EFFECT OF MAGNESIUM POWDER ADDITION ON SOME MECHANICAL PROPERTIES OF COMPOSITE GLASS-CERAMIC MATERIALS

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Abstract
Glass – ceramic material as main component in aerospace application (shuttle), bio-material for the veneering of metal restoration in destroy. In this work glass-ceramic from raw material (Oxides + BaO) was prepared. The XRD analysis showed that the heat treatment causes a very rapid crystallization process and at 900 °C, a new phase, $MgFe_2O_4$ structure appears in the glass matrix. Addition of different weight percentage of Magnesium metal to glass – ceramic were studied to estimate some properties such as density , young modulus, and hardness. The results show decreasing in density to 2.06*103kg/m^3 when add 9%Mg , this result prefer in application of glass-ceramic, especially in aerospace application (window of shuttle). The addition of 9% Mg leads to increase young modulus (E) to (73.5 Gpa). Mg addition on glass-Ceramic leads to decrease Hardness to (260.5 HB at 9% Mg). Microstructure inspection show the gradually spread of Mg metal through the glass matrix leading to a consolidate for all the alternative properties.

Keyword: Addition of Mg , Glass ceramic, density , mechanical properties .

تأثير إضافة مسحوق المغنسيوم على بعض الخواص الميكانيكية لمواد السيراميك – زجاج

الخلاصة
تمتلك مواد السيراميك – زجاج خواص كيميائية جيدة بالإضافة إلى الخواص البصرية والميكانيكية والحرارية الجيدة وهذه الخواص تجعل لهذه المواد تطبيقات مهمة أبرزها في التطبيقات الحياتية وكذلك في تطبيقات الفضاء (السفن الفضائية) نتيجة لخفة الوزن .
في هذه الدراسة تم تصنيع هذه المواد من مجموعة أكاسيد بالإضافة لـ BaO كمادة تنوية ، تم فحص XRD للعينات المصنعة بعد إضافة Mg فوجد حدوث عملية التنوية بشكل عشوائي وكذلك تكون مركب جديد هو $MgFe_2O_4$ والذي يمتاز بخواص مغناطيسية جيدة فحصت قيم الكثافة Density والصلادة Hardness ومعامل المرونة Young Modulus بعدها درس تأثير المغنيسيوم على هذه المواد , فوجد انه عند إضافة (9% Mg) تنخفض الكثافة الى $2.06*10^3\frac{Kg}{m^3}$ وهذه النتيجة تجعل هذه المواد مفضلة في كثير من التطبيقات والتي تحتاج إلى وزن خفيف وأهمها تطبيقات الفضاء حيث تستخدم في شبابيك السفن الفضائية ، ووجد أيضاً أن هذه الإضافات لها تأثير جيد على معامل المرونة إذ يرتفع معامل المرونة إلى (73.5 Gpa) عند إضافة (9% Mg).
أما فيما يخص قيم الصلادة فوجد أن قيم الصلادة تنخفض عند إضافة (Mg) لتصل إلى (260.5Gpa) عند إضافة (9% Mg) وإن هذه القيمة تكون ضمن القيم المقبولة لتطبيقات هذه المواد، عند فحص البنية المجهرية نجد أن Mg يكون بشكل أرضية (كطور أساس) لأنه ينصهر بدرجة حرارة ($650\ ^0C$).

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Introduction

Glass-ceramics have significant advantages over traditional powder-process ceramics. Among other, the flexibility and ease of forming is afforded by high speed processes such as rolling, pressing, blowing, and drawing. Meanwhile, the uniformity of microstructure and reproducibility of properties, which depend on structural consistency, are other major advantages resulting from the homogenous nature of the melting process [1].Glass-ceramic materials are fine grained polycrystalline solids containing residual glass phase, produced by melting glass and forming it into products that are subjected to controlled crystallization[2]. Controlled crystallization or heat treatments usually consist of a two-stage heat treatment, namely a nucleation stage and crystal growth stage. In the nucleation stage, small nuclei are formed within the parent glass. After the formation of stable nuclei, crystallization proceeds by growth of anew crystalline phase. The nucleation and crystallization parameters of glasses are important in the preparation of glass-ceramics with desired microstructures and properties [3].

