Vehicle Application of Chemical Thermal Energy Storage

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Contents

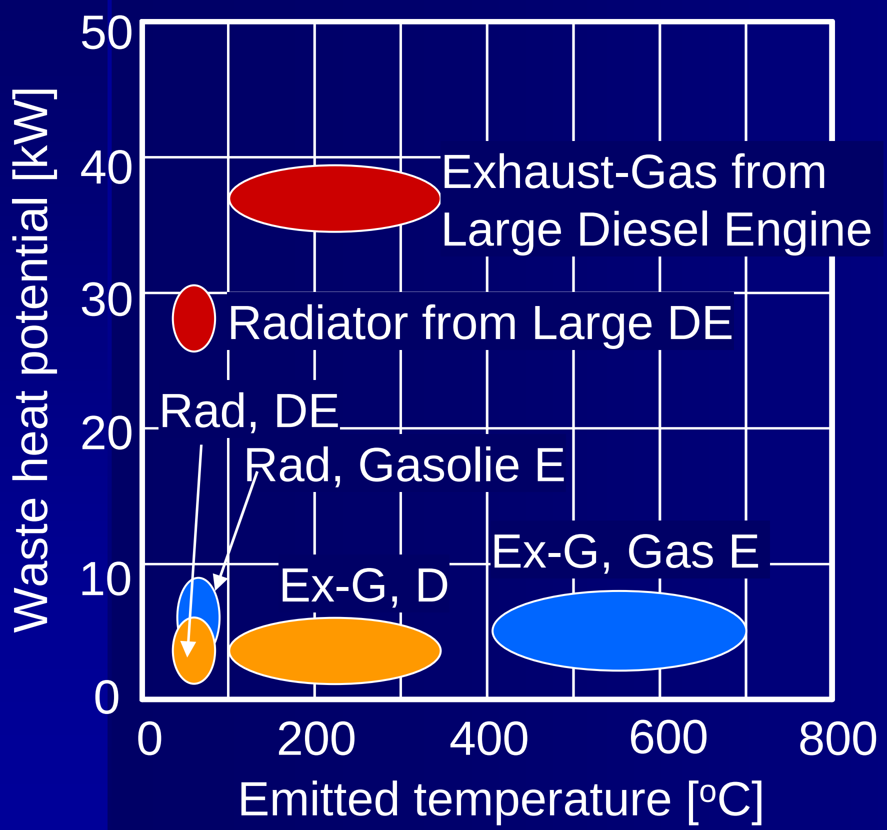
- Heat sources at middle temperature (100-300^{o}C)
  - Energy trend of vehicles
- Chemical thermal energy storage for medium temperatures
- Survey of chemical reactions for heat storage

