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Prof. Peng Fan, University of Utah

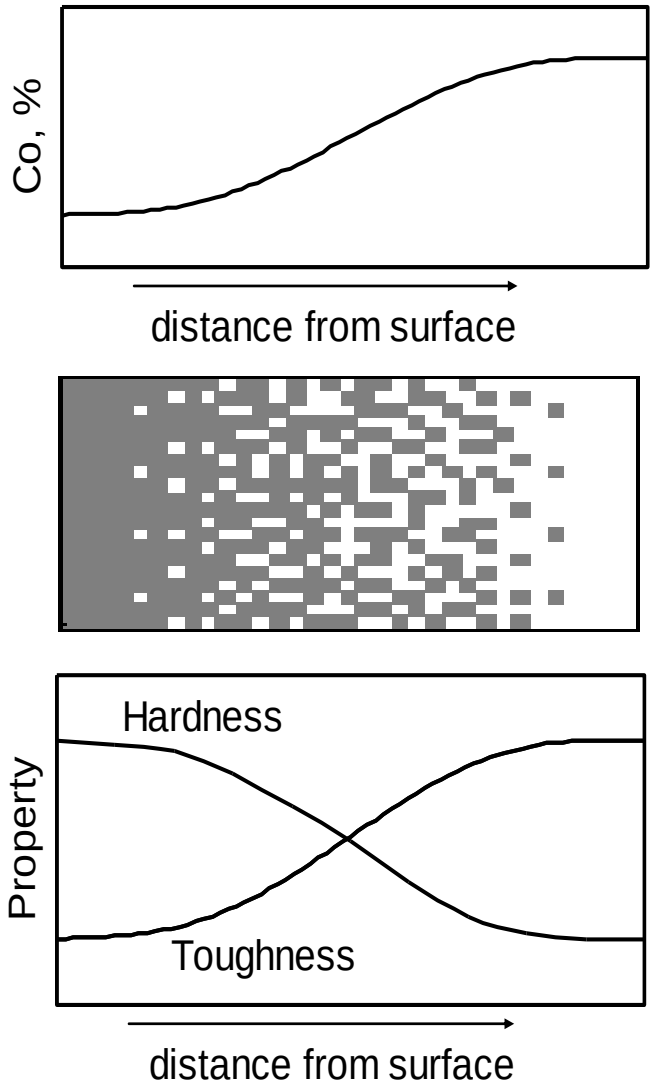
Research interests

- Powder metallurgy,
- Hard materials
- Functionally graded materials
- Extractive metallurgy
- Thermal energy storage materials
- Renewable and sustainable energy

