Preparation of Macro-Porous Alumina via Organic Additive and Characterizations Physical Properties by Using a Genetic Algorithm Method

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Abstract
The exhibited work is focused on the preparation of alumina based porous ceramics and its characterizations. Alumina ceramic with Macro - porous size and control of pore morphology was prepared by semi-dry pressing method via using organic yeast cell for pore forming. Where, alumina powder synthesis by sol-gel method using $Al\ (NO_3)_3\_9H_2O$ and ammonia, then it uses as raw material to produce a porous alumina bodies. During the heat treatment, the organic additions(yeast) was removed and produce a pore ,it was observed that with increasing amount of the yeast cell, the porosity tends to increase. The effect of both different mas ratio of alumina synthesis to yeast, pressing, calcination temperature and soaking time on the microstructure of the final bodies were an investigation. The obtain macro porous alumina had a pore size in rand (0.09-2 µm), porosity (53-75%).
Keywords: Alumina**, Yeast,** Sol-gel **process,** Semi-dry pressing, Genetic algorithm method

INTRODUCTION

Porous alumina have a wide use in many industrial field, such as catalyst supports, heat exchangers , thermal insulation, filtration liquid or metal molten, hot-gas purifier and in biomedical because of their properties such as low density , low thermal conductivity , high chemical stability, resistance to high temperature ,large surface area [1-2] . Already several processing techniques were used to prepare porous alumina ceramics, such as partial sintering method [3], gel casting, freezing casting [4], organic foam method [5] and pore-forming agent method [6]. Among these methods, pore-forming agent technique is the most common and highly effective technique. There is many pore-forming agents including yeast cell, starch, graphite, and naphthalene and rice husk. Yeast cells were employed in the synthesis of alumina with combined macro-/meso porosity. Because of solid cell wall structure of yeast whose hardness is perfect it was interest to withstand the pretreatment procedure [7].

Genetic Algorithm is an optimization technique, and it based on Darwin's theory of the survival of the fittest. However, it is regarded as one of the most successful meta-heuristic techniques for solving combinatorial optimization problems. Thus, a system using GA produces a variety of(individuals) and selects the fittest according to criteria, change the individual, and repeat the process on the next generation, GA works on an encoding of the parameter set rather than the parameter set itself[8-9].
In view of the above, the objective of this research is to macro porous alumina using alumina and yeast cell as starting materials Characterizations Physical Properties by Using a Genetic Algorithm Method

EXPERIMENTAL

Table 1 Characteristics of raw materials

Raw Material	
Aluminum nitrate	$Al\ (NO_3)_3 \bullet 9H_2O$
ammonium hydroxide	NH_4OH
Yeast	
Polyvinyl alcohol (PVA)	$(C_2H_4O)_x$

1- ALUMINA PREPARATION

50 ml of Aluminum nitrate ($Al\ (NO_3)_3 \cdot 9H_2O$), it was dissolved in deionized water under magnetic stirring. Then the

ammonium hydroxide solution was added as a droplet to the mixture. The initial aluminum/ammonia solution pH was 2 gradually increased and then rose up to 8.8 under continues stirring. The mixture was stirred continually at 40 C for 5 h, and then aged for 24 h at room temperature resulting convert the sol to gel. The gel was then filtered and washed with deionized water. The freshly prepared alumina gels was dry at 150◦C for 6 h, and resulted amorphous Boehmite-alumina powder.

2- MACRO POROUS ALUMINA PREPARATION.

The macro-porous alumina was prepared by dry mixing boehmite alumina powder (2 μm) thoroughly in a mortar pestle with yeast cell as pore- forming agent at different weight percent ratios (5%, 10%, 15%, and 20%). This was followed by addition 2% polyvinyl alcohol (PVA) which Specification was (PVA095-28) as binder between alumina and yeast cell and then formed using semi-dry pressing method by compacting the powder in steel die of diameter (20 mm) by compression hydraulic device at different compaction pressure The samples are then dried by heating at 100 °C for 4 and then sintering in different temperature (1200, 1300, 1400, 1500).