Trend of vehicles

- Excess of waste heat
- Lack of waste heat

Excess of waste heat from internal-combustion engine vehicle

- Vehicle of Internal Combustion Engine: 20% of fuel energy for drive



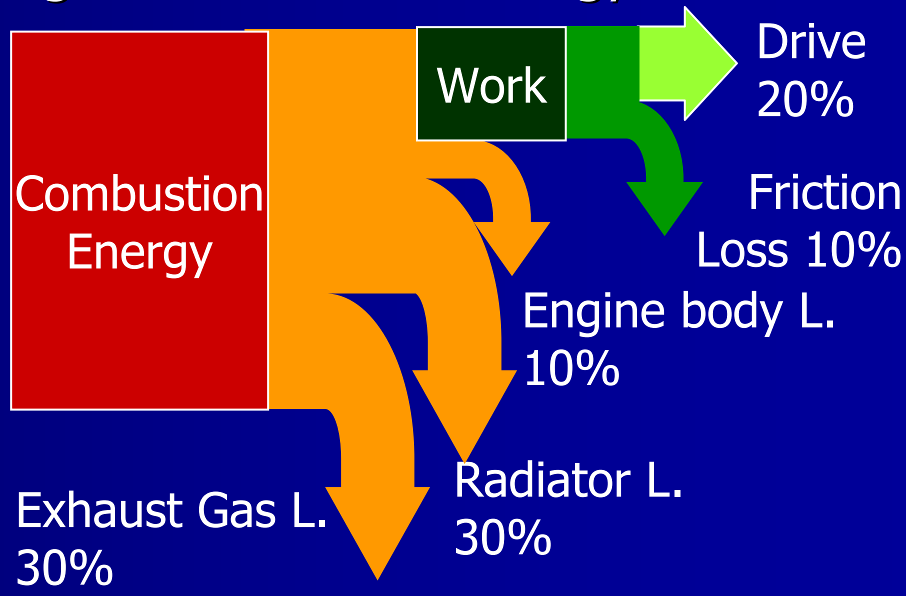


Fig. Automobile waste heat potential (up) Energy balance, (left) Temperature distribution

Ref: Suzuki, K.; “Map 11: Technology Road Map for Thermal Energy Management in Vehicles,” HONEBUTO Energy Road Map, pp. 105-113, H. Kameyama and Y. Kato ed., Kagaku-Kogyo-Sha, Tokyo, Japan (2005)

Lack of waste heat for EV, FC

Electric vehicle, EV

ELIICA□Keio Univ. http://www.eliica.com/blog/

Plug-in Hybrid□PRIUS
PHEV, Toyota

http://jafmate.jp/sp/pluginhv02/page2.html

Toyota FCHV (FCHV-4), Dec,2002

http://response.jp/issue/2003/0513/article50835_1.images/51654.html

Thermal energy storage for middle temperature

Potential demands of thermal energy storage for middle temperature, 100-300^{o}C

- Vehicle thermal energy management for efficient fuel use and reduction of CO_2:
  - Utilization of excess exhaust heat
  - Lack of heat source for cabin air-conditioning of electric and fuel cell vehicles
  - Reduction of time period for Cold-Start
- Heat sources: vehicle engines, cogeneration engines, fuel cells, industrial processes

