructure after adding the V_2O_5 Nano particles (0.01,0.02,0.03,0.04)Wt.% in figure 5 (A,B,C,D) respectively. The electrical properties representative by the dielectric constant and capacitance measured for the combination Y_2O_3 80 Wt.% SiC 20Wt.% sintered at 1400 ˚C for 3 hours at atmospheric air are, (K = 100) and, (C =1PF), respectively. That's values were increased after added the vanadium pent oxide Nano particles. From figure 6 the dielectric constant showed the increasing behavior as increasing in the V_2O_5 weight percentage, with highest mark of 145 at the combination (Yttrium oxide 80 Wt.% - Silicon carbide 20 Wt Wt.% with V_2O_5 0.04 Wt.%). And from the figure 7, which is represent the capacitance relationship with the added V_2O_5 Nano particles, we can notes the same behavior shown in figure 6. The maximum value reached was 8.5 (PF) at the combination (Yttrium oxide 80 Wt.% - Silicon carbide 20 Wt Wt.% with V_2O_5 0.04 Wt.%). This improvement reflect the clear effect of dispersed particles after sintering at 1400 ˚C, to form a modified microstructure with open porosity (Oxygen diffusivity), casing the increasing in both values of dielectric constant and the capacitance (Slavko, 2001).


A
SEM HV: 10.0 kV
WD: 4.36 mm
MIRA3 TESCAN
View field: 2.77 µm
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SEM MAG: 50.0 kx
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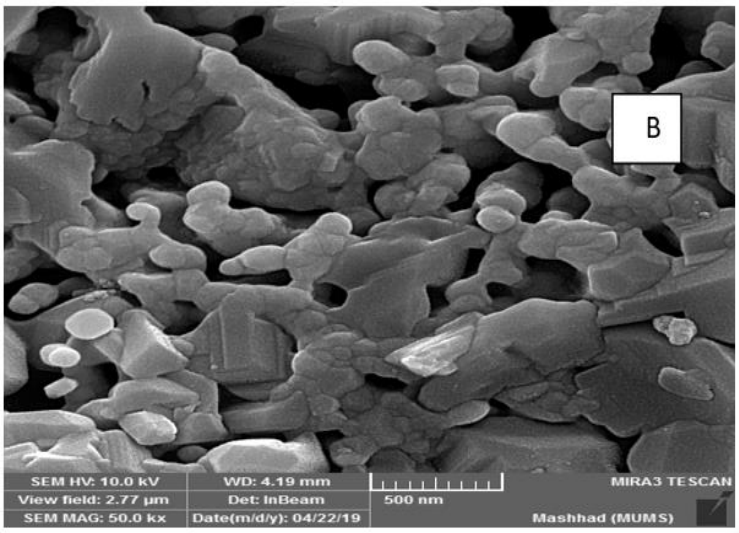
B
SEM HV: 10.0 kV
WD: 4.19 mm
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SEM MAG: 50.0 kx
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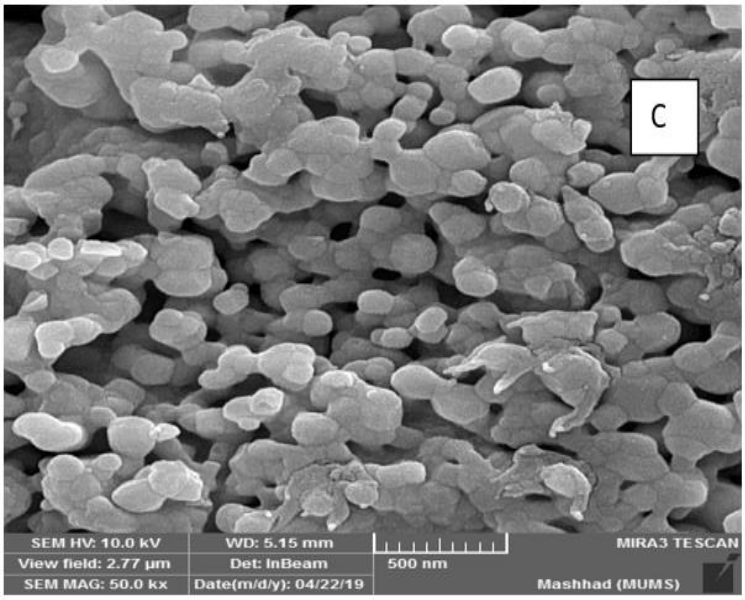
C
SEM HV: 10.0 kV
WD: 5.15 mm
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SEM MAG: 50.0 kx
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Mashhad (MUMS)