Characterization

The phase identification of the sintered specimens was performed using an X-ray diffraction (XRD) (Shimadzu 6000, Japan, Department of Ceramics Engineering and Building Materials, University of Babylon) using Cu Kα radiation at room temperature. Microstructures of the sintered specimens were observed by and scanning electron microscopy (SEM), (FEI, America, pharmacy. University of Babylon). The chemical composition of an element were obtained by EDS (Bruker XFlash 630 EDS, pharmacy. University of Babylon). The particle size distribution was determined by using Bettersize2000 laser particle size analyzer (Better size instrument Ltd., China) in the ceramic laboratories / College of Material Engineering/ University of Babylon.

PHYSICAL PROPERTIES

(١) porosity

The specimens were tested by Archimedes method according to (ASTM C373-88). The porosity is relationship between the open pores to exterior volume and can be determined as following:

$$P = \left(\frac{M-D}{V}\right)*100 \quad \ldots\ldots(1)$$

Where:

V= M-S

M= Saturated weight
D= dry weight
S= Suspense weight

(2) Bulk Density

The bulk density of specimens is calculated after sintering according to ASTM (373-88) by the following equation

$$\rho = D/v \quad \ldots\ldots (2)$$

RESULT AND DISCUSSION

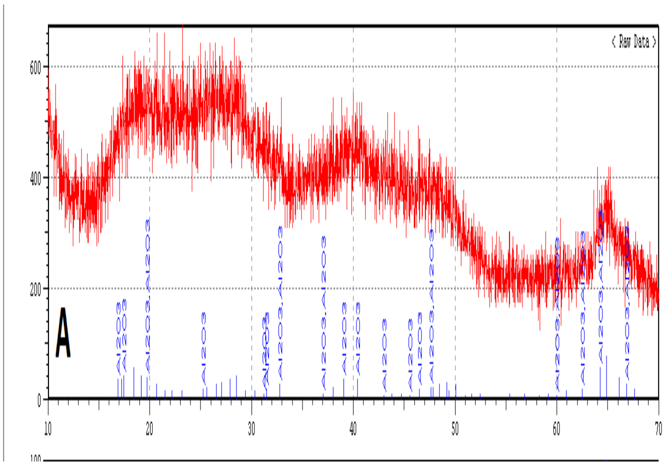
XRD RESULTS

The phases of prepared powders were identifying using XRD (Shimadzu 6000, Japan, Department of Ceramics Engineering and Building Materials, University of Babylon) in room temperature using Cukα radiation. Figure 1.a,b exhibits the result of X-ray diffraction testing (a) x-ray diffraction analysis alumina powder before heat treatment the results showed that is amorphous peak represent to boehmite phase (b) after heat treatment at above 1200,when increase the temperature there would been a Phase transformation from boehmite to alumina as a function of temperature

As we can see α- Al_2O_3 was the only phase present for the powder heat treatment above 1200°C.

ENERGY DISPERSIVE SPECTROSCOPY (EDS)

EDS was utilized to identify the chemical composition of an element under SEM (Bruker XFlash 630 EDS, pharmacy . university of Babylon), The existence of Al and O with weight percent which confirms by using EDS .EDS shows peaks of aluminum and oxygen and indicates fewer impurities in prepared Al_2O_3.



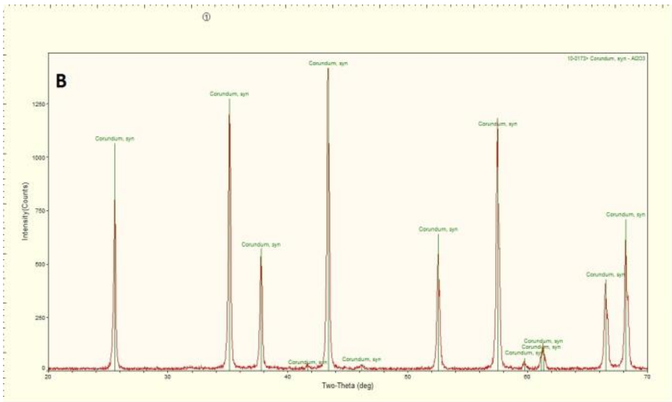


Fig. 1XRD pattern of (a) the result of x-ray diffraction analysis alumina powder before heat treatment, (b) after heat treatment at above 1200

