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Authors: T. Galvin, N.C. Hyatt, W.M. Rainforth, I.M. Reaney, D. Shepherd

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Molten salt synthesis of MAX phases in the Ti-Al-C system

T. Galvin[1], N. C. Hyatt[1], W. M. Rainforth[1], I. M. Reaney[1], D. Shepherd[2]*

[1]Department of Materials Science and Engineering, University of Sheffield, Sir Robert Hadfield Building, Mappin St, Sheffield, S1 3JD, UK

[2]National Nuclear Laboratory (NNL), NNL Preston Laboratory, Springfields, Salwick, Preston, PR4 0XJ, UK

[*] ***Corresponding Author**. E-mail address: trgalvin1@sheffield.ac.uk*

Abstract

The molten salt method was used to synthesise the MAX phase compounds Ti_2AlC and Ti_3AlC_2 from elemental powders. Between 900–1000 °C, Ti_2AlC was formed alongside ancillary phases TiC and TiAl, which decreased in abundance with increasing synthesis temperature. Changing the stoichiometry and increasing the synthesis temperature to 1300 °C resulted in formation of Ti_3AlC_2 alongside Ti_2AlC and TiC. The type of salt flux used had little effect on the product formation. The reaction pathway for Ti_2AlC was determined to be the initial formation of TiC_{1-x} templating on the graphite and titanium aluminides.

Keywords: Ti_2AlC, Ti_3AlC_2, MAX phase, molten salt, synthesis

1. Introduction

MAX phases are layered compounds with the space group *$P6_3/mmc$* formed from at least one transition metal (M), at least one metalloid element (A) and a non-metal (X), principally carbon or nitrogen. They are primarily considered to conform to the general formula $M_{n+1}AX_n$ and the nomenclature 211, 312 and 413 refer to the three simplest MAX phase formulae [1]. A number of other formula relationships exist for compounds of M, A and X elements which have similarities to those corresponding to the $M_{n+1}AX_n$ formulae but are not considered as true MAX phases but rather as 'MAX phase-like' [2]. Alloying of one or more elements within the M and/or A sublattices is also possible and potentially also the X sublattice, giving a very wide range of potential compositions beyond the 60 or so true MAX phases discovered composed from only three elements [3].

MAX phases were originally discovered/synthesised in the 1960s, but subsequently were little researched until their remarkable combination of properties was identified in the 1990s including relatively high fracture toughness compared to ceramics, machinability and good thermal and electrical conductivity; bridging the gap between metallic and ceramic materials [4]. They are now extensively researched. Typically, MAX phases have reasonable oxidation resistance, but in particular aluminium-containing phases have been shown to form a well-adhered protective alumina (Al_2O_3) scale upon heating in air, which does not spall off with heat-cycling [5] further protecting the