PREPARATION & CHARACTERIZATION OF STEP-WISE AL-AL_2O_3

ABSTRACT :-
In this work, simple ceramic-metal functionally graded materials with three different layers has been prepared and tested. Ceramic and metal materials were represented by alumina and aluminum respectively. Powder technology practices were used extensively in preparing each of four set of FGMs samples. All samples have the same chemical composition. Two variables were studied, compacting load and sintering temperature. All samples were imparting graded hardness reading across the thickness. The values of hardness readings are increased according to the hardest constituent's increment (i.e. Alumina) at constant sintering temperature and compacting load. Compaction load increment as well as sintering temperature imparts another reasons for improvement in hardness properties. Microscopic observations show an interesting features of the layers microstructure where composed from an aluminum and alumina particles and show good adhesive between alumina particles and Aluminum while Aluminum surrounded alumina particles from all studies due to good mixing practice during preparation stage.

الخلاصة :
تم في هذا العمل تحضير واختبار مواد المتدرجه بالخواص مكونه من ثلاث طبقات من سيراميك – معدن. السيراميك والمعدن متمثل بالالومينا والالمنيوم على التوالي. طريقه تكنولوجيا المساحيق استخدمت خصيصاً في تحضير اربع مجاميع من عينات المواد المتدرجه بالخواص، كل العينات تمتلك نفس التركيب الكيمياوي. وتم دراسه متغيرين ، حمل الكبس و درجه حراره التلبيد. ازدادت قراءات قيم الصلاده وفقا لزياده المكون الاصلد (الالومينا) عند ثبوت درجه حراره تلبيد و حمل الكبس. تلعب زياده حمل الكبس ودرجه حراره التلبيد كسبب اخر في تحسين خواص الصلاده. اظهرت الملاحظات التركيبيه خواص مميزه للطبقات والمتكونه من الالمنيوم ودقائق الالومينا واظهرت التصاقا جيدا بين دقائق الالومينا ومعدن الالمنيوم بينما احاط الالمنيوم دقائق الالومينا في جميع الحالات نتيجة للخلط الجيد اثناء عملية التحضير.

Keywords: - Al /Al_2O_3, functionally graded materials, step-wise, powder technology, metal-ceramic.

INTRODUCTION :-

Functionally graded materials (FGMs) are new of branch of materials which can be used for various conditions such as thermal and mechanical load applications. The FGMs are microscopically nonhomogeneous materials where the composition of the constituents of materials is changed continuously. The mechanical benefits obtained by a material gradient may be significant, as can be seen by the excellent structure performance of some of these materials. Hence, there has been considerable interest in recent years in the application of such materials in areas such as lightweight armors, high temperature applications and industrial fields such as electronics, biomaterials and so on, (Singh et al.,2007)
Functionally Graded Materials (FGMs) are heterogeneous composite materials in which the mechanical properties vary continuously from one surface to the other (Asemi et al.,2010). FGMs designed so that their properties vary continuously through the thickness from that of a ceramic on the side exposed to high temperature to that of a metal on the other side (Shinagawa,1997).Powder metallurgy is one of the methods to produce functionally graded materials (FGM) with metals and ceramics. In general, shrinkage behavior of ceramics during sintering is different from that of metals. Difference in shrinkage rate often induces distortion or cracks in sintered bodies. Sintering process should be controlled to avoid such defects. In another way, graded heating may be imposed to the powder compacts to adjust the sintering balance of the layers (Gasik, 2005). Paulino and Alokl. (2007) studies graded materials (FGMs) those possess a smooth variation of material properties gradient may change gradually from a pure ceramic to a pure metal. Mishnaevsky (2003) studied the effect of microstructure on graded SiC particle reinforced Al matrix composite on their mechanical behavior, strength and damage resistance. Chang-Chun et al. (2000) studies the development of functionally graded plasma-facing materials; three different processing technologies described for the fabrication of SiC/C (FGM), B_4C/Cu coating FGM and W/Cu FGM. The microstructure and physical properties of the FGMs are evaluated.
According to the above literature reviewing, it is clear that, fabrication of stepwise Al/Al_2O_3 functionally graded materials is very new area for investigation. Therefore, it is hoped in this work to prepare stepwise Al/Al_2O_3 functionally graded materials suitable to work in moderate high temperature applications. Physical and mechanical characterization of prepared materials was adopted through a set of experimentation. Microstructures were carefully monitored in each layer as well as the interfaces.