Functionally graded WC-Co

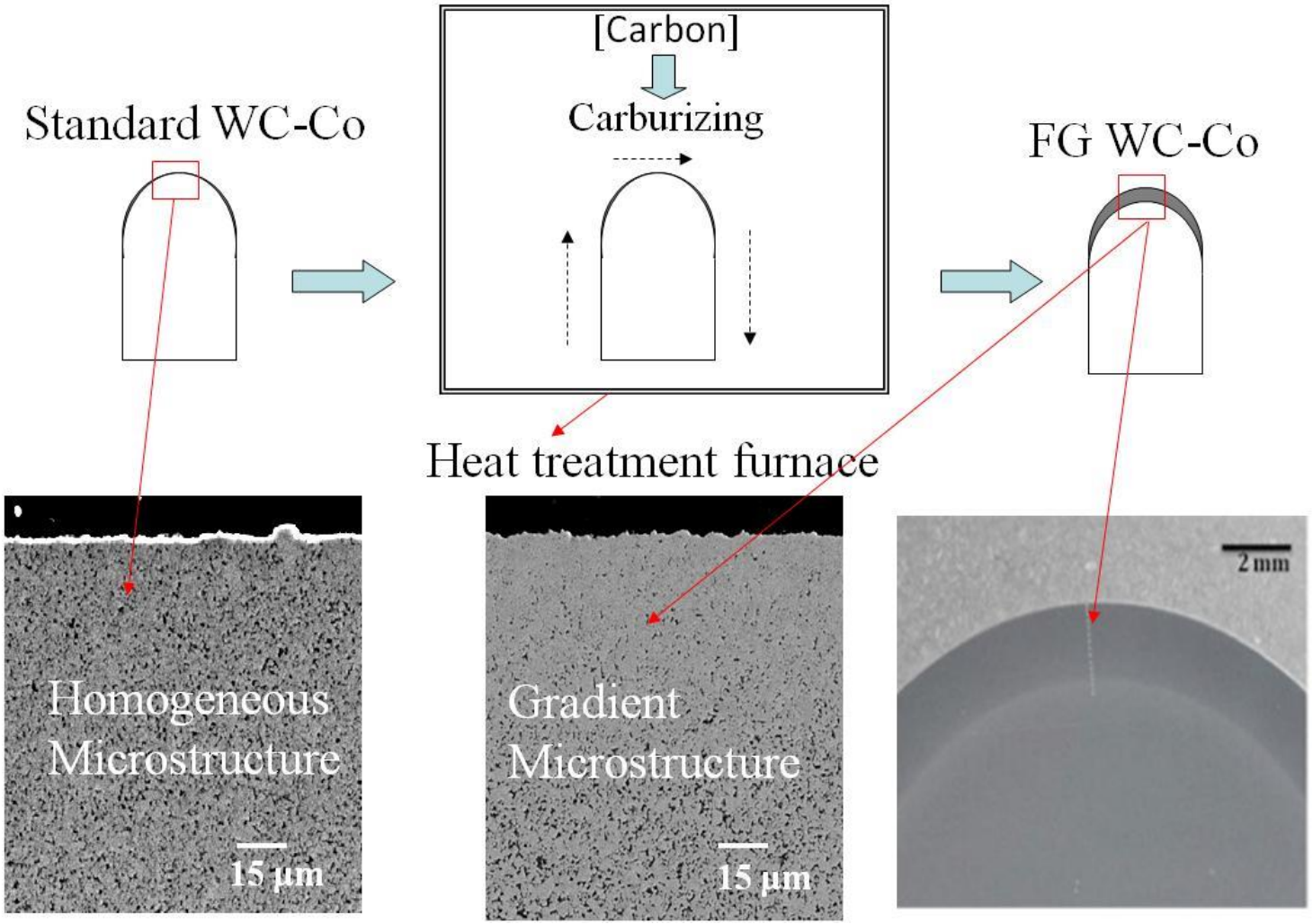
- WC-Co, cemented tungsten carbide, is the most widely used industrial tool materials
- It is extensively used in metal machining, oil and gas drilling, mining, and construction.
- Prof. Fan and his colleagues invented a novel process to produce functionally graded WC-Co with significantly improved life time of WC-Co tools.