1.Glass–ceramic

Vitreous enamels are defined as glossy inorganic composition which adhere to metals by fusion and protect them against corrosive conditions[1,2].In recent years, end user requirements have dictated the need for special coating materials with much superior properties than conventional enamels. Such coatings provide protection of the metal against high temperature and corrosive atmosphere and are commonly called glass–ceramic coatings. These are distinguished from conventional vitreous enamel coatings by the presence of suitable amounts of microcrystallines uniformly distributed in a glassy phase constituting the coating ,fig(1)[3,4].

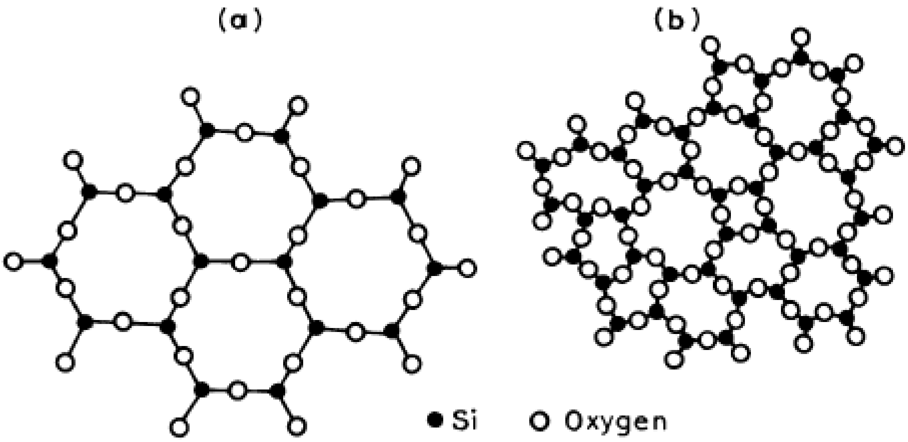


Fig.(1): (a) Crystalline material (b) glassy material(2).

The crystalline phases are produced by nucleation and crystal growth from and within the glassy phase coating material by suitable heat treatment process, so as to provide the unique combination of properties viz. high degree of resistance towards abrasion, impact, high temperature.

chemical corrosion and thermal shock to prevent the failure of the substrate metals under stringent operational conditions .Glass–ceramic materials are polycrystalline solids prepared by controlled crystallization of glass. Crystallizations accomplished by subjecting the glass composition to carefully regulated heat treatment schedule which results in the nucleation and growth of crystalline phases within the glass. The homogeneity of parent glass together with controlled conditions under which the crystals are developed, result in glass–ceramic materials having a very fine grained uniform structure free from porosity[2].

Experimental Part

Table (1) show that the materials that used in this study, its properties and weight percentage for batches.

Table (1): shows the materials that used in this study

material	Particle size (μm)	Purity%	source	Weight%
TiO_2	25	99.5	Germany	16
Al_2O_3	20	99.8	Germany	15
FeO	30	99.3	Australia	14
SiO_2	30	99,5	Australia	41
BaO	25	99.9	England	5
Na_2O	30	99.8	Australia	9
Mg	28	99.98	Germany	

1.Procedure

stage 1: Mixing the powder of oxides which shown in Table (1) to product glass-ceramic materials by mixture in speed 80 rpm for(3hrs.). After mixing batches were put in furnace and fired to (900^0C) for (4hrs.).The formed glass was quenched to room temperature and milled to a fine powder in ball mill for (7hrs.) at a speed of (80rpm).

Stage 2: Adding of Magnesium (Purity = 99.98%, Particle size =25 μm, Germany to glass-ceramic materials powder that produced by step 1 in different weight percentage which(1,3,5, 7and 9) % then mixed at(80rpm) for (4 hrs.), then formed specimens by pressing to a cylinder shapes under pressure (175 MPa), finally putting in furnace at (1000 °C) for (3hrs.).

stage 3: Grinding and polishing all the specimen by subject it to a period of grinding and machining on a machine type (mp 200, Germany) and the time were recorded.

