

10. Wolfinger T. Analysis of the Usability of Iron Ore Ultra-Fines for Hydrogen-Based Fluidized Bed Direct Reduction — A Review / T. Wolfinger, D. Spreitzer, J. Schenk // *Materials* 2022, 15, 2687.

Режим доступу: <https://doi.org/10.3390/ma15072687>

11. Лакомский В. И. Плазменно-дуговой переплав / В.И. Лакомский. – Киев: Техника, 1974. – 335 с.

12. M. NaseriSeftejani. Reaction kinetics of molten iron oxides reduction using hydrogen / M. Naseri Seftejani, J. Schenk // *La Metallurgia Italiana*. – July 2018.

Режим доступу: <https://www.researchgate.net/publication/327594827>

13. Masab Naseri Seftejani. Thermodynamic of Liquid Iron Ore Reduction by Hydrogen Thermal Plasma / Masab Naseri Seftejani, Johannes Schenk // *Metals*. – 2018. –8, 1051; DOI:10.3390/met8121051

Режим доступу: <https://www.researchgate.net/publication/329566574>

14. Saikat Kumar Kuila. Kinetics of hydrogen reduction of magnetite ore fines / Saikat Kumar Kuila, Ritayan Chatterjee, Dinabandhu Ghosh // *International journal of hydrogen energy*. – 2016. – № 41. – P. 9256–9266.

Режим доступу: <https://www.researchgate.net/publication/302555270>

15. Isnaldi R. Souza Filho. Green steel at its crossroads: hybrid hydrogen-based reduction of iron ores / Isnaldi R. Souza Filho, Hauke Springer, Yan Ma, Ankita Mahajan, Cauê C. Da Silva, Michael Kulse, Dierk Raabe. – 2022.

Режим доступу: <https://arxiv.org/ftp/arxiv/papers/2201/2201.13356.pdf>

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RESEARCH INTERACTION FeTi WITH HYDROGEN

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Hydrogen is an attractive energy source in terms of prevalence, environmental friendliness and energy efficiency with its participation. The development of hydrogen energy is limited by the problems of storage and transportation of hydrogen. Binary

alloy TiFe is suitable for storage for hydrogen storage. This alloy is known to have a high ability to absorb hydrogen with a ratio of hydrogen atoms (H) to metal atoms (M) H/M is near 1 and also fast absorption/desorption kinetics at ambient conditions. The low cost of the starting materials is also important for practical application. However, a lot of research still needs to be done to identify appropriate catalysts, study the existence of stable intermediate phases and their crystal structure, and understand the kinetics.

Consider the interaction and crystal structure of Fe-H, Ti-H and Ti-Fe-H. It is known that hydrogen has a low interaction with iron. At the same time, both the solid solution and FeH hydride are possible. At ambient temperature, α -Fe dissolves 0.005% of hydrogen with the BCC lattice $a = 2.8590 \text{ \AA}$. Hydrogen interacts well with titanium, forming the solid solution in a wide range. With increasing temperature, the mass fraction of hydrogen increases. This process is reversible, so titanium can be used to store hydrogen. Also, hydrogen is the stabilizer of the β -phase, which leads to the decrease in the temperature of the $\alpha \leftrightarrow \beta$ transformation of titanium. When the concentration of hydrogen increases to 4.04 wt %, the stable TiH_2 hydride is formed.

Let us consider TiFe alloys. They are able to absorb and desorb hydrogen. Hydrogenation processes is accompanied by an order-disorder phase transition from the CsCl-type structure to the BCC of TiFe metal lattice at high pressure and temperature. We observed lattice expansion of the sample when the TiFe alloy was kept in hydrogen fluid at 5 GPa and 600 °C. The lattice parameter of the sample before the hydrogenation experiment was $a = 2.979 \text{ \AA}$. At the first stage of hydrogenation the lattice parameter of the solid solution changed to $a = 2.961 \text{ \AA}$. After 60 min the hydrogenation treatment it is formed new cubic phase and the lattice parameter increased to $a = 3.132 \text{ \AA}$. After 150 min the hydrogenation treatment when the lattice increased to maximum, the hydride decomposed into TiH_2 hydride and TiFe alloy. Hydrogenation processes at 10 GPa and 600 °C were similar like at 5 GPa and 600 °C. Due to the property of titanium to form TiH_2 hydride, the partial substitution of iron (Fe) in TiFe alloys with manganese (Mn), nickel (Ni), chromium (Cr) and vanadium (V) has been proven to facilitate the activation and decrease the equilibrium pressure of the final hydrides but does not change the hydrogen storage capacity.

The sintering of TiH_2 and Fe by thermocycling at temperatures near the $\alpha \leftrightarrow \beta$ transformation of Fe did not give the desired result. The X-ray pattern showed the existence of two separate phases TiH_2 and Fe, which may indicate the stability of the TiH_2 hydride in the TiFe alloy.

Conclusion. TiFe alloys are attractive for their ability to absorb large amounts of hydrogen. Hydrogenation processes are accompanied by an order-disorder phase transformation. However, the use of TiFe hydrides is limited, because when the hydrogen concentration increases to 4.04 wt % H, the stable TiH_2 hydride is formed. Partial replacement of doped elements can improve hydrogenation kinetics without changing its ability to store hydrogen. Changing the pressure from 5 GPa to 10 GPa at temperature of 600 °C does not affect hydrogenation processes.

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**DETERMINATION OF COMPOSITE MATERIALS WITH DISPERSIVE
INCLUSIONS LONG-TERM STRENGTH**

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The strength and durability of composite materials depend on cohesive bonds (interatomic and intermolecular interaction), and from the defectiveness of their structure. Real strength is formed by the structure of materials and defects of various kinds.

A flat macroelement of a composite material is considered – a homogeneous matrix in which elliptical inclusions of different sizes and orientations from another elastic material are evenly distributed. Inclusions of this form are often found in metals (oxidized layers, graphite inclusions in cast iron, etc.).

The macroelement is located in a flat biaxial field of normal stresses P and $Q = \eta P$. The elastic properties of the matrix and inclusions are specified. The modulus of elasticity of the inclusions is small compared to the modulus of elasticity of the matrix. The inclusions are flattened in shape and their defining parameters are length