Chemical thermal energy storage for middle temperatures

Possibility of chemical thermal energy storage

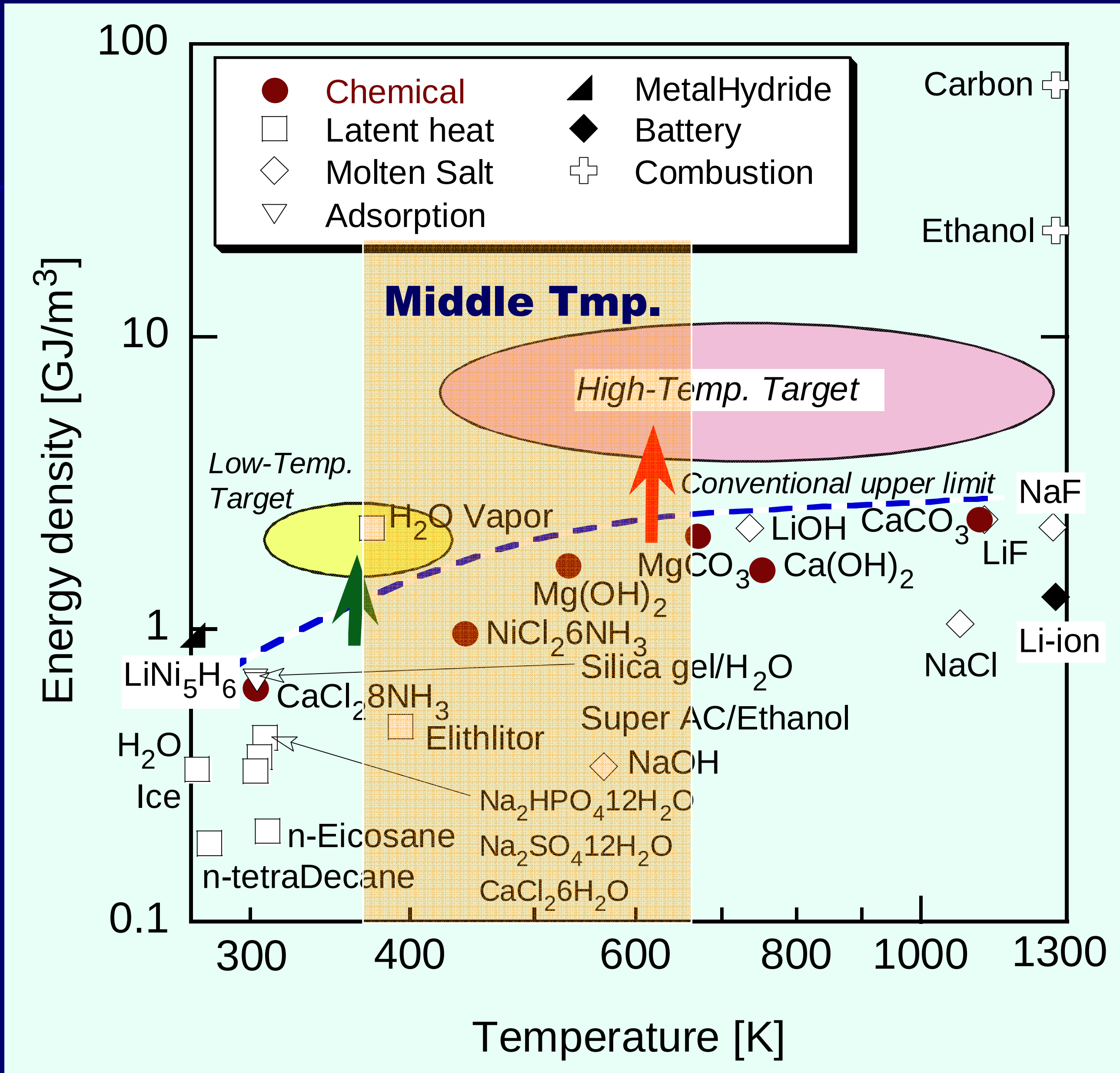


Fig. Map of volumetric density on thermal energy storage of energy materials vs. operation temperature (chemical change is based on product considering practical particle vacanvy. Temp. of 1000 deg. C is assumed for combustion and battery.)
Ref. Y. Kato, "HONEBUTO Energy Road Map", Kagaku-kogyo-sya, Japan (2005)

Example of chemical reaction for middle temp. heat storage

For 300°C

Heat output

Hydration →

$$MgO + H_2O = Mg(OH)_2$$

← **Dehydration**

Heat storage

$\Delta H = -81.0 kJ/mol$

Metallic oxide, chloride reactions for chemical heat storage

$MO+H_2O$ -> $M(OH)_2$

- $MgO+H_2O \rightarrow Mg(OH)_2$ for 350°C
- $CaO+H_2O \rightarrow Ca(OH)_2$ for 550°C
- $CaCl_2+nH_2O \rightarrow CaCl_2.nH_2O$ for <100°C

$MO+CO_2$ -> MCO_3

- $CaO+CO_2 \rightarrow CaCO_3$ for 850°C
- $PbO+CO_2 \rightarrow PbCO_3$ for 450°C