EXPERIMENTAL PROCEDURE :

Starting powder materials of Al (purity 99.7%, particle size 10μm) and Al_2O_3 (purity 99.5%, particle size 55μm) form MERK company Germany, are weighted in the proportions as shown in table (1). The powder of each layer was mixed for 1 hr at room temperature. Powder feedstock was fed to the mold starting from 1^{st} , 2^{nd} and 3^{rd} layer according to the calculated mass of each layer. Cylindrical steel mold with (10mm diameter) was used in compact all FGMs. After that, compacting practices were done under two different values of pressure (300 and 400 Mpa) respectively for 60 sec. FGMs were sorted according to the compacting pressure into (A, B, C and D) samples, table 2 show conditions for each sample. Each sample was subjected to sintering practices under two different temperature of T (400 and 500) °C for 2 hr for each temperature. The sintering heating cycle including a slow heating rate with 4.16 °/C min, (see figure 1). All sintering practices were carried out by using electric resistance furnace that equipped with an inert gas (Argon gas) supplying setup.

RESULTS & DISCUSSION

Hardness results:-

Aiming to obtain an average hardness values, the hardness of the FGMs faces are documented as can be seen in figure 2. It is clear, that as the ceramic percentage (i.e. Al_2O_3) increased, and the hardness is increased. Knowing that in all samples, chemical composition was set constant. Generally graded hardness properties were achieved in all samples prepared in this work. The ceramic percentage was increased from (0.0wt% in layer no. 1) to (25wt% in layer no.2) and then increased to become (50wt% in layer no.3). The slight improvement in hardness between the face no.1 and layer no.1 as well as between the face no.2 and layer no.3 coming as a result of slight increment in material compaction at the surface than the bulk. Furthermore, the improvement in hardness confirms that pure aluminum can be substantially strengthened by appropriate additions of the refractory material (alumina). Sample D, as show in figure 6 reported a noticeable improvement in hardness number along the Y-axis due to the increment in sintering temperature and compacting load.

MICROSTRUCTURE OBSERVATIONS:-

Despite their use in a variety of applications, the fundamental properties of metal-ceramic interfaces are still poorly understood. Historically, this has been due to experimental complications associated with the study of a buried interface, and to theoretical difficulties caused by complex interfacial bonding interactions. In the present project, a series of FGMs have been prepared with different composition layers. These materials layers containing multi classes of Al powder/ceramic powder interface systems with the goal of explaining and predicting the nature of metal-ceramic adhesion that developed. Since the strength of interfacial bonding plays a crucial role in determining the mechanical properties of an interface. The microstructure of the prepared FGMs depends mainly on the processing parameters. A solid-phase technique (i.e. powder metallurgy or technology) that used extensively in present work, involves preparing the material constituents in required particles size, mixing the matrix metal powder and ceramic powder and the subsequent sintering under inert gas heating after compacting. This method is relatively difficult for the aluminum matrix because aluminum has a protective oxide, and the oxide layer on the surface of each aluminum particle hinders sintering. However, Al_2O_3may be reactive with aluminum. Micrographic examination of the powder mixture reveals that strong surface forces of attraction are active during the mixing process during the preparation of each layer. These attraction forces may be lead to sticking of the Al_2O_3 particles to the Al particles surface during subsequent compaction and sintering process. There is, however, a limit to how many Al_2O_3 particles can be attached to an (Al particles) and hence, there are many more free Al_2O_3 particles in the higher Al_2O_3 content powder mixtures or layer. Micrographs of the regions around the boundary area of the layers in A-type FGMs are shown in figures (7 to 10). It is obvious that a so clear interface between the different layer of FGM. The intermediate layer consists mainly from 75% Al and the rest is the Al_2O_3 powder. Layer no. 3 was the 50:50 ceramic/Al layer and the high percentage of Al_2O_3 enhanced the formation of may be an intermediate phases.

