Method "Hydride cycle" (HC) SYNTHESIS OF ALLOYS AND INTERMETALLICS OF REFRACTORY METALS FROM HYDRIDES (LINK 4)

Current methods of binary and multicomponent alloys production are based on melting (induction, electric arc or electron beam) technologies or powder metallurgy. Each of these methods is provided by a significant laboriousness and instrumental complexity. They are long-time, demand a deep vacuum, the creation of inert medium at temperatures as high as 1800-2500°C, the repetition of melting process, etc. The modern material science needs in search of new efficient methods for producing binary and multicomponent alloys with given physico-technical properties. In our Laboratory for producing of refractory alloys of transition metals, a principally new, earlier unknown method, named "Hydride cycle" (HC), was developed. This method is based on the use of transition metal hydrides as starting materials. It was found that at heating of compacted mixture of two or more hydrides, the removal of hydrogen at temperature a little higher than the temperature of hydride dissociation, leads to formation of strong, nonporous alloys and intermetallics (Table 1).Below are the schemes of reactions of formation of alloys and intermetallics: $x\mathrm{Me'H_2} + (1-x)\mathrm{Me''H_2} + Q \rightarrow \mathrm{Me'_xMe''_{(1-x)}}$ **alloy** $+ H_2\uparrow$

$$x\mathrm{Me'H_2} + (1-x)\mathrm{Me''} \rightarrow \mathrm{Me'_xMe''_{(1-x)}}\ \text{alloy} + H_2\uparrow$$

- **The main advantages of HC compared** with the traditional methods (induction and arc melting, etc.) are :
- considerable decrease of working temperatures (from 1800-2600 to 600-1000ºC) and of duration (from tens to 1.0-2 hours) will essentially reduce required power expenditure;
- one-stage and waste-less processing during formation of the multicomponent and doped alloys of given chemical and phase composition (without necessity of repeated re-melting), also will lead to the lowering the power expenditures;
- existence of highly effective technological SHS process of synthesis of initial hydrides of transition metals, demanded for preparation of alloys in «hydride cycle», and of hydrides of prepared alloys:
- the alloys formed by a solid-phase mechanism, excluding melting;
- low energy consumption.

The interest in the transition metals of the IVA subgroup and their alloys is associated with their numerous and important practical applications. They are demanded in many areas of modern science and technology (space. aviation. nuclear power. chemical industry, defense etc.) as heat and thermal resistant durable structural materials

This method provides producuction of a wide range refractory alloys for various purposes: constructional, super-currency, biocompatible, hydrogen storage, alloys with a special crystal structure (α-, β-, γ-, ω- and other modifications), etc.

More than 100 refractory alloys and intermetallics of transition metals have been synthesized.

Some of the resulting alloys and intermetallics interact with hydrogen in SHS mode without crushing and form hydrogen-rich hydrides (Table 1). It is worth to note that the powders of alloy hydrides can be used as starting materials for the manufacturing of wares. Figures 1 and 2 show $Ti_{0.6}V_{0.4}$ and $Ti_{0.5}Nb_{0.5}$ alloys, and their hydrides, $Ti_{0.6}V_{0.4}H_{1.9}$ and $Ti_{0.5}Nb_{0.5}H_{1.88}$.

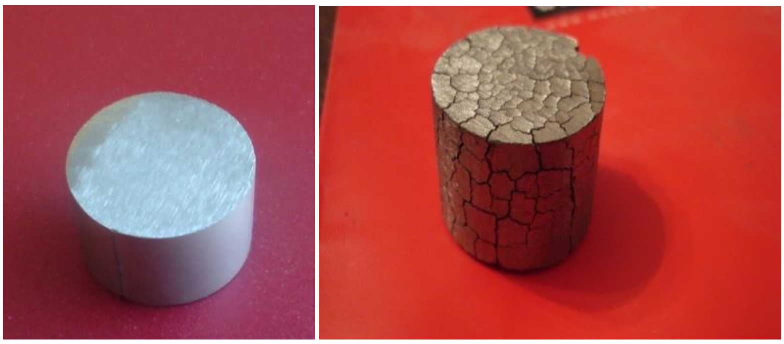
Table 1. Characteristics of alloys produced in hydride cycle