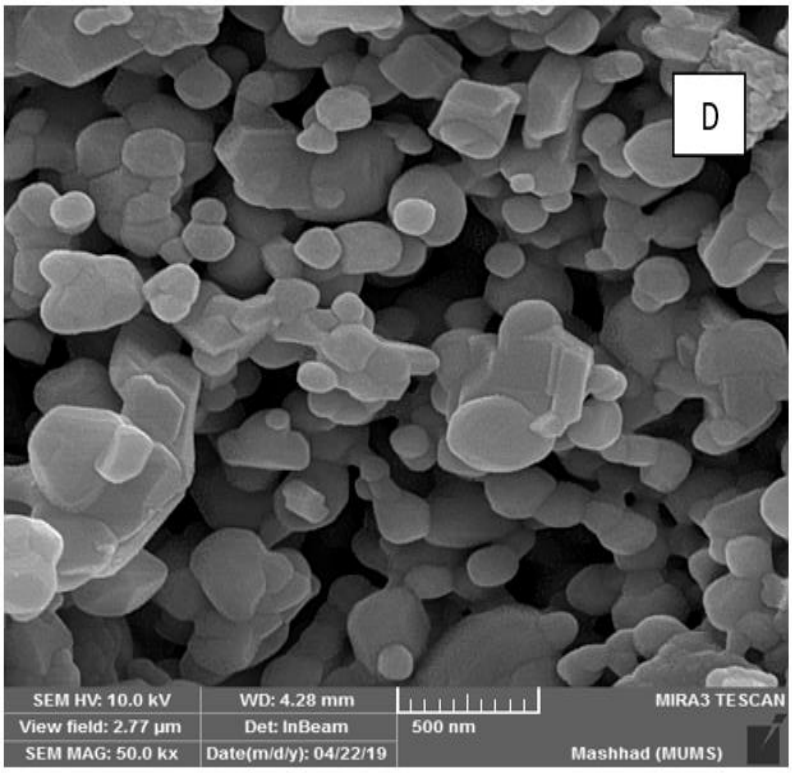

Figure 5. Scanning electron micrograph for the ceramics Yttrium oxide 80 Wt.% -Silicon carbide20 Wt.% with– V_2O_5Wt.%, sintered at 1400 ˚C at atmospheric air.

D) (Y_2O_3 80-SiC 20-0.01V_2O_5) Wt.%, B) (Y_2O_3 80-SiC 20-0.02V_2O_5) Wt.%, C) (Y_2O_3 80-SiC 20-0.03V_2O_5) Wt.%, D) (Y_2O_3 80-SiC 20-0.04V_2O_5) Wt.%.