Table 1: Weight composition distributions of Al-Al_2O_3

Layar no.	Layer wt% Al	Layer wt% Al_2O_3	Layer weight in gm.	Layer weight in gm.
1	100	0	13.57 Al	0 Al_2O_3
2	75	25	11.309 Al	3.77 Al_2O_3
3	50	50	8.293 Al	8.293 Al_2O_3

Table 2: show conditions for each sample

Samples	Compacting Pressure(Mpa)	Sintering Temp. (°C)
A	300	400
B	400	400
C	300	500
D	400	500

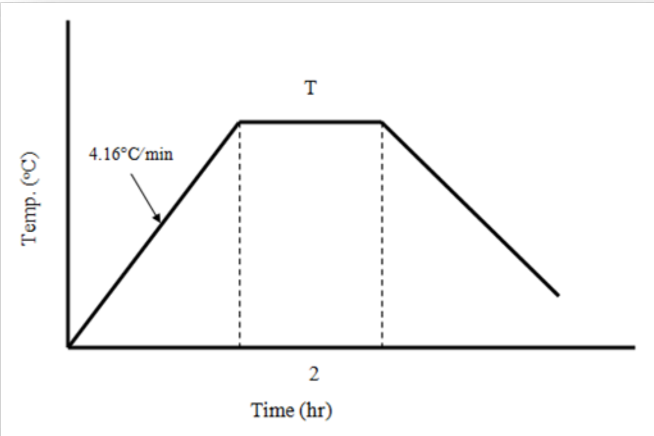

Figure 1: Furnace schedule used to sinter green compacts to final form.

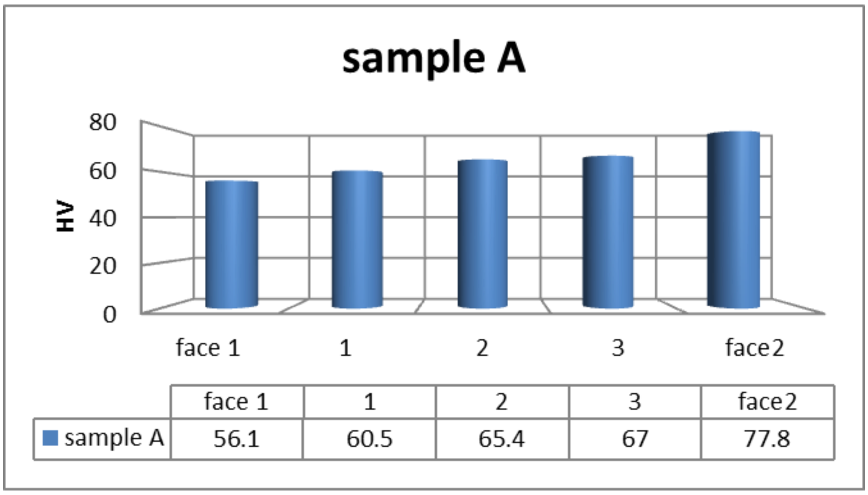

Figure 2: Show the Vickers hardness values for A-sample.

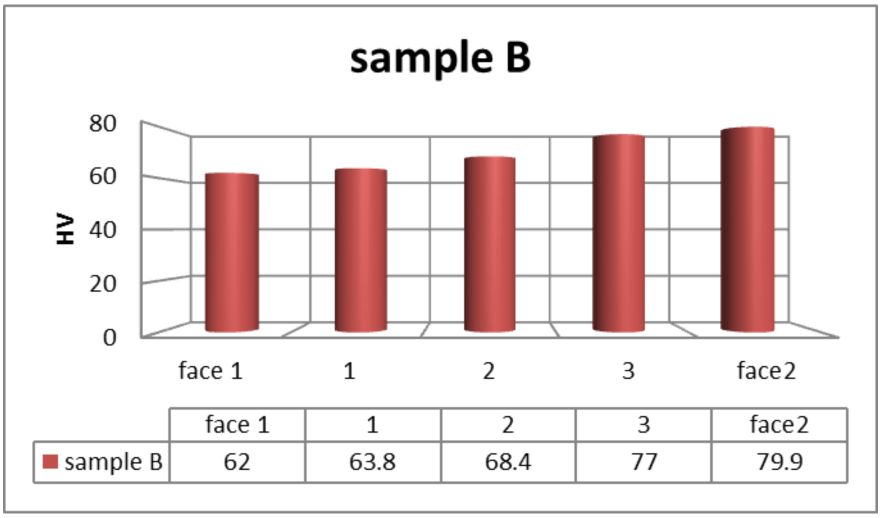

Figure 3: Show the Vickers hardness values for B-sample.

