The Effect of Pure Aluminum Weight Percent on Different Properties of a New Cermet Material Made of Al-Machinable Glass Ceramic

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Abstract

In this research high pure aluminum metal with the following weight percent (1,2,3,4,5) has been added to machinable glass-ceramic, after the preparation of the samples by pressing then firing the effect of this addition on the density, hardness, young modulus, and polishing and grinding time of the machinable glass-ceramic have been studied. It has been found that the increasing in aluminum percent lead to slightly increase in density while the hardness, young modulus, and polishing and grinding time decreased.

Keywords: - Macor, Machinable glass ceramic, Ceramic, Glass- ceramic, Cermet.

تأثير النسبة الوزنية للألمنيوم النقي على خواص مختلفة لمادة مركبة جديدة من معدن الألمنيوم و السيراميك الزجاجي القابل للتشغيل

الخلاصة

في هذا البحث تمت إضافة معدن الألمنيوم عالي النقاوة وبالنسب الوزنية المئوية التالية (1 ،2، 3 ،4، 5) إلى الزجاج السيراميكي القابل للتشغيل وبعد تحضير العينات بواسطة الكبس ثم الحرق تم دراسة تأثير هذه الإضافة على كل من كثافة،و صلادة، ومعامل مرونة الزجاج السيراميكي إضافة إلى تأثيرها على الزمن اللازم للصقل و التنعيم للزجاج السيراميكي القابل للتشغيل 0وقد وجد بان الزيادة في نسبة معدن الألمنيوم أدت إلى زيادة طفيفة في الكثافة بينما تناقصت كل من الصلادة، ومعامل المرونة وكذلك زمن الصقل و التنعيم0

مفاتيح البحث:- ماكور, الزجاج السيراميكي القابل للتشغيل, سيراميك, الزجاج السيراميكي، متراكبات المعدن و السيراميك.

Introduction

Glass ceramics are polycrystalline materials prepared by the controlled crystallization of highly viscous glass-forming melts. Their properties depend on the amount and composition of crystal phase formed and also on the residual glass composition [1]. Again the crystal phase formation is a strong function of heat treatment time, temperature, heating rate, presence of nucleating agent, and impurity etc.

Glass ceramic materials are already used in several applications as engineering materials and new uses constantly appears[2]. Machinable

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glass-ceramics, or (MACOR), based on (fluorine-phlogopite, $KMg_3AlSi_3O_{10}F_2$), with additions of B_2O_3 and SiO_2 to form a glass. The fluorine compound is micaceous which allows easy cleavage over short distances(3,4). The material is very useful as a machinable insulator, used in welding equipment, medical equipment [5]. Mica-containing glass-ceramics (macor) receive wide application due to their high machinability, which results in an increased versatility of the products and numerous possibilities for industrial application[6]. The main applications are; electronic and semiconductor industry [precision coil formers & high voltage insulators], laser industry [spacers, cavities and reflectors in laser assemblies]. High vacuum industry [thermal breaks in high temperature processing equipment, coil supports and vacuum feedthroughs]. And in aerospace and space industry [retaining rings on hinges, windows and doors of NASA's space shuttle, supports and components in several satellite borne systems][7-12].

Aim of this research is to produce a new cermet material composed from high pure aluminum metal and machinable glass ceramic (macor) and study the effect of Al-weight percent on density, hardness, young modulus, and polishing and grinding time.

Experimental setup

Raw materials:-

Table (1) illustrates the properties of oxides used to form the specimens and their properties. As an additive for macor we used Al metal with purity of (99.9%

Sample preparation:-

Six batches of oxide were weighed according to weight percent listed in table (2)using an electrical balance type (DENVER Instrument 0.01gm 200 gm USA). Mixing achieved by ball mill in dry condition for (6 hrs) in a speed of (70 rpm) using ball mill type (Hergestelltin der Deutschemark German), the product was analyzed by sieving process using device type (Longstand Germany) with shaking time of (1 hr) powder with grain size of (35 µm) was only used.

After mixing the batches were put in silicon carbide crucibles and fired in a tubular evacuated furnace type (Vecstar Ltd UK)at (1200˚C) for 3 hrs . The formed glass was quenched to room temp. and milled to a fine powder in ball mill type (Hergestelltin der Deutschemark German) for (48 hrs) at a speed of (70 rpm) . Before shaping the specimens aluminum metal was added in order of (1,2,3,4,5 wt%) after toughly mixing the specimens were formed by pressing to a cylindrical shapes under pressure of (5 tons) in a hydraulic pressing type (Retch, Germany)and fired again at (1000˚C) for (3 hrs).