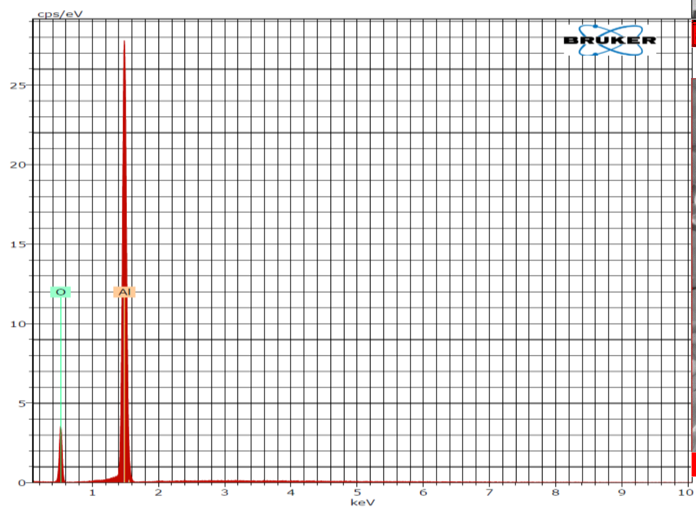


Fig.2 Energy dispersive spectroscopy (EDS) of Al2O3

Table٢. El AN Series unn. C norm. C Atom. C Error (1 Sigma)

		[wt.%]	[wt.%]	[at. %]	[wt.%]
Al	13K-series	72.55	74.62	63.55	3.39
O	8K-series	27.45	24.38	36.45	3.23
Total	100.00	100.00	100.00	100.00	

SEM Results

The microstructure of the alumina based porous ceramics was observed using (SEM) instrument (FEI, America, pharmacy. university of Babylon). Figure.3 (a) SEM shown micrographs of the porous alumina result from alumina with5 % of yeast. After sintering at1400 °C for 2h ,(b) with 10 % yeast after sintering at1400 °C for 2h.,(c) with 5% of yeast after sintering at 1200 °C . it show that when increased the amount of yeast it will be increase the porosity, it may be seen there are smaller pores with the size in range (90-400) nm that are generated by the variability of yeast cell.