MCl_2+nNH_3 -> $MCl_2.nNH_3$

- $BaCl_2+8NH_3 \rightarrow BaCl_2.8NH_3$ for <100°C

Survey of chemical reactions for heat storage

$MO+H_2O \rightarrow M(OH)_2$ $P_{H2O}=f(T)$

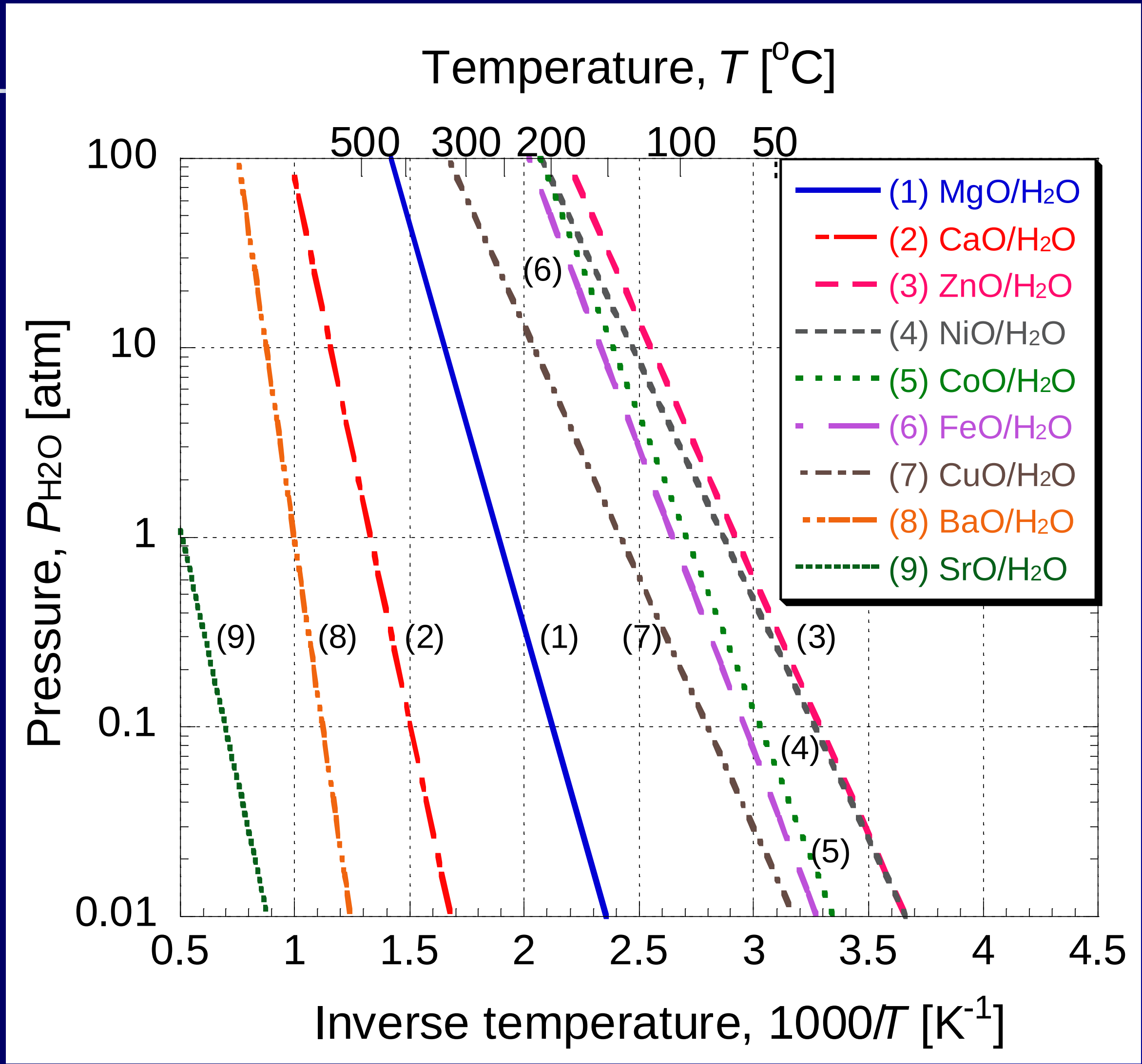
$$K = \frac{[\mathrm{MO}][\mathrm{H_2O}]}{[\mathrm{M(OH)_2}]} = \frac{P_{\mathrm{H_2O}}}{P_0}$$

