



# Application of metal hydrides as pore-forming agents for obtaining metal foams



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## ABSTRACT

One of the well-known ways of metal foam production consists of adding powder which releases gaseous decomposition product at high temperatures into a melted metal. When producing aluminum foams, titanium hydride powder is most frequently used, while its main disadvantage is its insufficient thermal stability. This results in a premature gas loss in the process of the powder introduction into a melted metal matrix. The paper discloses approaches to suppression of the undesirable premature titanium hydride decomposition by means of its preliminary thermal treatment, as well as the external pressure elevation over that of the system being processed during the foam formation. A method of using the thermally treated powder is proposed, in order to obtain aluminum foam samples having a required geometry and sufficiently uniform porous structure.

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## 1. Introduction

Metal foams are advanced structural materials used for numerous applications (see, for example, [1,2]). Depending on a foam production method it is possible to obtain materials with pores having different structures [2,3].

A metal can be foamed by means of adding pore-forming agents into the metal melt at a certain temperature because such agents are disintegrated actively and release gaseous decomposition products, which cause the melted mass foaming [1–3]. The subsequent cooling of the melt allows obtaining the metal foams, which are characterized by a relatively high uniformity of spatial structural porosity, if the process parameters are chosen correctly [2]. In order to implement the said method effectively, it is necessary to match a metal melting temperature and temperature range for gas release from a pore-forming agent [2,4]. If a foaming agent releases the gas at the temperature, which is significantly lower than the metal melting temperature, the metal will start to expand in its solid state, and therefore cracked pores will form leading to a non-uniform porous structure. If the foaming agent decomposition temperature is much higher than the metal melting point, the metal melt density will be too low for providing the stable foam formation [2,4].

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Aluminum foams are the most practical primarily due to aluminum relatively low melting temperature and its availability [2]. Besides, technologies for obtaining items from aluminum foams do not comprise the sample mechanical treatment step, thus reducing the final product cost. Actually, a powder pore-forming agent is introduced into the melted aluminum (or its alloy) and mixed with the metal, and then the mix is cooled fast, in order to prevent too intensive foaming. Then a required amount of the obtained half-ready product is placed into a desired part mold, which is heated up to the desired foam formation (see, for example [5]). It would be easier to mix the forming agent with aluminum powder [6,7], though this approach precludes the use of less expensive precursors resulting in a significant growth of the foam production cost.

In respect to aluminum foams, titanium hydride powder is most frequently used as the pore-forming agent as the most available and inexpensive material having the highest specific released gas content as compared to other possible foaming agents (see, for example, [2,4]). However, a significant disadvantage of this material is its tendency to fast decomposition during heating, while, in order to obtain a uniform foaming agent distribution in the aluminum melt, a certain exposure time is required without hydrogen release [4,5]. So, the goal of the present work is to determine the optimal conditions of oxidation process of titanium hydride powder by air oxygen and to provide methods of partly oxidized hydride introduction into aluminum melt that allow obtaining aluminum foams with sufficiently uniform porous structure.

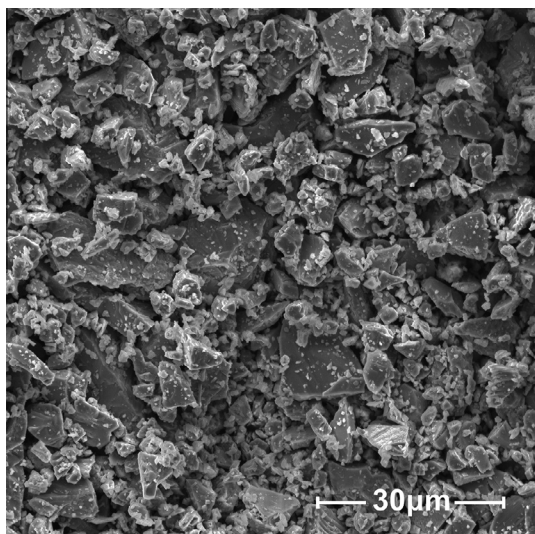


Fig. 1. The electron microscopy image of the titanium hydride powder.

## 2. Materials and methods

The present work proposes application of a shielding coating to the titanium hydride powder particles aiming at its thermal stability enhancement and delaying of hydrogen release during heating, in order to increase the decomposition initiation temperature. Literature review has shown that shielding can be provided by oxide and oxohydride layers, which are formed on the hydride particle surface as a result of its preliminary oxidation by the air oxygen [4,8–10]. It is known that a partly oxidized titanium hydride powder in aluminum melts provides uniform pore morphology in the foamed metal [2]. During the present studies it was necessary to determine optimal hydride oxidation modes allowing enhancing the powder thermal stability along with the maximum retention of the specific gas content.