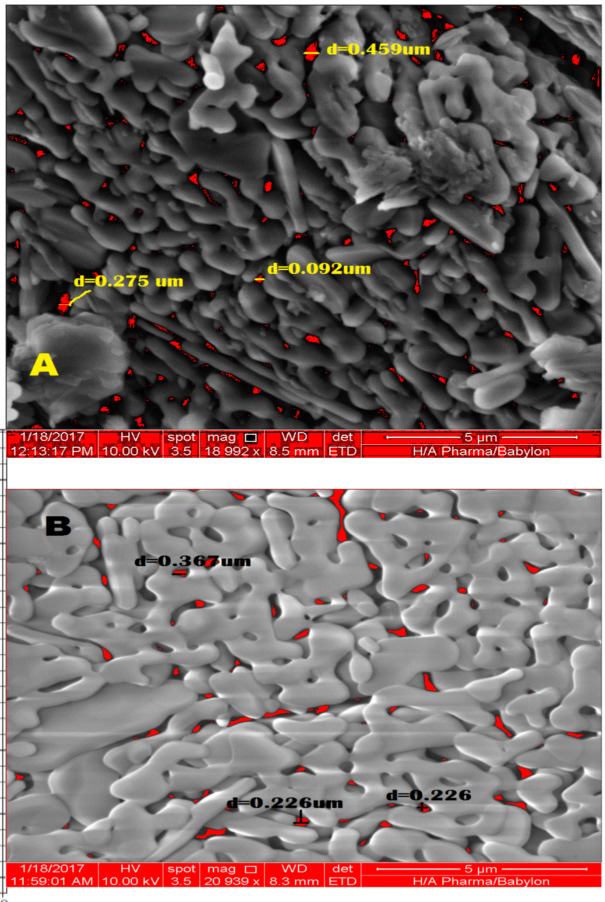


Fig.3 (a, b) SEM micrographs of the porous alumina

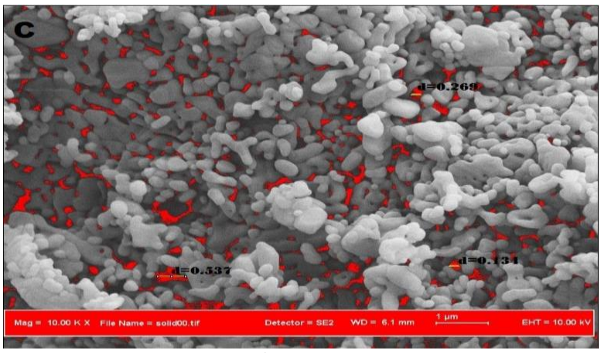


Fig.3 (C) SEM micrographs of the porous alumina

* Red color in a scanning electron microscope images represent the presence of pores

PARTICLE SIZE ANALYZER

The particle size distribution was determined by using Bettersize2000 laser particle size analyzer (Better size instrument Ltd., China) in the ceramic laboratories / College of Material Engineering/ Babylon University). Figure .4a,b show the result of analysis of particles size distribution for the alumina powder ,(a) before the calcination, (b) show the result of alumina powder after calcination at 1200 °C

It can be observed that when increased the temperature of calcination it will increased the particles size of the powder because at higher temperature the growth of particles will be quicker.

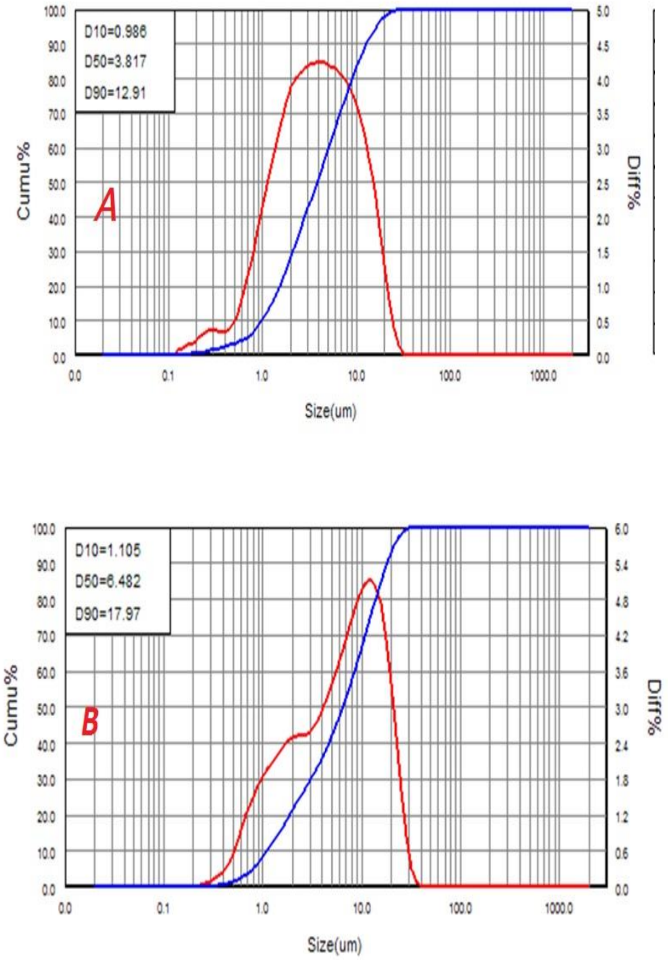


Fig .4. (a, b) the result of analysis of particles size distribution for the alumina powder

The optimization using genetic algorithm (GA)

The optimization of the density and porosity for macro-porous alumina using genetic algorithm approach on the data obtained by the experiments work. Its purpose is to find the values of the processing parameters by which a porous alumina can be produced semi dry processing.