$P_0=1.01\times10^5$ Pa

$$K = \exp\left(\frac{-\Delta G}{RT}\right)$$

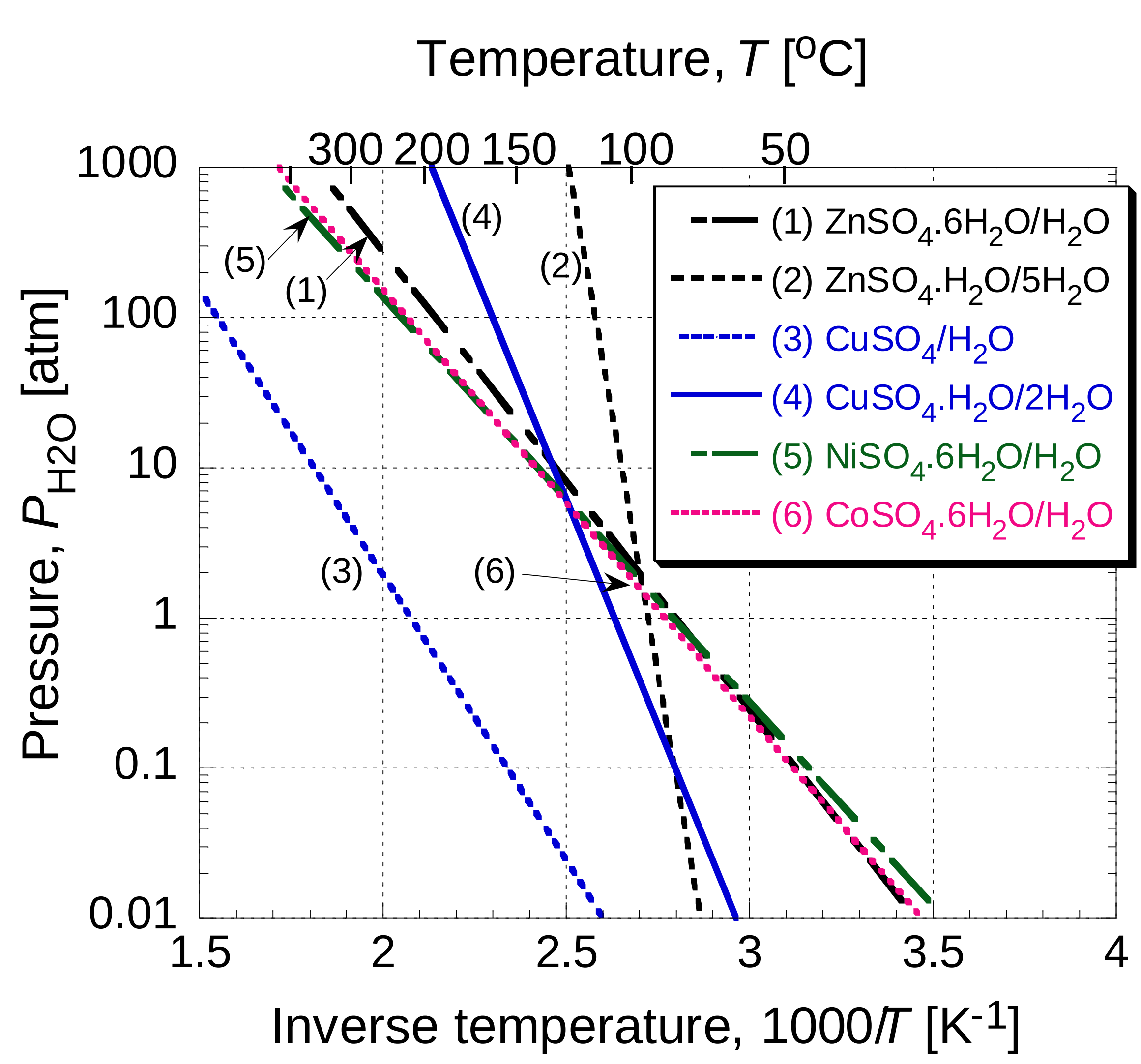
$$P_{\mathrm{H2O}} = \frac{-\Delta G}{R}\frac{1}{T} = P_0 \exp\left(\frac{-\Delta H}{R}\frac{1}{T} + \frac{\Delta S}{R}\right)$$