2.Testing:

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

$$\rho = \frac{M}{V}$$

2. Young's Modulus E: the test was occurred according to (ASTM C 623– 92), by using a set type (Instron1195 Tensile Test).The device was connected to a digital reading.
3. Hardness: this test consider destructive testing where the hardness of the specimen were measured by a Brinell testing device type (Wilson instrument, , Hardness tester)with a ball diameter according to (ASTM C 730 – 98).
4. Impact Test: Impact specimens of (60mm×10mm×10mm) dimensions were notched at the middle to a depth of (3mm) to create an area of stress concentration for initiating fracture. Each of the specimens (reinforced and unreinforced) was successively fixed on a Charpy impact testing machine to receive a blow from the fast moving hammer

released from a fixed height on the machine. The reading on a dial gauge on the machine showed the impact energy absorbed by the respective specimen. Repeated tests, carried out to confirm initial readings, indicated an accuracy of ±3% in the recorded impact energy values.

Result and Discussed

1.X-ray Diffraction

X-raydiffractometry (XRD) patterns (Model Pad V, Scintag Inc.,Cupertino, CA). Scans were recorded at room temperatureover a 2θ range of 20-90° at a scan rate of 0.02 /2 s (fig. 2).

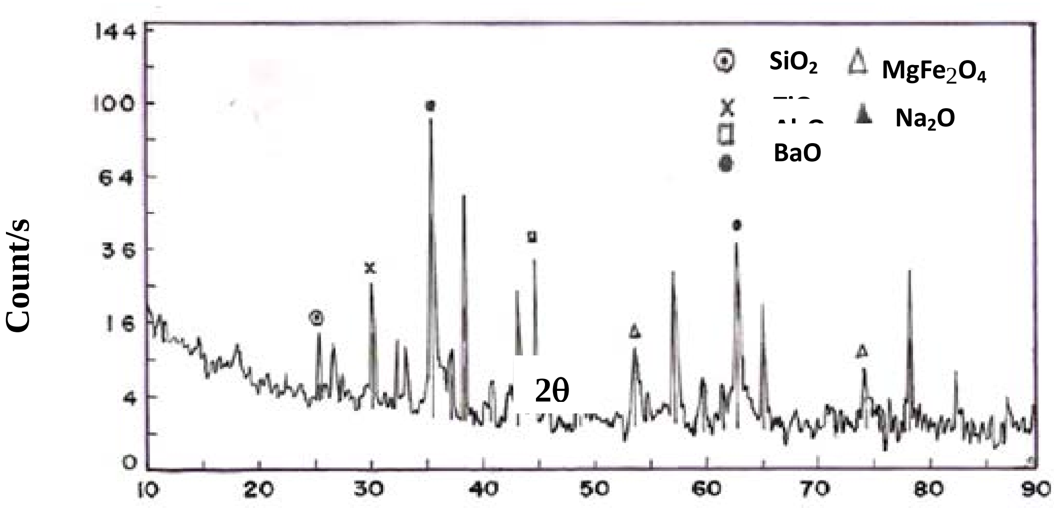


Fig. (2): XRD patterns of the glass – ceramic Materials

Fig. (2) shows the XRD analysis of the sample crystallized at different temperatures for 3 h. When glass is heat-treated at 900 °C, a new phase, $MgFe_2O_4$structure appears in theglass matrix. The XRD analysis showed that the heat treatment causes a very rapid crystallization process and the polycrystalline.

2.Density

Magnesium characterized by relatively low density (1.74*103kgm/m^3) which is less than the density of glass ceramic where its density is (2.21*10^3Kgm/m^3). Thus it better on the applications that need low weight. This is clearly shown in fig (2) which illustrate the relation between (Mg %wt) and density of specimens, In spite of this decrease the density of glass ceramic-Mg composite still higher than that of Magnesium, so in this way we get the most important property of glass ceramic materials which is the low weight[1,8].Fig (3) shows the relationship between densities versus (%Mg)

