Hydrogen processing as a way of producing fine metallic powders

Zeynep Ege Uysal[1,2], Sertac Altinok[1,2], Y. Eren Kalay[1] and Tayfur Ozturk[1]
[1]Middle East Technical University, Dept. of Metallurgical and Materials Engineering, Ankara, Turkey
[2]Turkish Aerospace Industries, Inc., Advanced Manufacturing Technologies, Ankara, Turkey

Hydrogen (H) commonly undergoes reactions with metallic elements forming metal hydrides (M-H) since metals can exhibit hydrogen diffusivity comparable to that of ions in aqueous solutions, allowing thermodynamic equilibrium to be attained relatively quickly, even at room temperature [1]. The capacity of hydrogen to form metal-hydride systems is generally attributed to its (a) moderate electronegativity, (b) small atomic size, and (c) low nuclear mass [2]. Metal lattices accommodate H atoms typically at their interstitial sites by going through fundamental changes in the crystal structure leading to the formation of different phases metal-hydrogen systems [2]. H atoms can be densely packed in metal hosts through a large exothermic reaction such that the density of hydrogen can surpass that of liquid hydrogen. The aforementioned factors stimulate the utilization of metal hydrides for energy storage purposes [3].

The impact of H on metals can be examined from various perspectives. Hydrogen embrittlement (HE) is a detrimental phenomenon for structural metals, as it can proceed to sudden failure even at low stress levels and concentrations of H. Conversely, the embrittlement is regarded as a convenient method for producing finely divided metal powders of transition and rare-earth (RE) metals which exhibit brittleness after H absorption. The brittle nature of H absorbing metallic systems stems from the significant volumetric changes that occurs during the formation of solid solutions and/or hydrides. Intermetallics such as $LaNi_5$, $SmFe_3$ and TiFe display high H absorption capacity and exceptional lattice expansion around 27.4%, 19%, and 18.8% respectively which results in the decrepitation of the material into fine powder form readily [4]. Hydrogen decrepitation (HD) is also a widely used route to obtain sinterable powders for strong permanent magnet production (e.g., $Sm_2(Co,Fe)_{17}$, $Nd_2Fe_{14}B$). Nd-Fe-B alloys become H hardened due to the formation of a Nd-rich hydride phase and disintegrate upon milling methods [5].

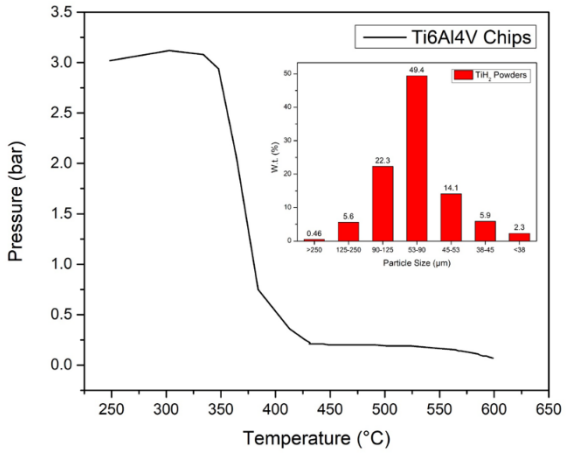

Figure 1. Hydrogenation process of Ti6Al4V chips

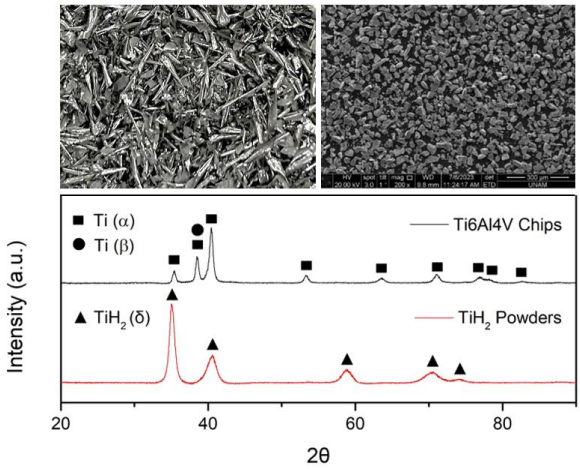

Figure 2. XRD spectra of hydrogenated Ti6Al4V powders

The elemental metals such as Pd, Ti, Zr also accomodate large amount of H in their lattice sites without losing their integrity. Therefore, most M-H systems require further mechanical force to form powders similarly to magnetic compounds.

In this study, Ti-H system is investigated by using a titanium alloy. Ti6Al4V chips are cleaned and hydrogenated at 650°C for 1.5 hours in a stainless-steel vessel. Then, the vessel is air cooled overnight for the formation of brittle TiH_2 phase. After, the chips are ball-milled for 30 minutes for the fragmentation process. Last, the powders are sieved and characterized. According to Figure 1, the hydrogenation started around 340°C and continued until the chips are fully hydrogenated. 50% of the powders were in between 53-90 μm and there were also particles below 38 μm. XRD spectra of the powders shows that there is only TiH_2 phase present without any α or β phases (Fig.2.).

Acknowledgements

This work is supported by the Scientific and Technological Research Council (TÜBİTAK) of Türkiye within 1004 program under the project number 20AG051.

References

[1] Kirchheim, R., & Pundt, A. (2014). Hydrogen in metals. Physical Metallurgy, 2597–2705.
[2] Fukai, Y. (1993). The metal hydrogen system basic bulk properties. Springer, 10-85.
[3] Latroche, M. (2004). Journal of Physics and Chemistry of Solids, 65(2–3), 517–522.
[4] Takeshita, T. (1995). Journal of Alloys and Compounds, 231(1–2), 51–59.
[5] Verdier, M., Morros, J., Pere, D., Shell, N., & Harris, I. R. (1994). 30(2), 657–659.

Zeynep Ege Uysal is with the Department of Metallurgical and Materials Engineering, Middle East Technical University. Having graduated from Middle East Technical University in 2022, Zeynep Ege Uysal is studying her M.Sc. since September 2022 at the same department while working at Advanced Manufacturing Technologies Department at Turkish Aerospace Industries. Her research interest covers metal hydrides, hydrogenation-dehydrogenation (HDH) process and hydrogen storage of metals and alloys.

Zeynep Ege Uysal, e-mail: uysal.ege@metu.edu.tr Tel: +90 5389369000