Commercial titanium hydride powder (GT brand) [11] made from titanium sponge was used as a test object. The electron microscopic image of the material particles is shown in Fig. 1. Average size of powder particles measured by optical microscopy was  $\sim 7 \mu\text{m}$ . The titanium hydride thermal treatment dealt with warming up of thin powder layers in the air atmosphere. The oxidation temperature preset for different batches of powder was within the range of 440–540 °C with a 20 °C step with account for the recommendations mentioned in Ref. [8]. The powder exposure time at the said temperature was within the interval of 1–3 h. Technological aspects of the oxidation process are described in more detail in Ref. [11].

## 3. Results and discussions

A comparison of thermal resistance of the powders heated in the open air at various temperatures was performed by means of the volumetric technique relying on measuring the rate of hydrogen release from a precisely weighted amount of the powder at a predetermined decomposition temperature (700 °C). The obtained dependencies of pressure vs time in the physical system being analyzed are shown in Fig. 2.

As is shown in Fig. 2, the rate of hydrogen release from titanium hydride, which was oxidized preliminarily in any of the aforementioned temperature modes, decreased drastically as compared to the non-oxidized precursor powder. Furthermore, according to the obtained results the oxidation temperature increase over  $\sim 500$  °C leads to a noticeable reduction in the hydride's specific gas content after the treatment (more than  $\sim 12\%$  [11]) due to its thermal decomposition. For the same reason, the heating time extension more than 1 h is undesirable too. The further refinement of the conditions for the titanium hydride powder oxidation with the atmospheric oxygen has shown that the best reproducible results are reached in case of the powder oxidation at  $\sim 440$  °C for an hour. So, this oxidation mode was chosen as the optimal treatment. A more detailed analysis of the experimental data is provided in Ref. [11,12].

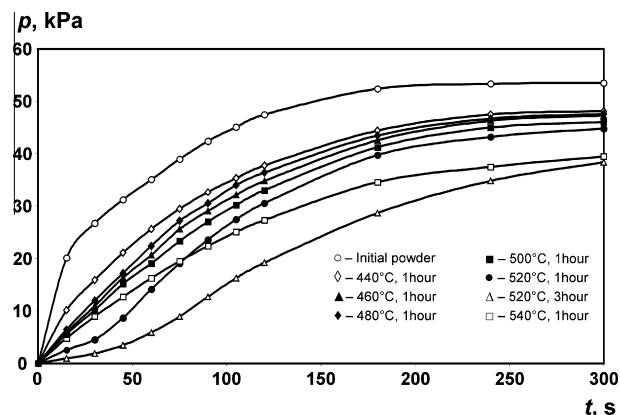


Fig. 2. The time dependencies of the hydrogen pressure in the physical system during the thermal decomposition process (at 700 °C) in the titanium hydride samples oxidized in various modes.

The use of zirconium hydride powder, which has a higher thermal resistance, was tried out as an alternative approach to the hydride powder thermal stability enhancement [4]. However, our experiments on obtaining aluminum foams using zirconium hydride powder as the pore-forming agent revealed that the said approach does not lead to the desired result. Actually, the aluminum melt heating up to higher temperatures required for the intensive zirconium hydride decomposition leads to the formation of a low-viscous melt, which causes the released hydrogen escape into the surrounding environment without producing the necessary porous physical system. Thus, according to our data, the titanium hydride powder, which has been pre-oxidized by means of heating in air following the aforementioned mode, is the most optimal pore-forming agent.

The next step was to provide the experimental verification of the possibility to mix the pre-oxidized at  $\sim 440$  °C titanium hydride powder with liquid aluminum, in order to obtain a homogeneous physical system. In that regard, using a specially designed facility specific tests were performed on adding the said material to liquid aluminum in the amount  $\sim 1.0$  mass%. These tests proved that the chosen foaming agent can be mixed with the melt using mechanical stirring during 2–3 min, while preserving a substantial quantity of the non-decomposed hydride necessary for the further metal foaming. Additionally, similarly designed tests were performed on mixing hard-melting disperse materials (metal oxides, borides and carbides) with the aluminum melt aiming at the formation of a rigid foam matrix containing porous cells [1,2]. The

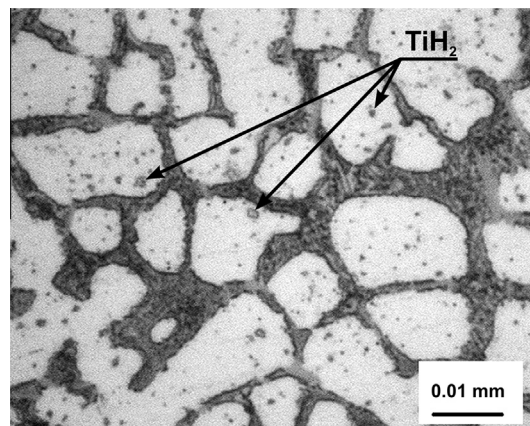


Fig. 3. Optical microscopic image of the cross section slice of metal granule sample, containing partly decomposed titanium hydride particles.

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