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An Overview of Functionally Graded Materials

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Abstract: *The present work looked into about Functionally Graded Materials (FGMs) as the practically evaluated materials (FGMs), a creative material has a place with a class of cutting edge material with changing properties over evolving measurement. The last properties of FGM are one of a kind and not quite the same as any of the individual material that shapes it. Normally, under brutal temperature conditions, the ordinary materials (metals or earthenware production) alone might not survive which prompted improvement of a development material i.e functionally graded material which is prepared to do withstanding high temperature under cruel conditions. Practically evaluated materials are generally utilized as a part of air ships, space vehicles and different items working at lifted temperatures. The range of utilization of FGMs is required to increment as the expense of material improving so as to prepare and manufacture procedures are diminished these procedures.*

Keywords: *Functionally graded materials, Centrifugal casting, Infiltration process, utilizations of FGMs*

INTRODUCTION

The term material alludes to a substance out of which something can be created. The expression "materials" extensively depicts all that we use to produce regular articles from toys to vehicles parts. Be that as it may under the impact of high temperature and/or warm inclinations, the ordinary materials (metals or ceramics) alone may not survive; we require progressed materials that give high particular execution in examination with ordinary materials. Progressed materials are utilized for items that have some better properties. Functionally graded material (FGM) is relatively a new concept and is used for components/parts subjected to high thermo-mechanical loading. The technology for fabrication of FGM was first proposed in Japan in 1984 during a space plane project. Where a combination of materials used would serve the purpose of a thermal barrier capable of withstanding a surface temperature of 2000 K and a thermal gradient of 1000K across a 10 mm section. Functionally Graded Material (FGM), an innovative material, belongs to a class of advanced materials with varying properties over changing dimension [2]. In many structures found in plants, microstructural gradients are formed in order to produce optimum structural and functional performance with minimum material use. [1,2]. For example, the composite may contain a spatially varying volume fraction of one of the phases (Fig. 1 (a)). In this case, the gradient material can be conveniently described by the use of a transition function f (x, y, z), where f is the volume fraction of one of the phases as a function of position. In many practical cases the compositional variation will be restricted to one coordinate, z, and the different gradients can then be described by a so-called transition function of the type:

$$f(z) = \left(\frac{z}{d}\right)^{p}$$

Where f denotes the volume fraction of one of the phases, d is the thickness of the graded region, and p is the so-called gradation exponent. However, a composition gradient is not inherent to all FGMs Microstructural orientation gradients may also be obtained in composites by changing the shape (Fig.1 (b)), (Fig.1 (c)), or size (Fig. 1 (d)) of the dispersed phase [3].

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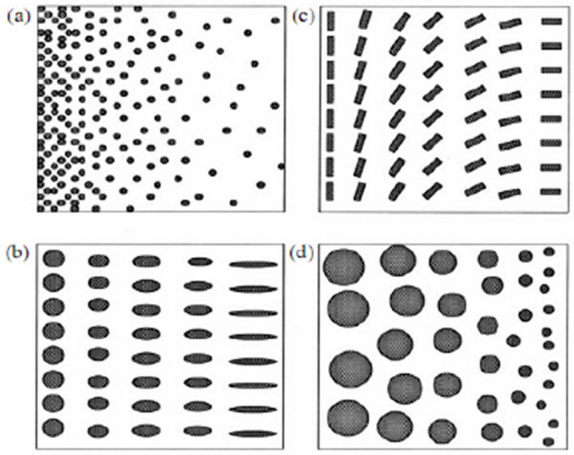

Figure. 1 Different types of functionally graded composites. Gradient of: (a) fraction, (b) shape, (c) orientation, and (d) size of