System	Alloys	Crystal structure
TiH_2/ZrH_2	$Ti_{0.8}Zr_{0.2}$; $Ti_{0.66}Zr_{0.34}$; $Ti_{0.4}Zr_{0.6}$; $Ti_{0.2}Zr_{0.8}$; etc.	αandω
TiH_2/HfH_2	$Ti_{0.8}Hf_{0.2}$; $Ti_{0.6}Hf_{0.4}$; etc.	α and ω
ZrH_2/HfH_2	$Zr_{0.8}Hf_{0.2}$; $Zr_{0.66}Hf_{0.34}$; etc.	α
$TiH_2/VH_{0.8}$	$Ti_{0.8}V_{0.2}$; $Ti_{0.7}V_{0.3}$; $Ti_{0.5}V_{0.5}$	α and β
$TiH_2/NbH_{1.7}$	$Ti_{0.8}Nb_{0.2}$; $Ti_{0.7}Nb_{0.3}$ $Ti_{0.5}Nb_{0.5}$	α and β
ZrH_2/YH_2	$Zr_{0.92}Y_{0.08}$	α
$ZrH_2/NbH_{1.7}$	$Zr_{0.3}Nb_{0.7}$	β
$TiH_2/ZrH_2/HfH_2$	$Ti_{0.34}Zr_{0.33}Hf_{0.33}$; $Ti_{0.66}Zr_{0.22}Hf_{0.12}$	α and ω
TiH_2/V	Sol.Solutions:$Ti_{0.8}V_{0.2}$; $Ti_{0.7}V_{0.3}$; $Ti_{0.4}V_{0.6}$; etc.	α and β
$TiH_2/VH/Mn$;	**$TiV_{1.2}Mn_{0.8}$;** $TiV_{0.8}Mn_{1.2}$; $Ti_{0.37}V_{0.38}Mn_{025}$; etc.	
TiH_2/Nb	Sol.Solutions:$Ti_{0.8}Nb_{0.2}$; $Ti_{0.7}Nb_{0.3}$; $Ti_{0.4}Nb_{0.6}$;	α and β

TiH_2/Re	Sol.Solutions: $Ti_{0.95}Re_{0.05}$; $Ti_{0.85}Re_{0.15}$;	α and β
TiH_2/Fe	TiFe	intermetallics
ZrH_2/Y	$Zr_{0.92}Y_{0.08}$	α
TiH_2/Al	**α_2-Ti_3Al; γ-TiAl; $TiAl_3$;** etc.	intermetallics
ZrH_2/Al	$ZrAl_2$; $ZrAl_2$	intermetallics
$NbH_{1/3}/Al$	Nb_3Al; $NbAl_2$; $NbAl_3$	intermetallics
$TiH_2/Al/NbH_x$	**$Ti_{0.5}Al_{0.25}Nb_{0.25}$; $Ti_{0.25}Al_{0.25}Nb_{0.5}$; $Ti_{0.25}Al_{0.15}Nb_{0.6}$**	intermetallics
$TiH_2/Al/ZrH_2$	**$Ti_{0.2}Al_{0.3}Zr_{0.5}$; $Ti_{0.5}Al_{0.3}Zr_{0.2}$l $Ti_{0.6}Al_{0.3}Zr_{0.1}$; etc.**	intermetallics
TiH_2/Al/ VH	**Ti6Al4V (Ti64)**	α and β
TiH_2/Ni	TiNi	intermetallics
TiH/NbH/ZrH	**$Ti_{0.74}Nb_{0.21}Zr_{0.05}$**	alloy (β type content of the 20.2% α phase
ZrH_2/Co	Zr_2Co;	intermetallics
TiH_2/Co	Ti_2Co Cubic.a=11.286	intermetallics
$TiH_2/ZrH_2/Ni$	$Ti_{0.44}Zr_{0.40}Ni_{0.16}$; $Ti_{0.45}Zr_{0.38}Ni_{0.17}$; $Ti_{0.52}Zr_{0.32}Ni_{0.16}$	intermetallics
Cu/NbH_x	**80Cu20Nb; 88Cu12Nb**	mechanical alloy

a b

Fig. 1. $Ti_{0.6}V_{0.4}$ alloy (a) and its hydride$Ti_{0.6}V_{0.4}H_{1..9}$ (b)



a b

Fig.2. $Ti_{0.5}Nb_{0.5}$ alloy (a) and its hydride $Ti_{0.5}Nb_{0.5}H_{1.88}$ (b)

Application of the developed method will result in significant changes in the field of traditional metallurgy and materials science of alloys of transition metals and their hydrides. The prospects of this proposal are very attractive for the industry. ***The developed methods may be of commercial interest.***

Areas of application of alloys: atomic and hydrogen energy, aerospace and shipbuilding, chemical, automotive, metal-working industry, machine building and machine-tool production, radio engineering, electrical engineering and electronics, composite materials for nuclear power plants; medicine (biocompatible materials), etc.

Areas of application of hydrides of metals and alloys: hydrogen and nuclear power (protective and structural materials), condensed hydrogen storage. etc.

LIST OF MAIN PUBLICATIONS

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