

Review

Synthesis, properties and applications of titanium aluminides

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Attractive elevated-temperature properties and low density make the titanium aluminides very interesting for both engine and airframe applications, particularly in the aerospace industry. The challenge to the materials scientist is to maintain these characteristics while building-in "forgiveness". The basic phase diagram and crystal structure of both the Ti_3Al and $TiAl$ phases are reviewed, followed by a consideration of chemistry-processing-microstructure-deformation/fracture-mechanical property relationships in monolithic material. Conventional and innovative synthesis methods are presented, including use of hydrogen as a temporary alloying element. Composite concepts as a method to enhance not only "forgiveness" but also elevated-temperature behaviour are discussed. Environmental effects are evaluated prior to consideration of present and projected applications of both monolithic and composite material. It is concluded that while the titanium aluminides in monolithic form can be used now in non-demanding applications, much further research and development is required before this material class can be used in critical applications, especially in composite concepts.

1. Introduction

Advanced materials are key to technological advancement [1, 2], and enhanced structural materials are particularly vital to aerospace system improvements where the extremely demanding conditions require that the new materials are "stronger, stiffer, hotter and lighter". These advanced materials will often be "tailored" or "engineered" to exhibit the properties required for a given application by use of composite concepts [3-17]. Cost can be a major concern, but an integrated design, manufacturing and use approach can lead to cost-effective application, where these new materials are considered as structures rather than in the same way as traditional materials such as metals.

An attractive class of "advanced materials" are the intermetallic compounds [18] which can be simply defined as an ordered alloy phase formed between two metallic elements [19], where an alloy phase is ordered if two or more sublattices are required to describe its atomic structure [20, 21]. The ordered structure exhibits attractive elevated-temperature properties (strength, stiffness, environmental resistance, etc.) because of the long-range ordered superlattice which reduces dislocation mobility and diffusion processes at elevated temperatures [22-25]. However, this reduced dislocation motion also results in generally extremely low ambient-temperature fracture-related properties including ductility and fracture toughness. Recent research has focused on

understanding and controlling this brittleness while maintaining the attractive elevated-temperature characteristics.

Because of their low density the ordered intermetallic titanium aluminides, based on Ti_xAl ($x = 1$ or 3), are particularly attractive candidates for applications in advanced aerospace engine and airframe components, in both monolithic and composite concepts [26-33]. A comparison of the characteristics of the monolithic titanium aluminides with other aluminides is shown in Table I [34] and with conventional titanium alloys in the creep curves shown in Fig. 1 [9]. The present materials mix in an advanced jet engine is shown in Fig. 2 [34] and a possible material mix in a 2010 engine in Table II [34]. A

TABLE I Melting points and densities for aluminides [34]

Aluminide	Melting point (°C)	Density (g cm ⁻³)
Ti_3Al	1600	4.2
$TiAl$	1460	3.9
Fe_3Al	1540	6.7
$FeAl$	1330	5.6
Ni_3Al	1390	7.5
$NiAl$	1640	5.9
Superalloys (typical)	1325-1400	9

* On leave from Ben Gurion University of the Negev, Beer Sheva, Israel.

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Low Temperature Chemical Routes To Synthesis And Processing Of Titanium Aluminides Intermetallics:

Low Temperature Chemical Routes to Synthesis and Processing of Titanium Aluminides Intermetallics, 1996 The goal of this project was to synthesize gamma TiAl using low temperature chemical processing techniques Four different chemical processes based on the electropositive and reducing power of lithium were used to investigate their potential for the synthesis of the aluminides The reactions conducted in polar solvents resulted in the formation of TiAl along with TiC as a secondary phase Among the various polar solvents attempted THF appears to be the most suitable solvent since the carbide phase was very much reduced It also appears from these preliminary studies that subjecting the precursors to pre treatment in H₂ makes them stable towards oxidation Washing the preheated powders in water at this stage helps in minimizing and even elimination to a large extent impurity phases which may be related to lithium The uses of inert solvents were found to be unsuitable due to the formation of insoluble adducts that lead to the generation of the formation of unknown phases in addition to TiC The presence of TiC as an impurity is related to the coordination of TiCl with the solvent The process offers promise and future efforts should be concentrated on removal of the solvent molecules coordinated to the metal groups so that single phase gamma TiAl can be synthesized At the same time it is possible that these TiAl TiC composites may have some potential structural application