The procedures of GA

The prediction model for porosity and density is established by taking density, porosity as dependent variable and input variables (temperature, socking time, concentration of the yeast, pressing) as independent variables. Therefore, the design of experiment has used based on 60 experiments for four factors and four levels. The fitness function, or regression equation, was formed using Minitab 17 software for density and porosity.

Given in Equation for porosity

$$'F(x) = 7.8 + 0.0329\,x(1) + 0.53\,x(2) - 26\,X(3) + 8.5\,X(4) - 0.00031\,x(1)*x(2) + 0.028\,x(1)*X(3) - 0.0031\,x(1)*X(4) - 1.53\,x(2)*X(3) - 0.509\,x(2)*X(4) - 34.6\,X(3)*X(4) + 0.00107\,x(1)*x(2)*X(3) + 0.000344\,x(1)*x(2)*X(4) + 0.0248\,x(1)*X(3)*X(4) + 1.82\,x(2)*X(3)*X(4) - 0.00138\,x(1)*x(2)*X(3)*X(4).$$

Given in Equation for density

$$''F(x) = -130 + 0.145\,x(1) + 4.24\,x(2) - + 13.9\,x(3) + 53.5\,x(4) - 0.00291\,x(1)*x(2) - 0.0100\,x(1)*x(3) - 0.0411\,x(1)*x(4) - 0.417\,x(2)*x(3) - 0.87\,x(2)*x(4) - 1.03\,x(3)*x(4) + 0.000287\,x(1)*x(2)*x(3) + 0.00057\,x(1)*x(2)*x(4) + 0.00071\,x(1)*x(3)*x(4) + 0.066\,x(2)*x(3)*x(4) - 0.000042\,x(1)*x(2)*x(3)*x(4)$$

Where:

'F(x): porosity

''F(x): density

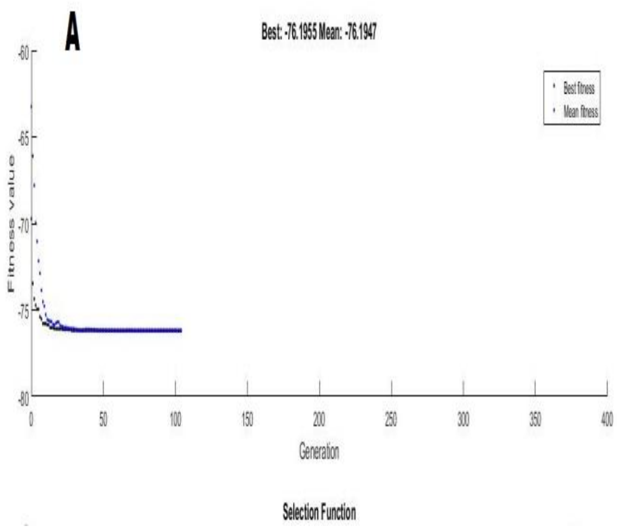
X (1): Temperature

X (2): pressing

X (3): concentration of yeast

X (4): socking time

The Objective Function and Parameter of Genetic Algorithm. The genetic algorithm option in the optimization tool of Matlap software. This software is available in the computer cluster in Department of Ceramics Engineering and Building Materials/ College of Materials Engineering/ University of Babylon was used to represent solution of the optimization problem. Objective value result in Matlap software, which was (76.19%) for maximum porosity and (49.31%) for minimum density