Metallic oxide/H_2O



FeO/H_2O
CoO
NiO
ZnO

Metallic sulfate/H_2O



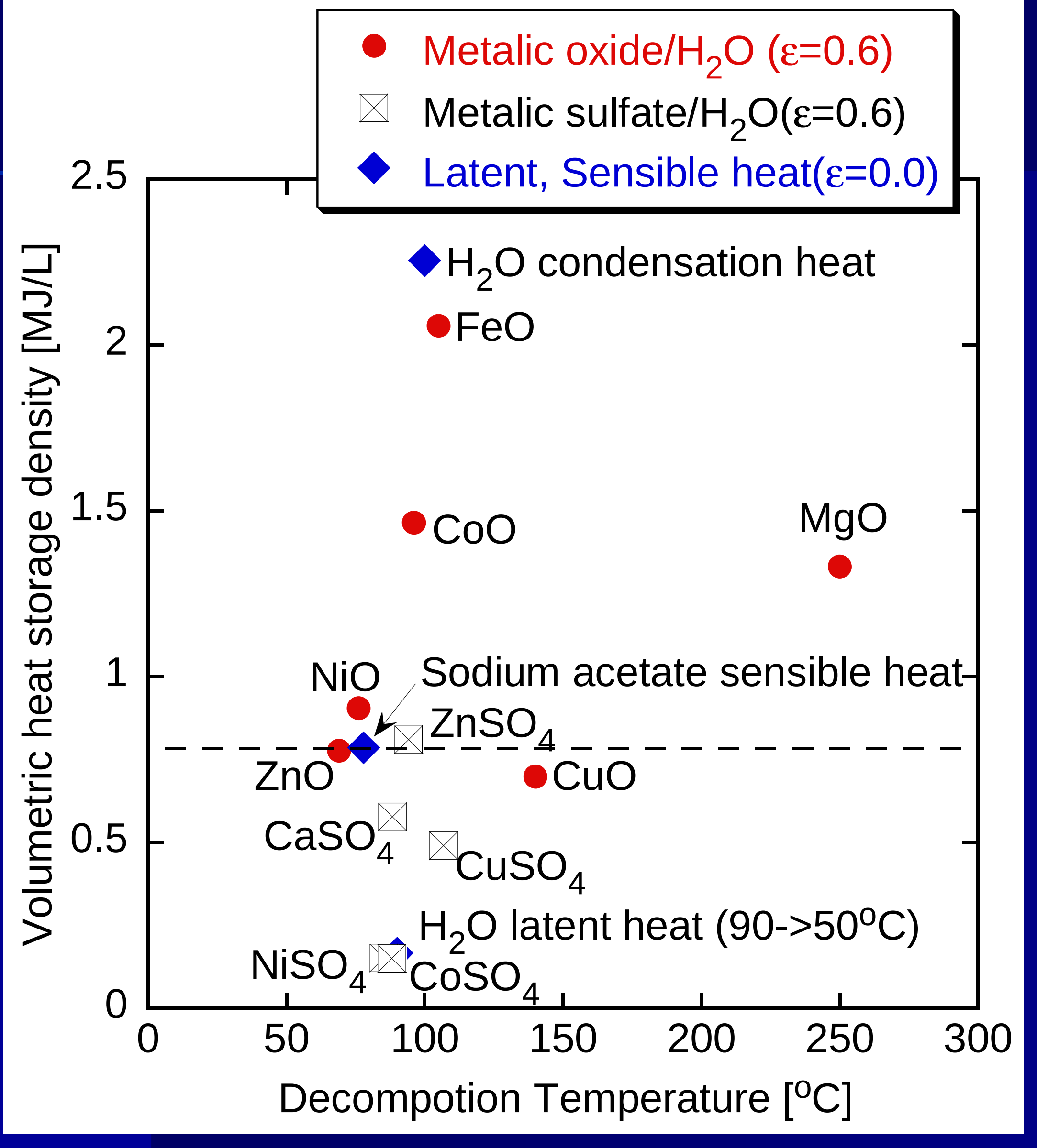
$ZnSO_4/nH_2O$

$CuSO_4$

$NiSO_4$

$CoSO_4$

Heat storage density



$NiO + H_2O \rightarrow Ni(OH)_2$

$CoO + H_2O \rightarrow Co(OH)_2$

$CuO + H_2O \rightarrow Cu(OH)_2$

Working temperature expansion for 200-300 ºC heat recovery

Dehydration (decomposition) process corresponds to heat storage

