

# METAL-HYDROGEN SYSTEMS AT HIGH H<sub>2</sub> PRESSURES: NEW MATERIALS AND METAL HYDRIDE COMPRESSORS

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“Hybrid” H storage combines metal hydrides (MH) and compressed H<sub>2</sub> gas and yields an improved by 50 % overall H storage system capacity. This improvement requires: (a) Decreased dehydrogenation enthalpy of around 20 kJ/mol H<sub>2</sub>; (b) Small hysteresis between hydrogen absorption and desorption; (c) Pressure dependence of H storage capacity increasing with pressure. We will review our recent studies of the metal-hydrogen systems at high hydrogen/deuterium pressures, at 1 kbar H<sub>2</sub><sup>1</sup> or at around 30 kBar D<sub>2</sub> at 300 °C<sup>2</sup>. We will present the results for the ZrFe<sub>1.98</sub>Al<sub>0.02</sub>-D<sub>2</sub><sup>1</sup>, MgNi<sub>2</sub>D<sub>3</sub><sup>2</sup>, (La,Pr,Nd)<sub>3-x</sub>Mg<sub>x</sub>Ni<sub>9</sub>D<sub>10-13</sub><sup>3</sup> and LaMg<sub>2</sub>Ni<sub>9</sub>D<sub>9</sub><sup>4</sup> featuring a number of unusual behaviors including (a) An exceptional effect of Al on the formation and stability of the ZrFe<sub>2-x</sub>Al<sub>x</sub> hydrides; (b) Hydrogen-induced rebuilding of the C36 Laves-type intermetallic into a MoSi<sub>2</sub>-related structure in MgNi<sub>2</sub>D<sub>3</sub>; (c) Strong dependency of the hydrides thermodynamics in La<sub>3-x</sub>Mg<sub>x</sub>Ni<sub>9</sub>-H<sub>2</sub> allowing to change H<sub>2</sub> equilibrium pressure in 1000 times by controlling the Mg content; (d) LaNi<sub>5</sub>-assisted hydrogenation of MgNi<sub>2</sub> in the hybrid structure of LaMg<sub>2</sub>Ni<sub>9</sub>.

Metal hydride thermal sorption compression, one of the most important applications of the MHs, is an efficient and reliable method allowing an energy conversion [heat] → [compressed hydrogen gas]. The presentation will review <sup>5,6</sup> (a) fundamental aspects of the materials development with a focus on structure and phase equilibria in the metal-hydrogen systems suitable for hydrogen compression; and (b) applied aspects, including their consideration from the thermodynamic viewpoint, system design features, performances of the metal hydride compressors and major applications. Future prospects of the technology will be outlined presenting the role of the MH compression in the overall development of the hydrogen-driven energy systems.

## References:

- [1] V. A. Yartys, R.V. Denys, C. J. Webb, J.P. Mæhlen, E. MacA. Gray, T. Blach, O. Isnard, L. C. Barnsley. // *J. All. Compds*, 509 (2011) S817. [2] V.A. Yartys, V.E. Antonov, D. Chernyshov, J.-C. Crivello, R.V. Denys, V.K. Fedotov, M. Gupta, V.I. Kulakov, M. Latroche, D. Sheptyakov. // *Acta Mater.* 98 (2015) 416. [3] V. Yartys, R. Denys.// *J. All. Compds*, 645, Suppl.1 (2015) S412. [4] R. V. Denys, V. A. Yartys, E. MacA. Gray, C. J. Webb. // *Energies*. 8 (2015) 3198. [5] V. A. Yartys, M. Lototsky, V. Linkov, D. Grant, A. Stuart, J. Eriksen, R. Denys, R.C. Bowman, Jr. // *Appl. Phys. A*: 122 (4): 415 (2016) 1. [6] M.V. Lototsky, V.A. Yartys, B.G. Pollet, R.C. Bowman, Jr. // *Int. J. Hydr. En.*, 39 (2014) 5818.



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