# DEVELOPMENT AND CHARACTERISATION OF LANTHANUM-BASED BULK METALLIC GLASS (BMG) WITH LOCALISED DUCTILISATION

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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 institution.

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# ABSTRAK

Logam kaca padu (LKP) menawarkan sifat-sifat yang lebih unggul berbanding aloi logam perindustrian pada masa kini. Sifat-sifat tersebut yang melebihi logam kristal dari segi kekerasan, kekuatan, kelesuan dan tahap hubungan tekanan-regangan yang lebih tinggi. Di dalam penyelidikan ini, fenomena jalur ricih diperhatikan melalui pemampatan beban ke atas sampel-sampel LKP $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$. Fenomena tersebut diperhatikan melalui mikroskop elektron pengimbasan (MEP) dan mikroskop elektron pengimbasan pelepasan medan (MEPPM). Kemajuan teknologi penghasilan LKP dalam beberapa tahun kebelakangan ini menggunakan pemprosesan laser menambahkan ketersediaan kaedah-kaedah untuk penciptaan LKP. Di bahagian lain penyelidikan, penciptaan sampel-sampel LKP dengan kawasan-kawasan kemuluran setempat telah dilakukan melalui pemprosesan laser. Proses laser tersebut memfokuskan tenaga ke zon terjejas haba (ZTH) dan dipilih sebagai kaedah pemanasan setempat. Sampel-sampel ini kemudiannya telah dibuat menjadi bahan yang digred secara fungsian (BGF) yang berasaskan LKP lanthanum. Salah satu pencapaian penting yang dikemukakan dalam karya semasa ini adalah parameter-parameter pemprosesan laser yang optimum bagi LKP $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$. Sebagai tambahan kepada sejumlah besar ujian pencirian terhadap LKP $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ untuk memperluaskan pengetahuan sedia ada terhadap sistem aloi LKP khusus ini. Ini menambah baik ilmu pembuatan LKP sebagai kawasan mulur kristal. Selain daripada itu, penemuan menarik yang lain di bawah karya ini untuk LKP $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ adalah fenomena patahan-pelepasan (*fracto-emission*) dan tindak balas keretakan dengan elemen-elemen struktur mikronya. Kelemahan LKP adalah kerapuhan yang secara semula jadi diperoleh dari strukturnya yang amorfus, berikutan fenomena jalur ricih yang boleh menyebabkan keretakan pramatang. Batasan-batasan LKP pada masa ini adalah saiz seperti acuan tuangan, kerapuhan yang mempengaruhi kemesinan dan suhu tinggi yang mempengaruhi kestabilan LKP. Dalam penyelidikan masa depan, prosedur-prosedur pasca pemprosesan logam pada aloi logam standard, seperti merivet, menskru dan menempa dapat dilakukan di kawasan setempat LKP. Keupayaan untuk menggabung atau memesin bahagian LKP ke bahagian logam kristal atau bahagian LKP lain dapat meningkatkan saiz bahagian tersebut, bentuk dan kepraktisan LKP. Kemuluran LKP bersasar yang menghasilkan LKP BGF boleh menjadi suatu teknik yang boleh dilaksanakan untuk menyelesaikan isu kemampuan pembuatan LKP pada masa hadapan.

## ABSTRACT

Bulk Metallic Glass (BMG) offers properties superior to the present industrialised metal alloy. The properties exceed crystalline metal in terms of hardness, strength, fatigue, and a higher level of stress-strain relation. In this research, the shear band phenomenon was observed through the compression loading on the $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ BMG samples. The phenomenon was observed through the scanning electron microscope (SEM) and field emission scanning electron microscope (FESEM). In another part of the research, BMG samples with localised ductilisation areas were created through laser processing. The laser process focused the energy into the heat-affected zone (HAZ) and was chosen as the localised heating method. These samples were then made into functionally graded material (FGM) that were based on lanthanum BMG. One of the essential achievements presented in the current work was the optimum laser processing parameters of the $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ BMG. In addition, ample amount of characterisation testing towards the $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ BMG samples for expanding the existing knowledge towards this specific BMG alloy system were presented. This would aid with the advancement of BMG manufacturability as the crystalline ductile area. Other than that, other exciting findings under this work for the $La_{61.4}Al_{15.9}Ni_{11.35}Cu_{11.35}$ BMG were the fracto-emission phenomenon and the fracture response with its microstructure elements. The disadvantage of BMG is the brittleness inherently gained from its amorphous structure, following the shear band phenomenon, which could cause a premature fracture. The advancement of BMG production technology in recent years using laser processing has added an option to the methods available for BMG creation. In future research, post-metal processing procedures on standard metal alloy, such as riveting, screwing and forging, could be prepared on the BMG localised area. The current restrictions of BMG are the size is as-cast inherent brittleness, which affected the machinability and high-temperature process, which affected the meta-stability of the BMG. The capability to join or machine the BMG part to other crystalline metal or BMG parts would increase the part size, shape and BMG practicality. Localised ductilisation of BMG that produced FGM BMG could be a feasible technique to solve the future BMG manufacturability issue.

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