Testing:-

Density:- The bulk density (*B*) in grams per cubic centimeter was measured according to (ASTM C 373 – 88), of a specimen is the quotient of its dry mass divided by the exterior volume, including pores. Calculate the bulk density as follows:-

$B = D/V$………………………. (1)

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Where (D) is the dry mass in grams, (V) is volume in cubic centimeter, dimensions were measured using a digital vernal type(Hugin, Japan) and a high sensitive electrical balance type (Dunhill, USA, 0.0001 gm).

Young Modulus:- the test was occurred according to (ASTM C 623 – 92), by using a set type (Instron 1195 Tensile Test) with load of (5KN) and strain range of (0.5 mm/min). The device was connected to a digital reading and graphing unit type (PLC 1800).

Hardness:- this test consider a destructive testing where the hardness of the specimen were measured by a Brinell testing device type (Wilson instrument, , Hardness tester, USA) with a ball diameter of and according to (ASTM C 730 – 98). The device was connected to a digital system type (Sony 210) which give direct results and.

The grinding and Polishing all the specimen were subject to a period of grinding and machining on a machine type (mp 200, Germany) and the time were recorded.

The specimen were pictured by light microscope type (Hern & R.W. Newman, USA) with a maximizing degree of 400x.

Results & Discussions

Using aluminum metal as an additive for machinable glass ceramic based on several concepts which may summarized by the following points:-

1-Aluminum and its alloys characterized by relatively low density (2.7 gm/cm^3) which is very close to the density of machinable glass ceramic where its density is (2.52 gm/cm^3). Thus it will not effected on the applications that need high mechanical properties and low weight. This is clearly shown in fig (1) which illustrate the relation between Al weight fraction and density of specimens, at early stages the increase in density was very small but when weight percent exceeds (4% wt) the increase become sharp and clear comparing with early stages. In spite of this increment the density of Macor-Al still lower than that of aluminum metal and its alloys, so in this way we kept the most important property of macor which is the low weight. The use of high sensitive electric balance, and digital vernal lower the error range.

Fig (2) indicates the effect of Al addition on Young modulus of (Macor-Al), it is clear that aluminum increase modulus of elasticity of machinable glass ceramic, this may be a large benefit since this increase mean more ductility and less brittleness which is a very restricted property for ceramic materials as they are remarked to be brittle materials. In fig (3) we see the effect of aluminum addition on Brinell hardness of (Macor-Al) the addition lead to a small decrease in hardness number of macor to some extant it is very acceptable value for any material to have a hardness (247.8). Both Young modulus and Hardness devices were connected to a digital reading and graphing system type (PLC 1800), and (Sony 210) respectively.

2- The ductility of aluminum metal will largely decrease the machining time for example the grinding and polishing time as in fig(4) this decrease may lead to an increase in the production rate and decrease in cost of production.

3- The main reason for the choice of aluminum metal as an additive to macor fired in 1000^{o}C we may ensure that all the aluminum will dissolve and spread with in the specimen giving us a tightly bond (if it is correct) composite material composed of macor and aluminum. Fig (5) illustrate the effect of Al-metal on the microstructure of machinable glass ceramic, at first we saw a pure machinable glass ceramic (A), fig (5 B to F) show the gradually spread of aluminum metal through the specimens leading to a consolidate for all the alternative properties. This diffusion process occurred because of low melting point of Al-metal (660^{o}C), and the evacuated atmosphere of tubular furnace.

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Table (1) raw materials and their properties

Oxide name	Chemical formula	Grain size µm	Purity	Source
Silica	SiO_2	25	99.5	CHEM-Supply South Carolina USA
Alumina	Al_2O_3	30	99.9	QLC Australia
Magnesia	MgO	20	99.3	QLC Australia
Potassia	K_2O	20	99.5	MERCK Germany
Boron oxide	B_2O_3	25	99.7	MERCK Germany
Sodium Florine	NaF	30	99.9	MERCK Germany
Aluminum	Al	25	99.9	BDH – Netherland