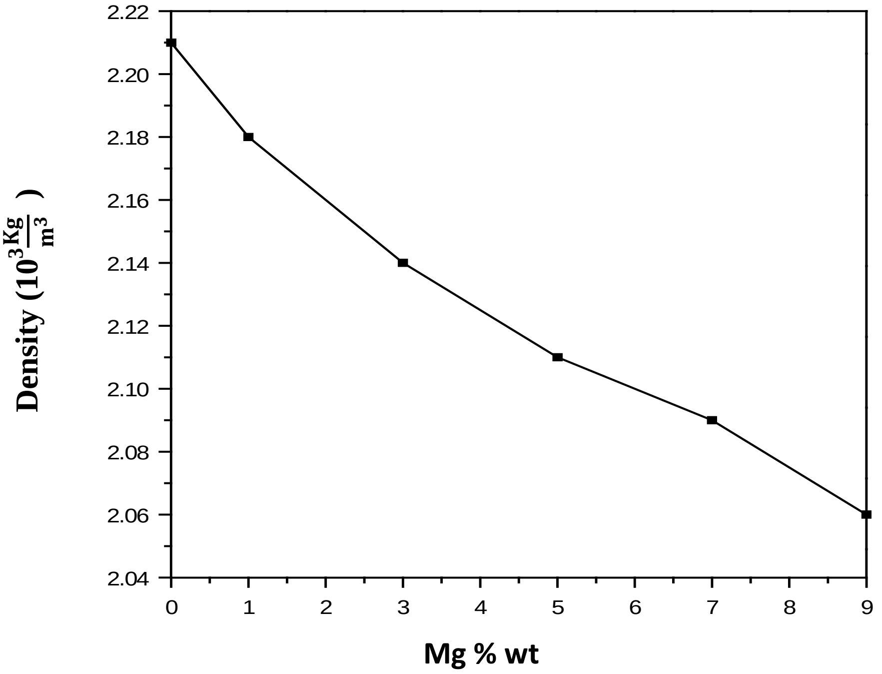


Fig. (3): effect of Mg addition on density.

3. Young Modulus

Fig (4) indicates the effect of Mg addition on Young's Modulus of (glass ceramic-Mg) composite, it is clear that Magnesium increase modulus of elasticity of glass ceramic material, 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[5].

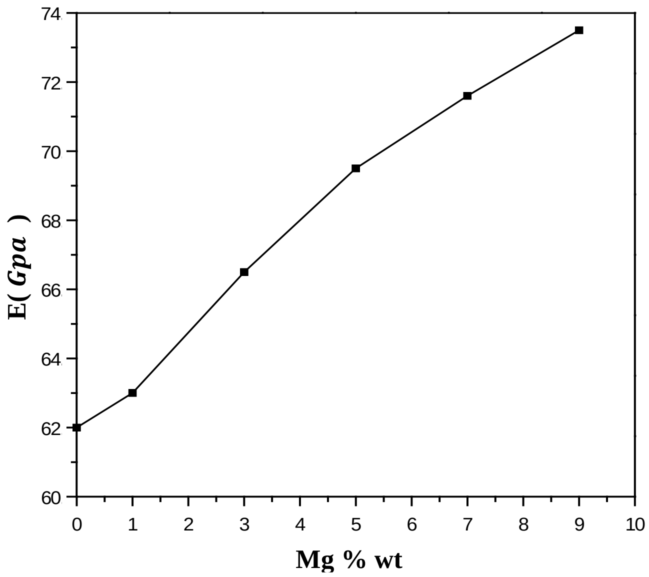


Fig. (4): effect of Mg addition on Young's Modulus

Magnesium metal as an additive to glass ceramic fired in (1000^{o}C) we be ensure that all the magnesium will dissolve and spread with in the specimen giving us a tightly bond of composite glass ceramic and magnesium[2,3,7].

4.Hardness

In fig (5) we see the effect of magnesium addition on Brinell hardness of glass ceramic-Mg composite the addition lead to decrease in hardness number of glass ceramic materials to some extent it is very acceptable value for any material to have a hardness (260) [4].