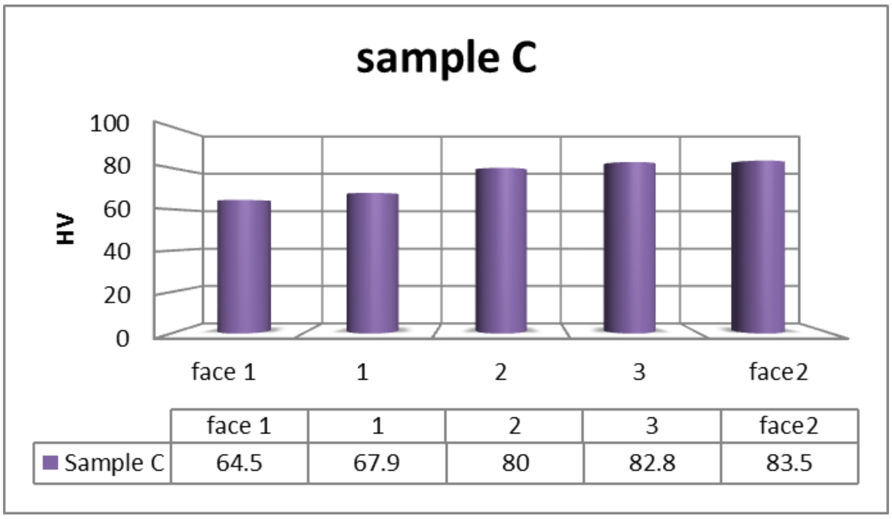

Figure 4: Show the Vickers hardness values for A-sample.

