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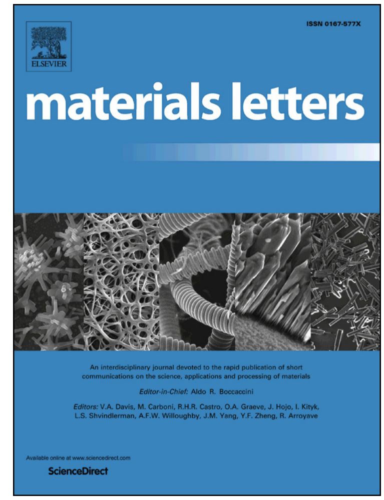

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Laves phases in selective laser melted TiCr1.78 alloys for hydrogen storage

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Abstract

Hydrogen is one of the most promising clean energy carriers within alternative fuels. The need for its absorption/release at reasonable p/T conditions within materials, like metallic Ti-Cr alloys, is primary for its use in renewable and sustainable energy applications.
In this work $TiCr_{1.78}$ compound was produced via selective laser melting (SLM) first time. Due to lack of commercially available powders of Ti-Cr compositions, two powders prototype precursors, premixed or prealloyed, were prepared and investigated. Correlation among powder type and microstructure of SLM built was studied. Prealloyed powders allowed Laves phases to be obtained in SLM parts while premixed did not fully react. Relative density of SLM products was strictly correlated to energy density.

Keywords: SLM, Laves phases, Additive manufacturing, microstructure.

Introduction

Ti–Cr alloys have been object of great research interest due to their promising high temperature strength, excellent wear, oxidation resistance and long-term stability at temperature above 1000°C for developing medical and aerospace applications [1-3]. $TiCr_2$ crystallizes in three Laves phases, namely C14, C36 and C15, exhibiting large interstitial sites to accommodate guest molecules, like H_2. $TiCr_2$ based alloys can be applied to sustainable energy applications for reversible H_2 storage [4-6], each Laves phases being able to absorb similar amount of H_2 [7]. H_2 absorption mechanism is a multistep process, involving adsorption on metal surface by molecular H_2, its split into single atomic species, followed by diffusion of atomic hydrogen into the alloy forming a hydrade [8]. As the mechanism involves surface interactions, materials with controlled microstructure and porosity are desired. Ti-Cr alloys have shown good physical/chemical properties, but brittleness remains their greatest limitation [9]. Consequently, powder metallurgy assisted by additive laser processing can be a valid alternative technique with respect to conventional deposition or melting methods for producing parts. Porosity obtained in conventional powder metallurgy processes relies on powder type, shape and processing conditions and controlled indirectly. SLM provides the possibility to design interconnected and engineered geometries, able to tailor both mechanical and chemical properties of H_2 storage device.
Only two works regarding fundamental aspects of laser deposition of TiCr alloys are described in literature. Zhang reported about in-situ laser micro-cladding of elemental powder mixtures. Composition gradient structure from Ti to $Ti_{60}Cr_{40}$ (at.%) was prepared. Rapid solidification resulted in generating metastable β-Ti(Cr) and $TiCr_2$ [10]. Banerjee observed metastable matrix of β-Ti(Cr) with different precipitates: α-Ti in its pure form and alloyed to Cr(α-Ti(Cr)), and C14 Laves phase [11]. Evidently the use of powder-bed fusion technique, like SLM, would allow for higher geometrical flexibility and details.
Accordingly, this work explores the use of SLM for producing $TiCr_{1.78}$ parts. Two viable precursors at a material prototyping level namely, elementally mixed spherical and prealloyed powders, were tested with a flexible and open SLM platform. Density and microstructure of built parts were assessed as function of precursor type. Small samples were produced varying energy density for both powder types. Microstructure was studied through X-Ray Diffraction (XRD) and Scanning