Table (2) Weight percent of macor

Oxide	SiO_2	Al_2O_3	K_2O	MgO	NaF	B_2O_3
wt%	46%	16%	10%	17%	4%	7%

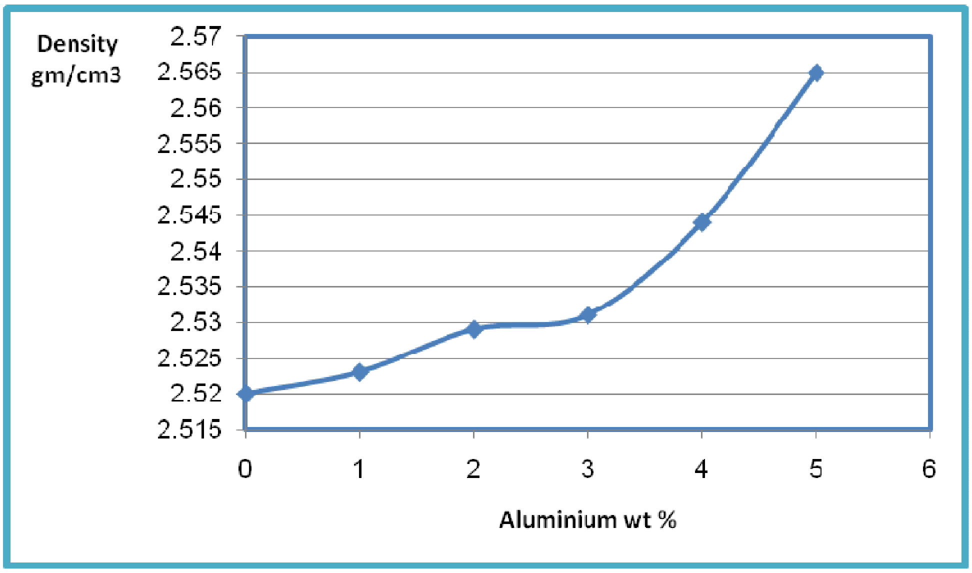

Figure (1) The effect of Aluminum Weight Percent on Density of Machinable Glass-Ceramic

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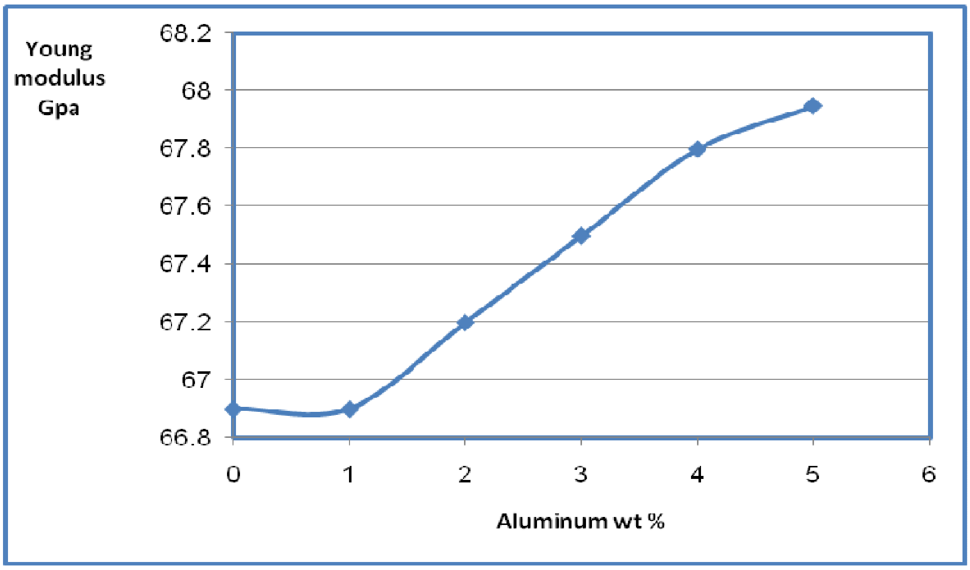

Figure (2) The effect of Aluminum weight percent on Young Modulus of Machinable Glass-Ceramic