Concept of functionally graded WC-Co

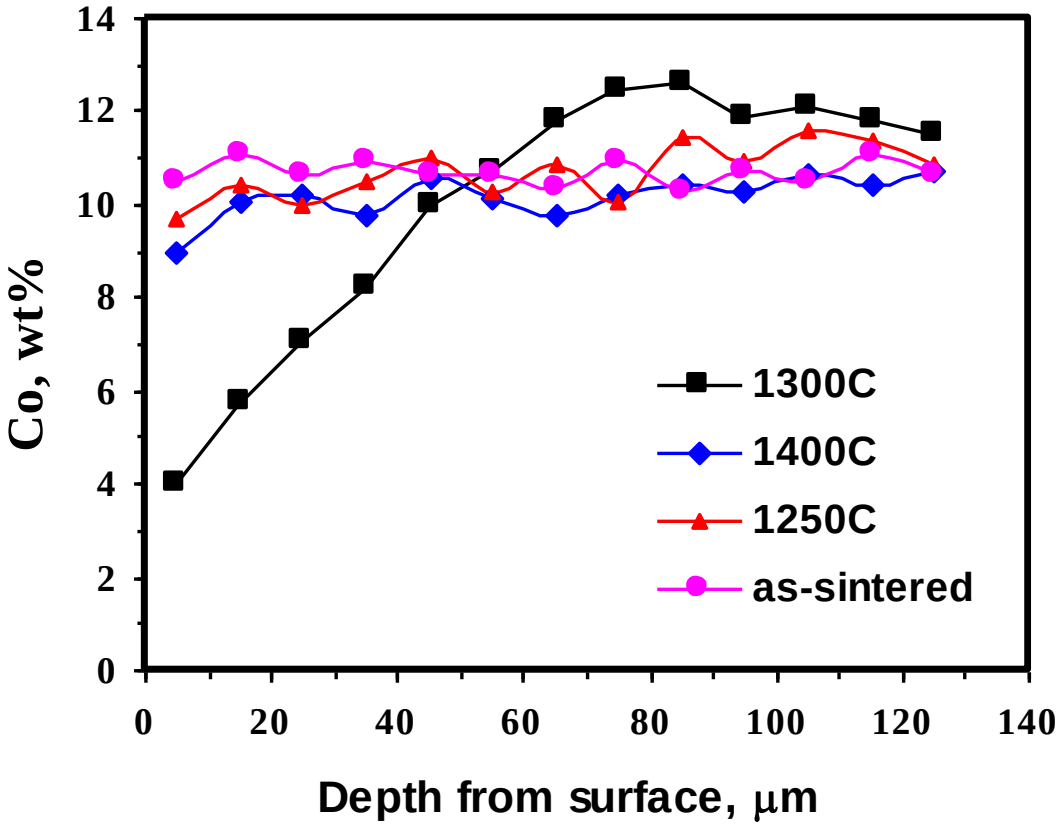


Unlike conventional WC-Co with uniform Co distribution, FG WC-Co has lower Co content at surface region and thus a hard-surface tough-core structure, which leads to superior combinations of mechanical properties, e.g., increased wear resistance without sacrificing fracture toughness.

Novel process to make FG WC-Co



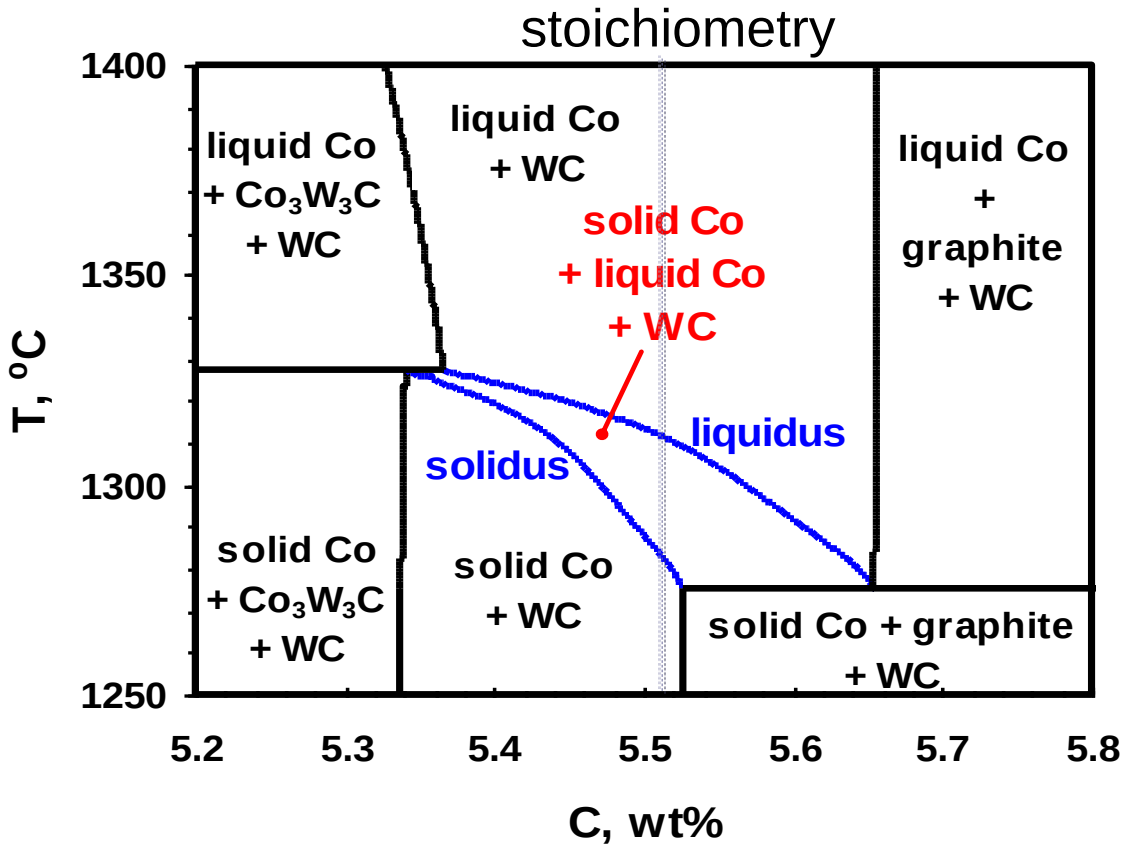
Key process parameter: temperature



Co content profiles in sintered WC-10%Co specimens before and after carburizing heat treatment at different temperatures.