Centrifugal Casting of FGM

An investigation on the microstructure and composition gradients in some aluminum based FGMs including Al/SiC, Al/Shirasu, Al/Al_3Ti, Al/Al_3Ni, Al/Al_2Cu combinations have been made by evaluating the dispersion of the different phase particles within the FGM structures fabricated via some different centrifugal casting processes. The study found that Al/SiC, Al/Shirasu and Al/Al_3Ti FGMs can be fabricated by the centrifugal solid-particle method while the different technique of centrifugal in-situ method is suitable for the fabrication of Al/Al_3Ni and Al/Al_2Cu FGMs. The combination of both processing methods then are required for Al/(Al_3Ti+Al_3Ni) hybrid FGMs. Although centrifugal casting is a practical mechanism for FGM fabrication as it has the feasibility of scaling up to mass production while maintaining the low cost, this method is only limited for the fabrication of FGM with continuous gradient in the composition. The phase compositions of FGMs fabricated using this approach are strongly depend on the condition of centrifugal sedimentation process including the duration time, rotation speed, solid and dispersive fluid contents. Self-propagating high temperature synthesis reaction is added as one of the step followed by the centrifugal casting in the fabrication of TiC-reinforced iron base (Fe-TiC) FGM. The observation of the fabricated specimen indicated an increasing trend of the hardness profile from the outer surface to the TiC-rich inner surface. The wear performance of the TiC rich inner face was found better compared to the particle free outer surface of ferritic steel matrices.

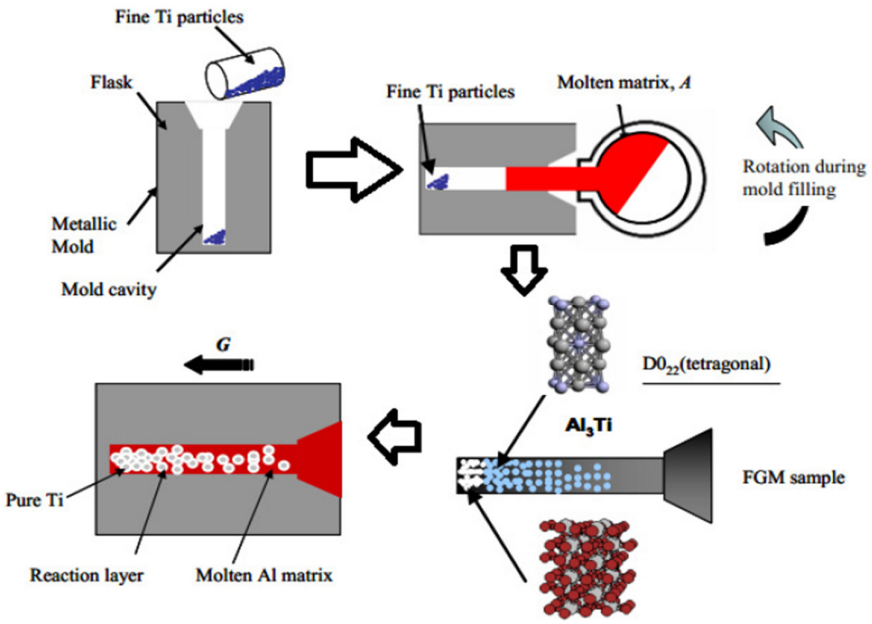

Figure 2. A schematic illustration showing CMPM

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Centrifugal mixed-powder method (CMPM) shown in Figure 2 is another method introduced as a solution to the limitation of centrifugal casting method in fabricating FGMs containing nano size particles. The study has been extended to propose another method called reactive centrifugal mixed-powder method (RCMPM) which able to produce better surface properties instead of controllable compositional gradients. The formation of gradient solidification is another aspect evaluated in the investigation made on the FGMs fabricated via centrifugation. In this study, SiC, B_4C, SiC graphite hybrid, primary silicon, Mg_2Si and Al_3Ni reinforced aluminum based FGM were prepared by centrifugal casting. The densities and the size of reinforcements were found as two major roles that influence the formation of graded microstructure. High density particles such as SiC and Al3Ni form gradation towards outer periphery while the particle having lower density such as graphite, primary silicon and Mg_2Si form gradation towards inner periphery. The B_4C particle which has closer density to Al alloy is the only particle that distributed more randomly compared to the other systems. Considering the processing of slurry form raw materials, another step named floc-casting has been proposed to be implemented after the centrifugation. During the fabrication, the floc-casting at 80°C is applied on the SiO_2-Mo FGM to form the homogeneity of the slurry green body before being fired at 1750°C for 10 min in Ar. Floc casting was found beneficent to control the slurry characteristics and henceforward making the centrifugation of slurry successful[4].