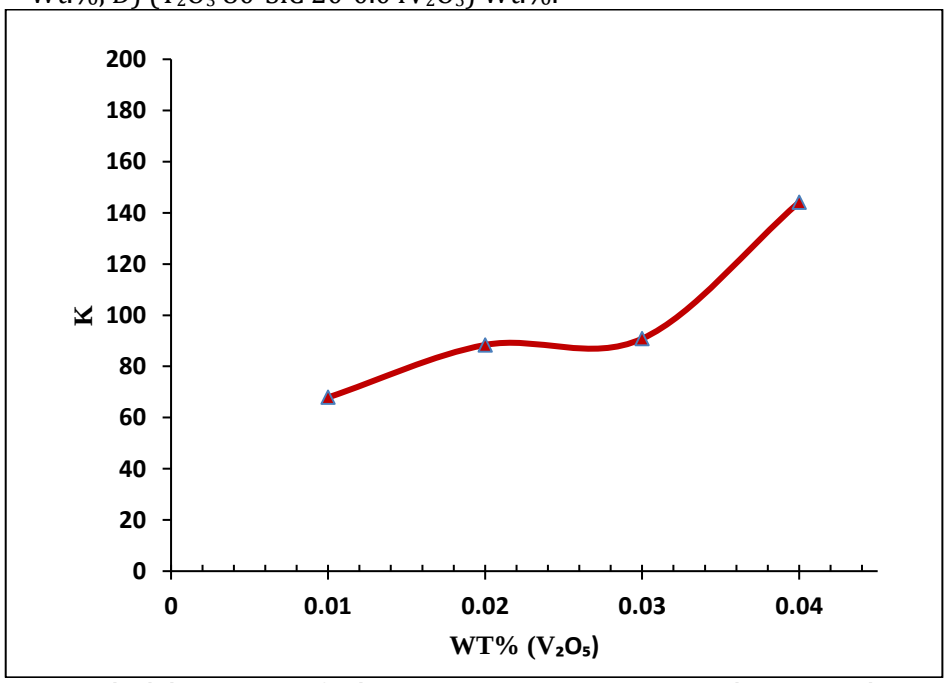

Figure 6. The dielectric constant for the composites ceramics, sin Yttrium oxide 80 Wt.% -Silicon carbide20 Wt.% with– V_2O_5 Wt.% sintered at 1400 ˚C at atmospheric air for, for three hours**.**

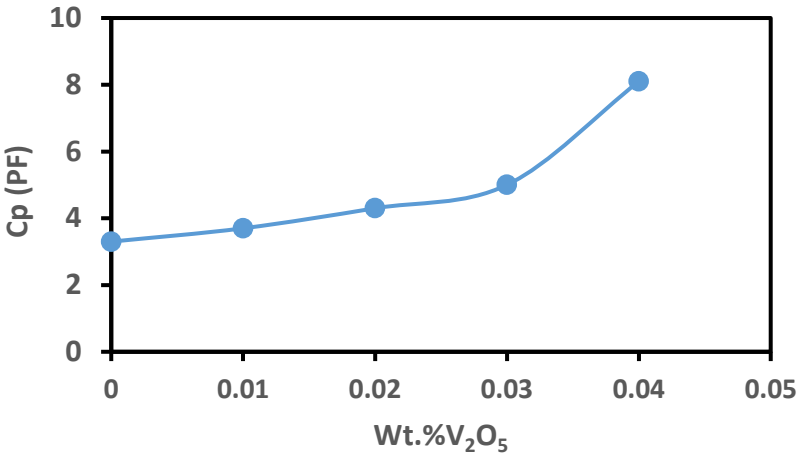

Figure 7. The capacitance for the composites ceramics Yttrium oxide 80 Wt.% -Silicon carbide20 Wt.% with– V_2O_5 Wt.%, sintered at 1400 ˚C at atmospheric air for, for three hours.

Conclusions

Influence of diffused V_2O_5 Nano particles were noticed for all compacted composites ceramics Yttrium oxide 80 Wt.% - Silicon carbide20 Wt.%, sintered at 1400 ˚C, at atmospheric air for four hours, that's crate the phase unique one which is (Y_5Si_3). The new microstructure characterization were achieved by the porosity distribution. which reflected the improvement in dielectric constant and the capacitance specially for the combination (Yttrium oxide 80 Wt.% Silicon carbide20 Wt.% with V_2O_5 0.04Wt.%, sintered at for 4 hours at 1400 ˚C, and at air atmospheric.

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