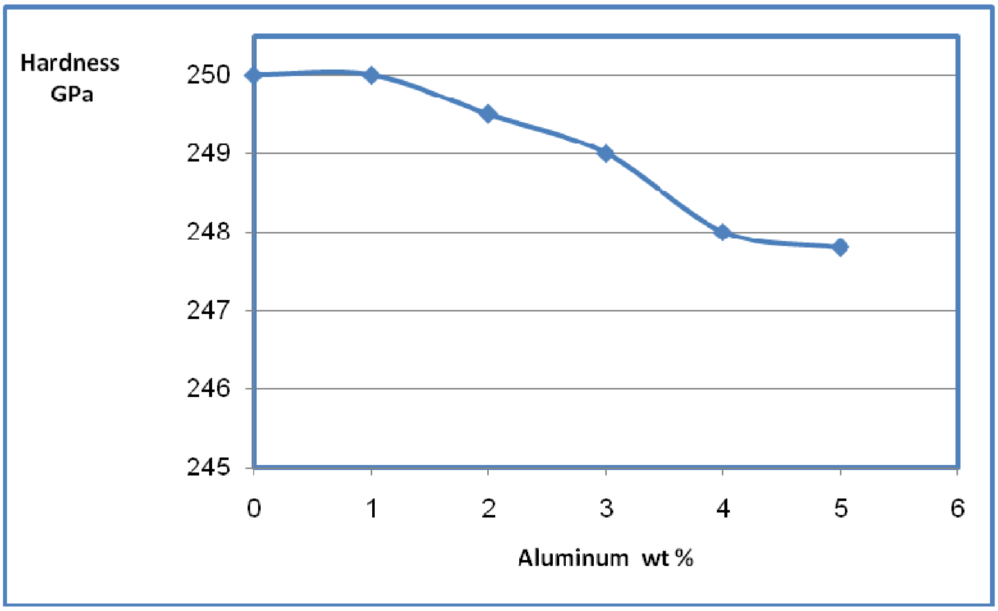

Figure (3) The effect of Aluminum weight percent on Hardness of Machinable Glass-ceramic

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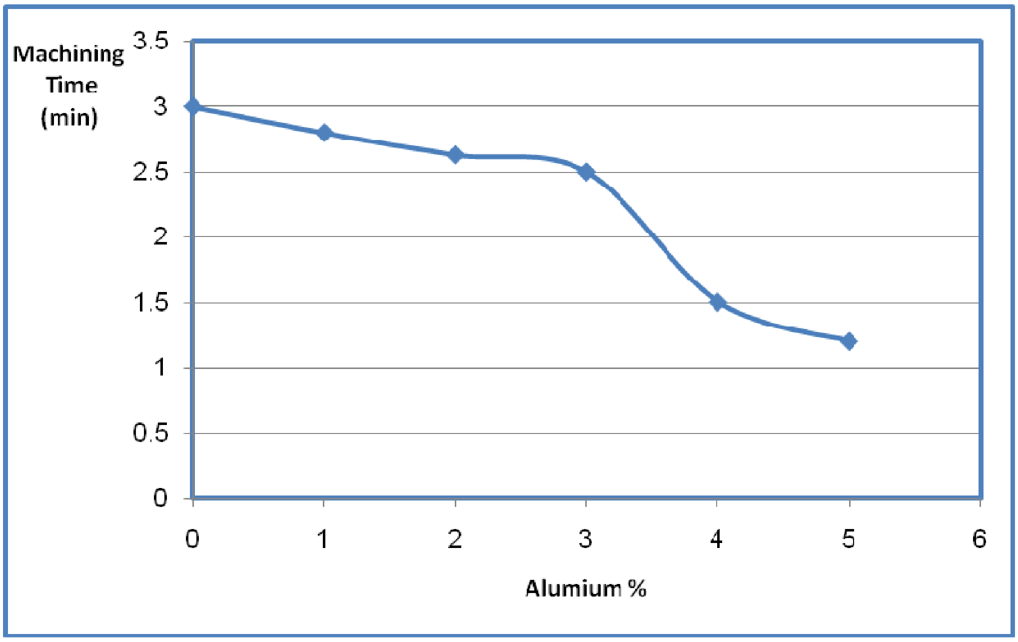
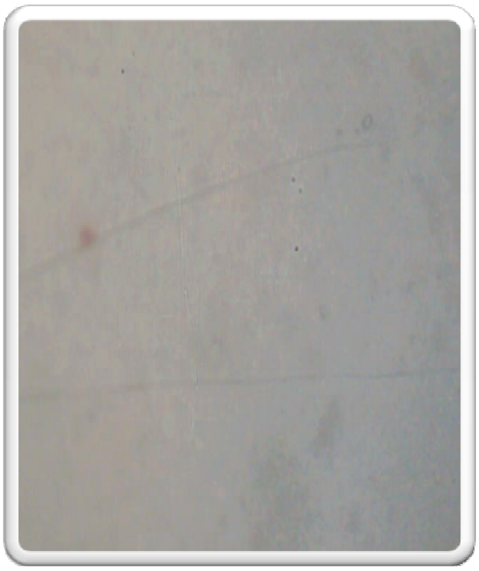