$MO_x \cdot (H_2O)_n \rightarrow MO_x + nH_2O$

MgO/H_2O
with high-reactivity
+
Chemical materials having lower decomposition temperature; $Ni(OH)_2$, $Co(OH)_2$

Mixed metal hydroxides
$Mg_xNi_{1-x}(OH)_2$
$Mg_xCo_{1-x}(OH)_2$

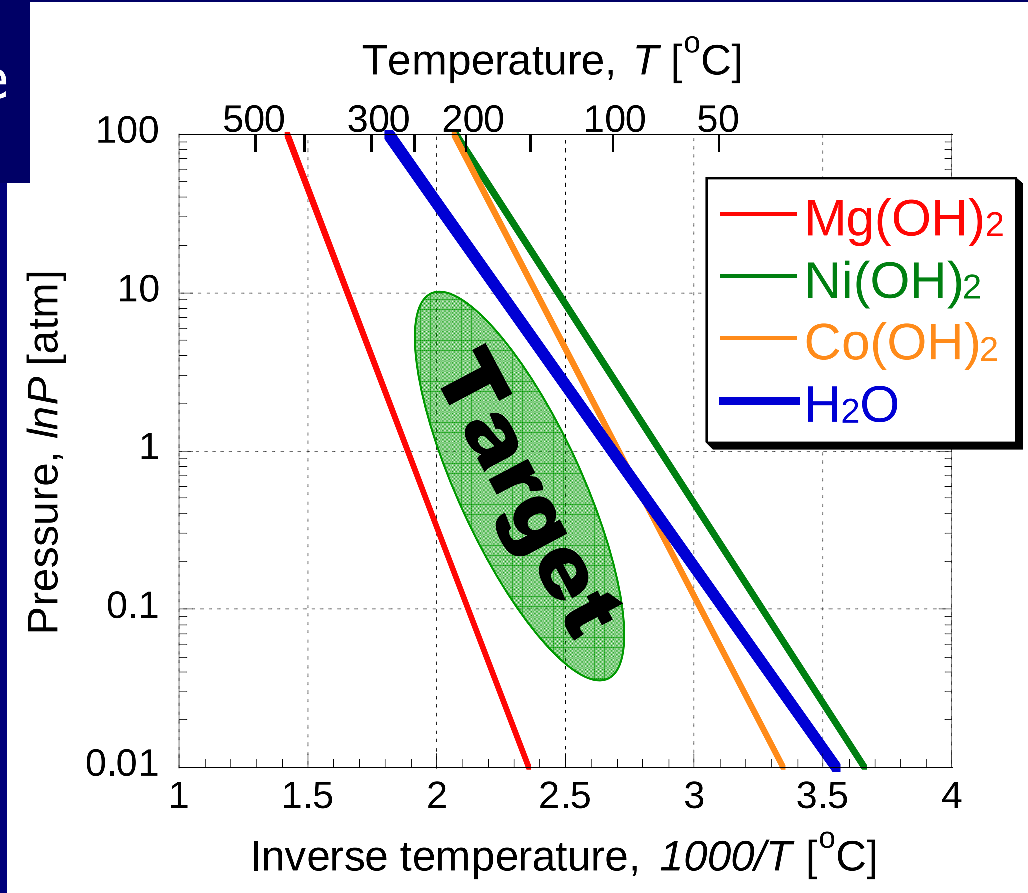


Fig. Chemical Equilibrium Lines of Metal oxide/water reaction systems

J. Ryu, R. Takahashi, N. Hirao and Y. Kato; J. Chem. Eng. Japan, 40 (2007), 1281-1286.

Vielen Dank!