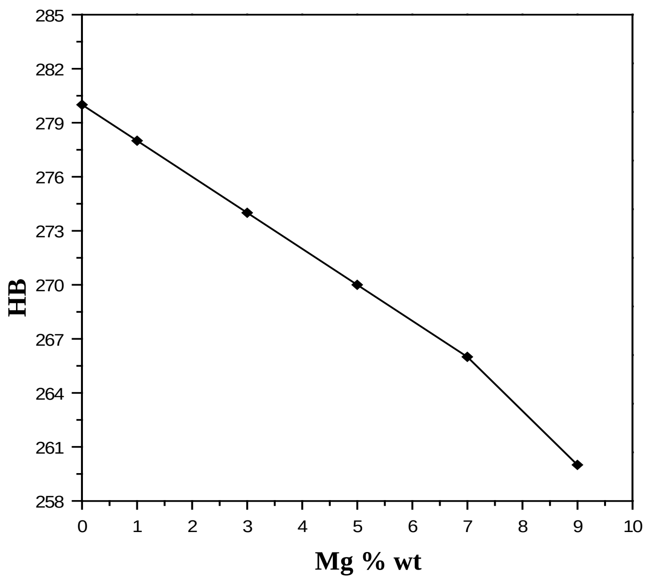
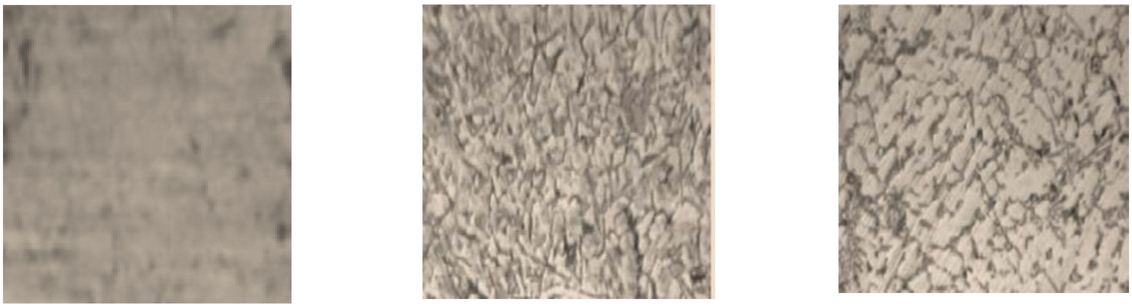


Fig. (5): effect of Mg addition on Brinell hardness

Fig (6) illustrate the effect of additive magnesium metal on the microstructure of glass ceramic (100X).



A B C

Fig. (6): Effect of Mg addition on the microstructure of glass ceramic. A:befor addition, B: 3%Mg, C: 9%Mg

At first we saw a pure glass ceramic (A), fig (6 B and C) show the gradually spread of Mg metal through the specimens leading to a consolidate for all the alternative properties. This diffusion process occurred because of low melting point ofMg-metal (650^{o}C).
Fig (7) shows effect of Mg addition on impact energy of glass-ceramic composite .Impact energy was found to increase with to (27.1 Nm) when add (9%) of Mg. This could be

attributed to the improved internal stress, due to the particulate reinforcement, andenhance of ductility of the specimen.

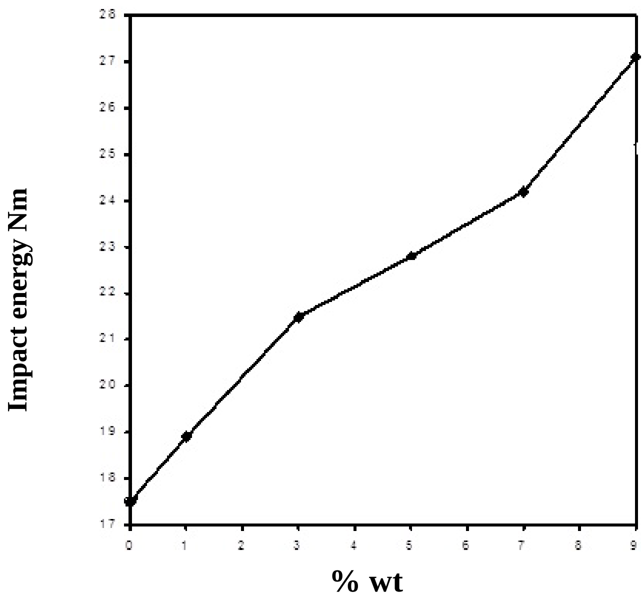


Fig. (7): effect of Mg addition on impact energy.

Conclusions

1- In XRD noted that when glass is heat-treated at 900 °C, a new phase, $MgFe_2O_4$structure appears in the glass matrix.
2- Magnesium addition decrease density of glass ceramic materials to ($\rho \approx 2.06*10^3 \frac{Kg}{m^3}$ when add 9% Mg.
3- Magnesium addition leads to Increase Young Modulus of glass ceramic materials , (E≈73.5 Gpa when add 9% Mg).
4- Magnesium addition lead to decrease in hardness value of glass ceramic materials to (≈260HB when addition 9% Mg.
5- In microstructure the addition Mg metal through the specimens leading to a consolidate for all the alternative properties.
6- Impact energy was increase with increase when Mg addition.

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