Figure (4) The effect of Aluminum percent on Machining Time of Machinable Glass-ceramic



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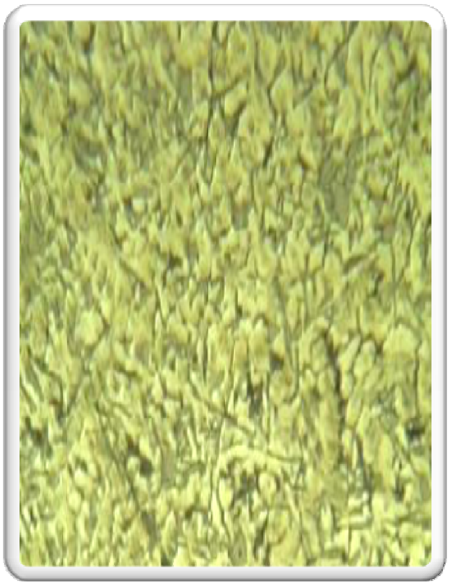
B



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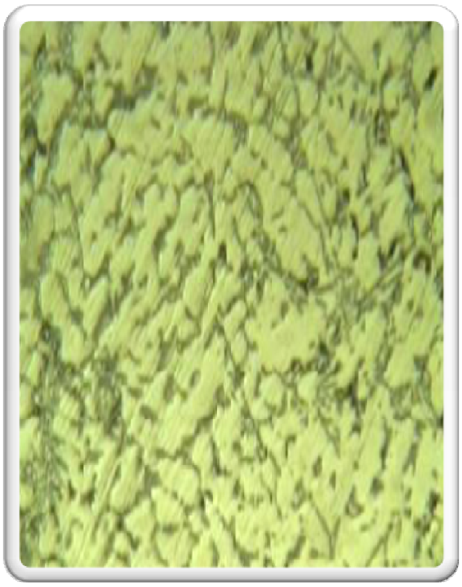

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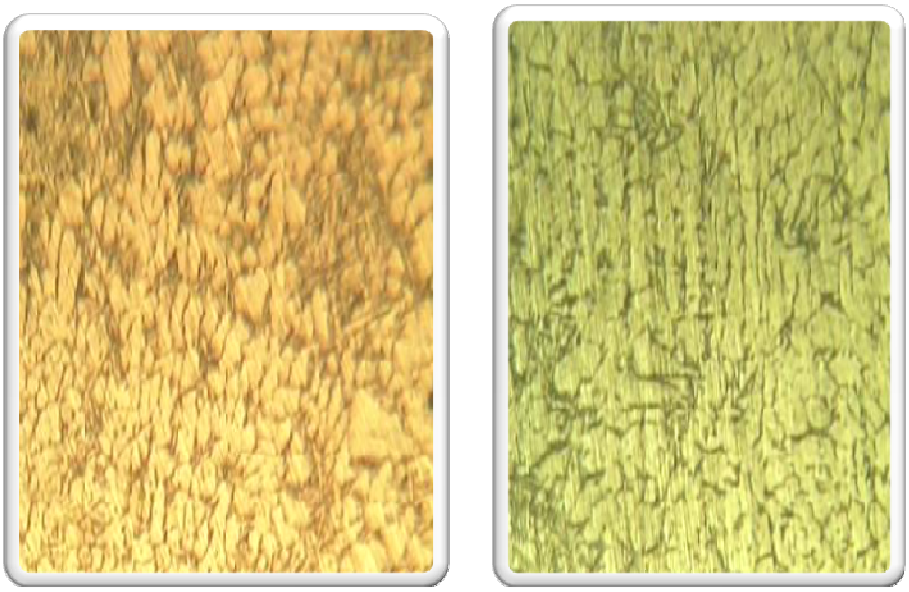

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Figure (5) The effect of aluminum on the microstructure of macor (A) before addition, (B) 1gm al, (C) 2gm Al, (D) 3gm Al, (E) 4gm Al, (F) 5gm Al