FGM using Infiltration Process

Infiltration or the scientific term called hydrology is the process by which fluid on the ground surface precipitates into the soil. This process is governed by either gravity or capillary action forces. The rate of infiltration is depends on the soil characteristics such as storage capacity, transmission rate through the soil and the ease of entry. The rate and capacity of the infiltration process can be controlled by adjusting some parameters including the soil texture, vegetation types and cover, the content of water in the soil, the soil temperature and rainfall intensity. The infiltration method was introduced for certain FGMs with a complex shape preparation. The fabrication with this method needs little or no bulk shrinkage and more rapid reaction kinetics.

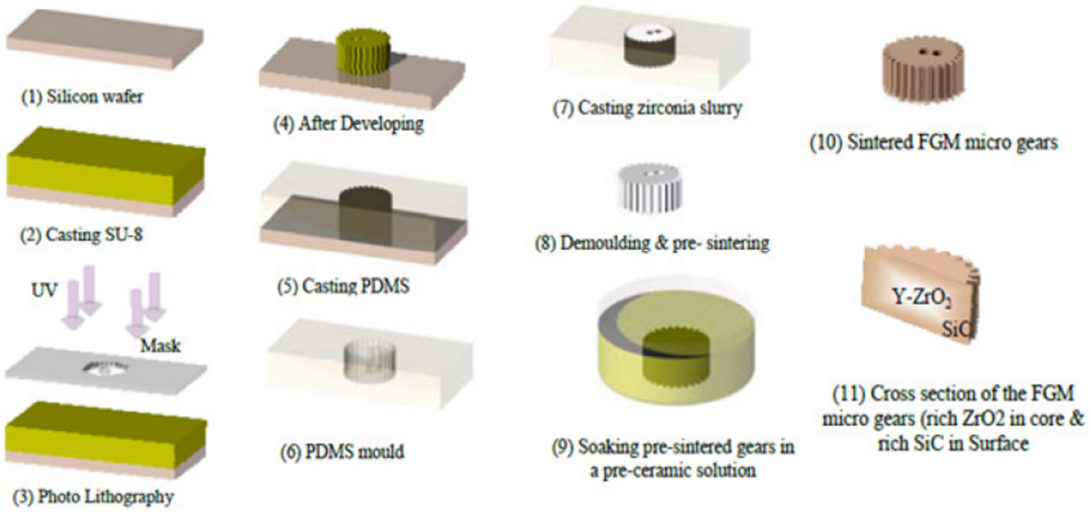

Figure. 3 Schematic diagram of infiltration process of YSZ/SiC FGM [6]

As the common process for the mold shaping is heating the powder to a temperature that is higher than liquid phase, the requirement to make sure no bulk shrinkage is quite challenging. From the literature, there is limited numbers of infiltration process implementation are reported. It is believed that the ticklish process handling and high costing demand are two main factors that make the infiltration become challenging to be used. The infiltration method has been implemented for FGM processing since many years before. A compositionally graded Al-SiCp composite was successfully fabricated using pressureless infiltration method at the early of last one decade. It has been indicated that the thermal conductivity of the produced FGM increasing in nonlinear trend while the volume fraction of the ceramic element decreased. An innovative way which introduced infiltration processing route with microwave sintering and environmental barrier coating (EBC) is subsequently presented for the fabrication of Si_3N_4 FGM that composed of α-Si_3N_4-Yb-silicate green parts and porous β-Si_3N_4 ceramics as the substrates[5,7].

Conclusion and Future Work

Functionally graded material is a great propelled material that will alter the producing world. There are various obstacles for understanding this objective. Lots of studies have been directed on conduct of functionally graded material and the writing is exceptionally rich on this in light of the fact that of the wide territories of use of this novel material. Functionally graded materials are

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essential in designing and different applications however the expense of delivering these materials makes it restrictive in some applications. This study exhibits an outline on FGM, its Characteristics, different manufacture strategies and its wide applications. In view of these criteria, this study inferred that the powder metallurgy as the most suitable strategy for the assembling of FGMs later on works. It is trusted that the fundamental issue in actualizing the PM strategy which is the sintering procedure ought to be further investigated keeping in mind the end goal to accomplish change in the microstructure and mechanical properties of the subsequent FGMs.

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