Structural evolution and mechanical properties of Al-Cu-Fe quasicrystal reinforced 6082 Al matrix nanocomposites by mechanical milling and spark plasma sintering

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The formation of QC phases in Al-Cu-Fe ternary systems are well reported in the literature due to its non-toxicity, low price and easy availability of constituent's elements [1]. In the past, considerable efforts were made towards understanding its structure in detail. This Al-Cu-Fe based QC may be exploited as a potent material for reinforcement in Al matrix composites (AMCs). In the present investigation, 6082 Al matrix is reinforced with Al-Cu-Fe quasicrystals (QC) through mechanical milling (MM). The phase evolution, composition, morphology and thermal stability of MM Al-QC nanocomposites powder were studied through XRD, TEM, SEM and DSC respectively. During MM of these Al-QC AMCs, it was observed that a minor fraction of QC transforms to $Al_{13}Fe_4$ type (a=1.549 nm, b=0.808 nm, 1.248 nm, α=β=90˚, γ=107.72˚; mC102; C2/m) crystalline phases [2].

Further, efforts were made to consolidate these Al-based hybrid nanocomposites by spark plasma sintering (SPS). The effect of SPS temperature and pressure on these AMCs were investigated through electron microscopy of interfaces and mechanical properties. The microstructural characteristics and mechanical properties of these composites were studied through electron microscopy, instrumented indentation techniques & compressive testing. The present study provides insight into the structural transformation of QC reinforcement to crystalline phases during the consolidation of these AMCs through SPS. The AMCs SPSed at 550 °C (823 K) has appreciable compressive yield strength and ultimate strength ~ 519 MPa and 639 MPa respectively, with Young's modulus of 134 GPa. The SPS of milled powder was also carried out at high pressure (~500 MPa) and moderate temperature to avoid the formation of crystalline phases related to QC. The AMCs SPSed at a temperature of 200 (473 K), 300 (573 K) and 400 °C (673 K) results in the formation of Al-30QC composite with relative density of ~95%, 99% and 100% respectively. The tuning of SPS parameters for tailoring of structure and microstructure leads to enormous rise in the compressive strength ~900 MPa. This significant rise in the mechanical properties may be attributed to the direct and indirect strengthening due to QC reinforcements in AMCs. The present study provides an insight into the microstructural evolutions and the interfacial strengthening of the Al-based composites reinforced with QCs.

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Canceled

Quasicrystals for Hydrogen Production and Storage

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Energy is an important part of human civilization; however, the world is facing an energy crisis due to exponential population growth and limited availability of fossil fuels. It needs essential attention about its availability; therefore, solving this energy demand using more efficient or clean alternative energy sources will save the planet from harmful effects caused by pollution. Quasicrystals, may be an important material that could be considered as catalysts for energy generation and also for storage because of their complex structure containing transition metal elements. In order to achieve this goal, we have attempted to fabricate2-dimensional layered Al-Pd-Mn and Al-Co-Cu quasicrystalline structure-based catalyst for hydrogen production [1,2]. We demonstrate an easily scalable technique for the synthesis of layered metallic alloys from their 3D quasicrystalline precursors. The layered alloy possesses 2-fold decagonal quasicrystalline symmetry and consists of two- or three-layer-thick sheets with a lateral dimension of micron. These metallic layers were combined with the atomic layers of tungsten disulfide to form the stacked hetero structures, which is demonstrated to be a stable and efficient catalyst for hydrogen evolution reaction. We have also demonstrated the catalytic activities of leached Al-Cu-Fe quasicrystals for hydrogen storage in MgH_2 and complex hydride $NaAlH_4$ [3,4]. The 2-hour leached as grown and mechanically activated Al-Cu-Fe layer materials was subjected for catalyst application in hydrogen storage materials for MgH_2. The leached ball-milled Al-Cu-Fe catalyzed $NaAlH_4$ sample has shown a lower hydrogen desorption temperature (140 ºC) than other catalyzed and uncatalyzed $NaAlH_4$ samples. The catalytic effect of leached quasicrys-talline alloys on the de/re-hydrogenenation characteristics has been studied in details. The hydrogenation behaviour including absorption and desorption kinetics will be discussed in details.

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Direct Ink Writing of Quasicrystalline ZnO Structures

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Direct Ink Writing (DIW) is an extrusion-based 3D-printing process that presents itself as an innovative method of manufacture to create complex structures from advanced materials. These materials can possess desirable bulk characteristics such as light or acoustic bandgap properties, or multi-material architectures. [1] Whilst 3D-printed complex structures discovered in research are almost always confined to lab-based experiments and studies, the scope exists beyond this realm to expand its applications. This work aims to demonstrate the benefits that additive manufacturing (AM) of functional materials can offer in metamaterials, a rapidly growing field.
Using a GCode designer [2] and DIW techniques [3] we propose a way to construct and print a 3D quasicrystal based on a square Fibonacci tiling (Fig. 1). [4] We will present our design and coding approaches, the results of the processing and characterisation of ZnO formulations for DIW, as well as examples of the printed Fibonacci structures. We will also discuss future work to evaluate the EM wave properties of such structures, starting with fundamental studies to determine whether the bandgaps shown elsewhere in theoretical calculations are present in our own conceptualised designs. The ultimate goal of this work is to better understand how the physical properties of these macro-scale QC structures relate to the atomic-scale QC structures that are currently achieved through common surface science techniques.

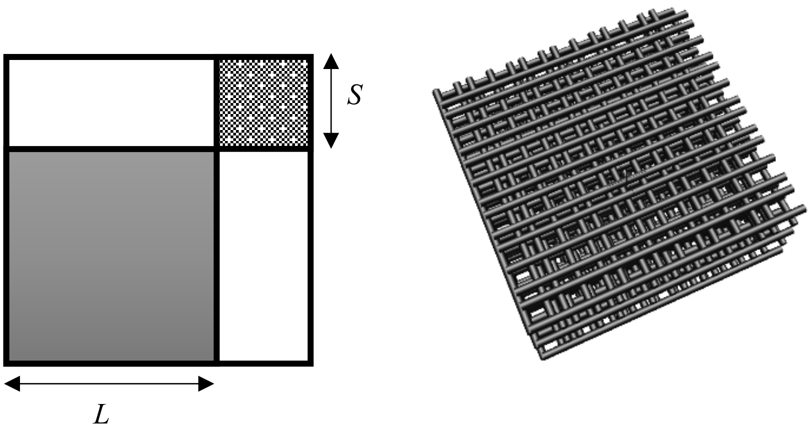

Fig. 1: (left) The three allowed tiles (Long and Short).
(right) A 3D model of the Fibonacci square quasicrystal.

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