PREPARATION AND CHARACTERIZATION OF Al-Al_2O_3 GRADED COMPOSITE MATERIALS UNDER DIFFERENT SINTERING CONDITIONS

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We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Bahan-bahan yang berfungsi mengikut gred (FGMs) merujuk kepada bahan komposit termaju di mana komposisi dan struktur mikro diubahsuaikan secara tempatan supaya variasi sifat bahan setempat dicapai. Dalam penyelidikan ini, komposisi aluminium (Al) sebagai fasa logam, dan aluminium oksida (Al_2O_3) sebagai fasa seramik dalam bahan komposit bergred Al-Al_2O_3 disiasat disebabkan oleh ketidaksepadan ciri-ciri haba dari kedua bahan. Objektif utama penyelidikan ini adalah untuk mengkaji kecacatan dan kegagalan yang mungkin berlaku contohnya lapisan yang terhakis, lapisan yang terpisah dan pecahan lapisan semasa pemprosesan yang mempengaruhi parameter pensinteran pada ketumpatan, pengecutan radial, mikro-kekerasan dan struktur mikro bergred Al-Al_2O_3. Tesis ini melaporkan penyediaan bahan-bahan komposit bergred aluminium-aluminium oksida (Al-Al_2O_3) yang menggunakan teknik pemprosesan serbuk, termasuk penyediaan serbuk, pemadatan sejuk dan pemadatan tanpa tekanan. Bahan-bahan komposit bergred Al-Al_2O_3 yang mempunyai empat lapis gred berjaya dihasilkan dengan bebas kecacatan di bawah profil peleburan yang berbeza (dua langkah dan tiga langkah), suhu (600°C dan 620°C) dan masa (120 minit dan 180 minit). Al-Al_2O_3 FGM telah dianalisis untuk mengetahui kesan keadaan proses pensinteran pada kepadatan, pengecutan, mikro-kekerasan dan struktur mikro. Dari hasil kajian eksperimental, pemadatan dan kekerasan mikro Al-Al_2O_3 FGM bertambah baik kerana masa prosess pensinteran memberikan peranan yang paling penting semasa pemprosesan. Sementara, pengecutan dan struktur mikro Al-Al_2O_3 FGM bergantung pada suhu pensinteran. Dari analisis mikro struktur Al-Al_2O_3 FGM, didapati bahawa penyebaran keseragaman zarah seramik Al_2O_3 dalam matriks Al di ketiga-tiga lapisan komposisi bercampur dengan pengumpulan zarah yang minimum. Semua syarat sintering yang dipilih seperti suhu, masa dan profil, memainkan peranan utama sepertimana mikrograf menunjukkan perubahan dalam pengagihan zarah, ukuran pori dan lapisan antara muka dengan garis hampir lurus dan selari, bukan garis bergelombang.

ABSTRACT

Functionally graded materials (FGMs) refer to advanced composite materials where the compositions and microstructures are locally varied to allow certain variations of local material properties. In this research, the combination of aluminium (Al) as the metallic phase, and aluminium oxide (Al_2O_3) as ceramic phase in Al-Al_2O_3 graded composite materials are investigated because of mismatch of their thermal properties. The main objective of this research is to investigate the defects and failures such as delamination, decohesion and cracks that might occur during processing which influenced the sintering parameters on density, radial shrinkage, micro-hardness and microstructure of Al-Al_2O_3 graded structures. This thesis reports the preparation of the four-layered aluminium-aluminium oxide (Al-Al_2O_3) graded composite materials using powder metallurgy techniques, including the preparation of powders, cold compaction and pressure-less sintering. The free defects four-layered Al-Al_2O_3 graded composite materials were successfully fabricated under different sintering profiles (two-step and three-step), temperature (600°C and 620°C) and time (120 min and 180 min). The Al-Al_2O_3 FGM have been analysed to find out the effect of sintering conditions on density, shrinkage, micro-hardness and microstructural. From the result of experimental study, densification and micro-hardness of Al-Al_2O_3 FGM improves as the sintering time gives most significant roles during processing. While, shrinkage and microstructure of Al-Al_2O_3 FGM depending upon the sintering temperature. From the microstructural analysis of Al-Al_2O_3 FGM, it was found that uniform distribution of Al_2O_3 ceramic particles in the Al matrix in all three layers mixed composition with minimum agglomeration. All sintering conditions chosen such as temperature, time and profile, play main role as the micrograph indicated the improvement in distribution, size of pores and interfacial layer with almost straight and parallel line, rather than wavy lines.

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LIST OF SYMBOLS

C, K	Celsius, Kelvin (unit of temperature)
HB	Brinell Hardness
HV	Vickers Hardness
L_G	Length of green sample
L_S	Length of sintered sample
T	temperature
T_s	sintering temperature
Pa	Pascal (unit of pressure)
W	Weight
a	air
d	diameter
h	thickness
g	weight fraction
kN	kiloNewton (unit of force)
m, cm, μm	meter, centimetre, micrometer (unit of length)
ton	tonnage
t_s	sintering time
w	water
ρ	density

LIST OF ABBREVIATIONS

CIP	Cold Isostatic Pressing
CTE	Coefficient Thermal Expansion
EDX	Energy Dispersive X-ray
FGMs	Functionally Graded Materials
OM	Optical Microscope
PM	Powder Metallurgy
ROM	Rule of Mixture
SEM	Scanning Electron Microscope
TD	Theoretical Density
Al	Aluminium
Al_2O_3	Aluminium Oxide
mol.%	molecular percentage
wt.%	weight percentage

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