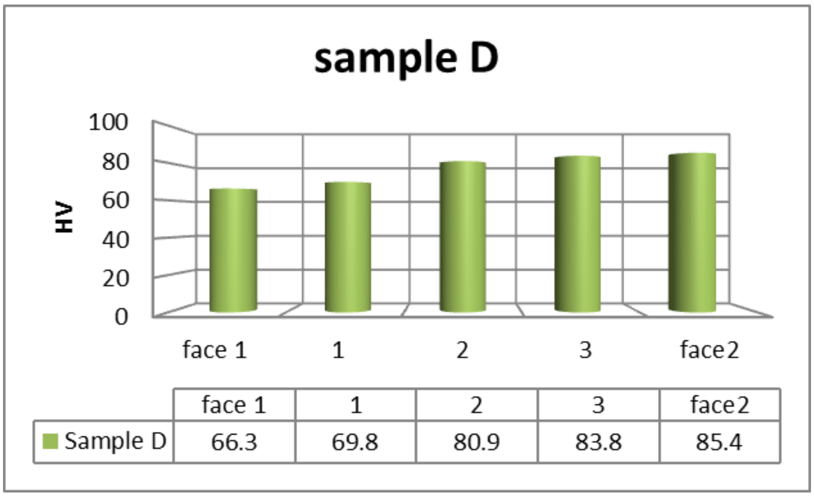

Figure 5: Show the Vickers hardness values for sample-D

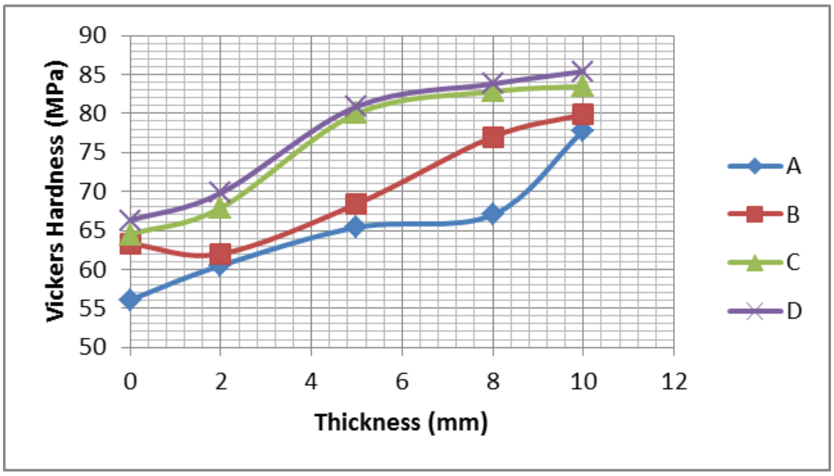

Figure 6: Vickers hardness profile along thickness for A, B, C &D sample

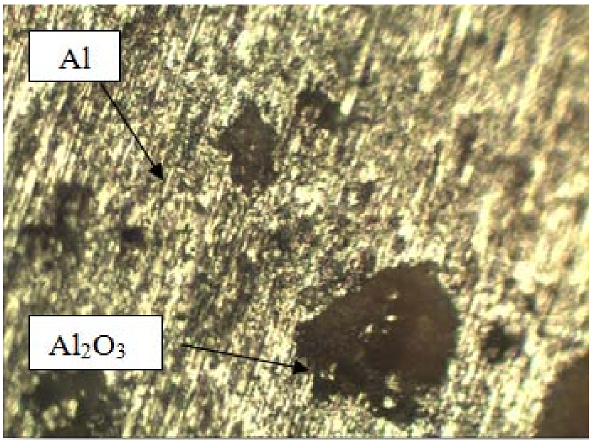

Figure 7: Microstructure of face no.1 of A-sample (10 X).

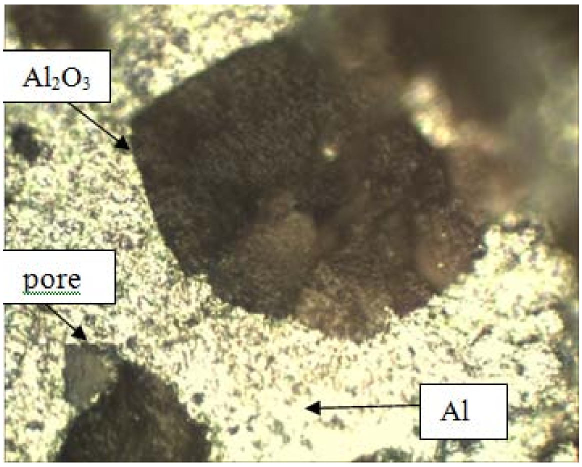

Figure8: Microstructure of A-sample between layer no.1 and layer no.2 (10 X).

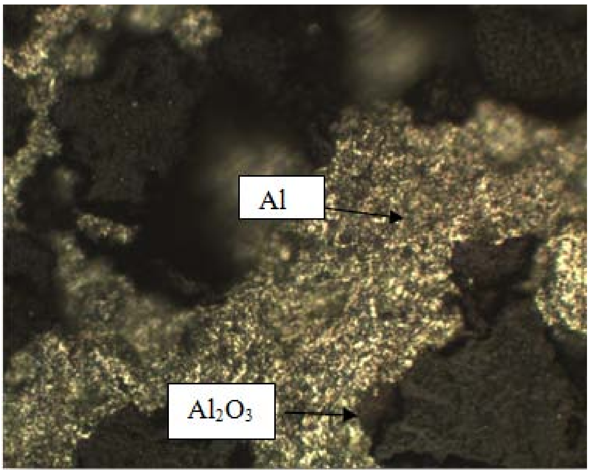

Figure9: Microstructure of A-sample between layer no.2 and layer no.3 (10 X).

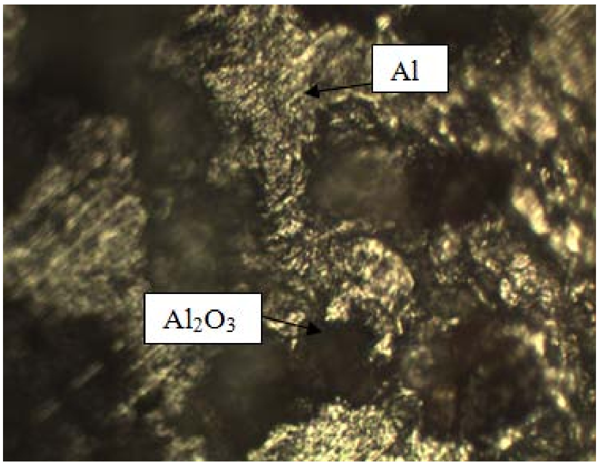

Figure10: Microstructure of face no.2 of A-sample (10 X).

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