Program Solicitation, 1989 Intermetallic Matrix Composites Rahul Mitra, 2017-05-25 Intermetallic Matrix Composites Properties and Applications is a comprehensive guide that studies the types and properties of intermetallic matrix composites including their processing techniques characterization and the various testing methods associated with these composites In addition it presents modeling techniques their strengthening mechanisms and the important area of failure and repair Advanced complex IMCs are then explained such as Self healing IMCs and laminated intermetallic composites The book concludes by delving into the industries that use these materials including the automotive industry Reviews the latest research in intermetallic matrix composites Contains a focus on properties and applications Includes contributions from leading experts in the field

Synthesis, Processing and Modelling of Advanced Materials F. H. Froes, T. Khan, 1993 The volume presents the results of the 2nd ASM Paris conference on advanced materials The theme of the meeting was selected to recognize that materials have matured to a stage where significant advances in the future require more than the traditional microstructure mechanical property relationships approach Greater emphasis must rather be placed on synthesis processing and modelling of advanced materials to achieve enhanced levels of physical and mechanical performance

Characterization of Metals and Alloys Ramiro Pérez Campos, Antonio Contreras Cuevas, Rodrigo A. Esparza Muñoz, 2016-10-24 This book covers various aspects of characterization of materials in the areas of metals alloys steels welding nanomaterials intermetallic and surface coatings These materials are obtained by different methods and techniques like spray mechanical milling sol gel casting biosynthesis and chemical reduction among others Some of these materials are classified according to application such as materials for

medical application materials for industrial applications materials used in the oil industry and materials used like coatings
 The authors provide a comprehensive overview of structural characterization techniques including scanning electron
 microscopy SEM X ray diffraction XRD transmission electron microscopy TEM Raman spectroscopy image analysis finite
 element method FEM optical microscopy OM energy dispersive spectroscopy EDS Fourier transform infrared spectroscopy
 FTIR differential thermal analysis DTA differential scanning calorimetry DSC ultraviolet visible spectroscopy UV Vis infrared
 photo thermal radiometry IPTR electrochemical impedance spectroscopy EIS thermogravimetry analysis TGA thermo
 luminescence TL photoluminescence PL high resolution transmission electron microscopy HRTEM and radio frequency RF
 The book includes theoretical models and illustrations of characterization properties both structural and chemical Metals
Abstracts ,1996 Gamma Titanium Aluminide Alloys 2014 Young-Won Kim,Wilfried Smarsly,Junpin Lin,Dennis
 Dimiduk,Fritz Appel,2014-09-24 This book is a collection of papers presented at the 4th International Symposium on Gamma
 TiAl Alloys ISGTA 2014 that was held in conjunction with the 2014 Annual Meeting of The Minerals Metals Materials Society
 Papers discuss and assess advances in application and implementation experience in current alloys fundamental aspects in
 current gamma alloy materials technology new processes development and assessment and emerging new alloys their
 potentials and limitations and breakthroughs Papers that originated in the panel discussion of the symposium are intended to
 help the scientific community realize the limitations of current alloys materials and processes and discuss possible solutions
 Six topic areas selected for this purpose included Wrought processed alloys status dilemmas and pathways to future Cast
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Particle Technology ,1995 Ceramic Abstracts ,2000 *Gamma Titanium Aluminides 2003* Young-Won Kim,Helmut
 Clemens,Andrew H. Rosenberger,2003 A March 2003 meeting provided a forum for scientists to share information on
 progress in gamma TiAl alloys Selected papers from the meeting 77 in all are presented here and cover applications
 fundamentals alloy design and development processing joining microstructure property evaluation an **Scientific and**
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