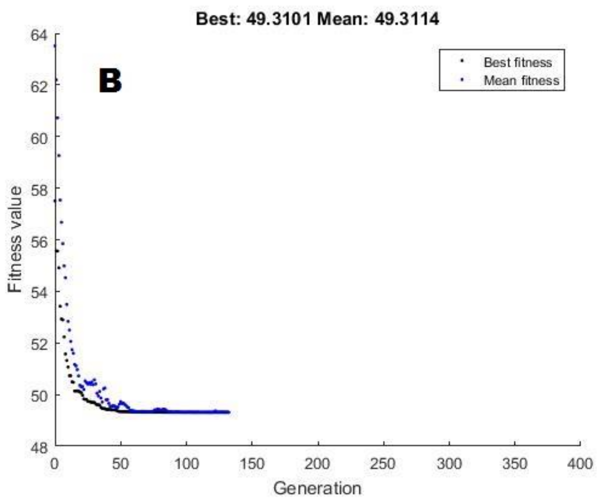


Fig 5. (A, B)the fitness value versus generation

CONCLUSIONS

Macro-porous alumina was successfully prepared using semi-dry pressing method, utilizing natural yeast cell as pore forming agent The porosity obtained was in the range 53-75% and it increased as the percentage ratio of yeast cell increased. The genetic algorithm optimization was used to optimize the problem parameters, which are involved (temperature, socking time, concentration of yeast and pressing). The maximum porosity using genetic algorithm was 76.195, in approximate agreement with experimental value 75 .and for the density obtained in range (50-77) the genetic algorithm optimization for minimum density id 49.31, in approximate agreement with experimental value 50.1.

FUTURE WORK

Study of the mechanical, thermal properties and optimize them by using genetic algorithm and neural artificial network to complete the present work

Macro-porous alumina will prepared by using Natural yeast cell via slip-casting methods.to achieve this point will study of mechanical, physical and thermal properties. Then, optimize them by using genetic algorithm and neural artificial network.

REFERENCES

1-F. Patel, M.A.Baig, T.Laoui; Processing of porous alumina substrate for multilayered ceramic filter, Journal of Desalination and Water Treatment Vol. 35 , NO. 1-3, (2011)33–38.

2- Xue Dong, Mingchao Wang, Anran Guo : Synthesis and properties of porous alumina ceramics with inter-locked plate-like structure through the tert-butyl alcohol-based gel-casting method, Journal of Alloys and Compounds Vol. 694,(2017) P. 1045–1053

3-.D. Hardly, D .J .Green: Mechanical properties of a partially sintered alumina, Journal of the European Ceramic Society. Vol. 15, No. 8, (1995)769–775

4-Y.F. Tang, Q .Miao, S. Qiu, K. Zhao , L. Hu, Novel freeze-casting Fabrication of aligned lamellar porous alumina with a Centro symmetric structure, Journal of the European Ceramic Society, Vol. 34, No.15, (2014), P. 4077–4082.

5-J.H. Ha, R. Ahmad, In- Hyuck Song, A novel method of coating a particle-stabilized alumina foam on a porous alumina substrate, Journal of Materials Letters. Vol. 34, (2012), 40–42.

6- Guogang Xua, Jian Lia, Hongzhi Cuia, Qingkun Hea, Zhihui Zhanga, Xiaoyuan Zhana: Biotemplated fabrication of porous alumina ceramics with controllable pore size using bioactive yeast as pore-forming agent, Ceramics International Journal. Volume 41, No. 5, (2015), P. 7042–7047.

7- Valentin Valtchev, Svetlana Mintova, and Michael Tsapatsis: Ordered porous solid, recent advances and prospects. 1st Edition, Elsevier Science; eBook ISBN: 9780080932453. (2008).p. 800

8- Terrazas, G., Otero, F.E.B., Masegosa, A.D.: Nature Inspired Cooperative Strategies for Optimization (NICSO 2013): Learning, Optimization and Interdisciplinary Applications (Studies in Computational Intelligence), Springer; 2014 Edition. New York (2013). p. 355.

9- Al-dujaili, Mohammed A. Ahmed, Jaheel, Shaker, Abbas, Hasanain Nadhim: Preparation of HA/β-TCP scaffold and mechanical strength optimization using a genetic algorithm method, Journal of the Australian Ceramic Society, Vol.53, Issue 1, 2017,pp 41–48, DOI: 10.1007/s41779-016-0007-5.