Processing temperature needs to be in the three phase region of 1275 to 1325 C.

Mechanism of process



A vertical section of the ternary phase diagram of W-Co-C at constant 10wt% Co.

Mechanism of process

Surface carburization =>

Solid Co in surface region partially or totally transforms to liquid =>

Liquid Co in surface region increase =>

Balance of liquid Co distribution between surface and core regions breaks =>

Liquid Co migrates from surface region to core region =>

Co gradient forms.

Successful scale up of process

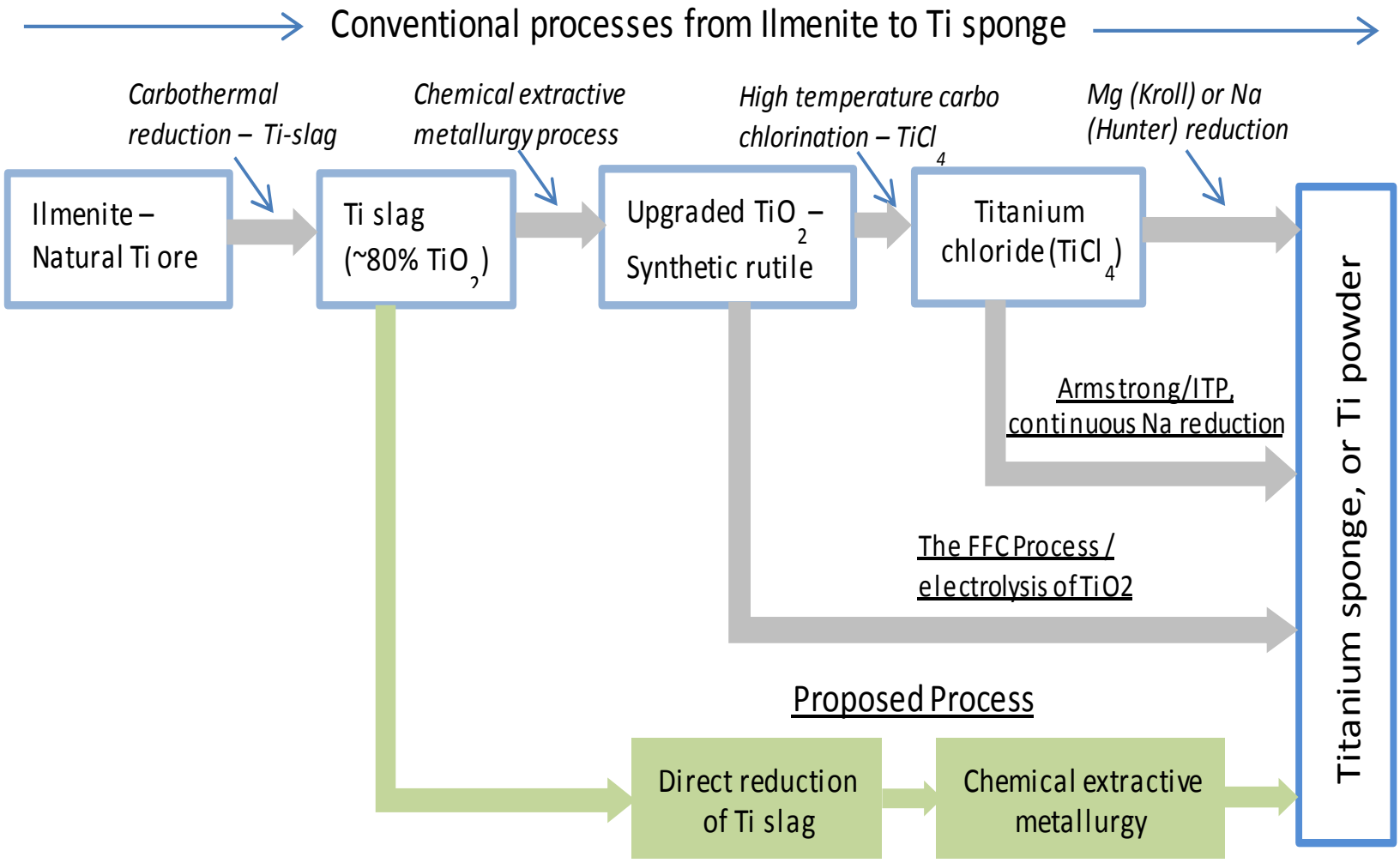
Tube furnace:

<1 kg WC-Co per run

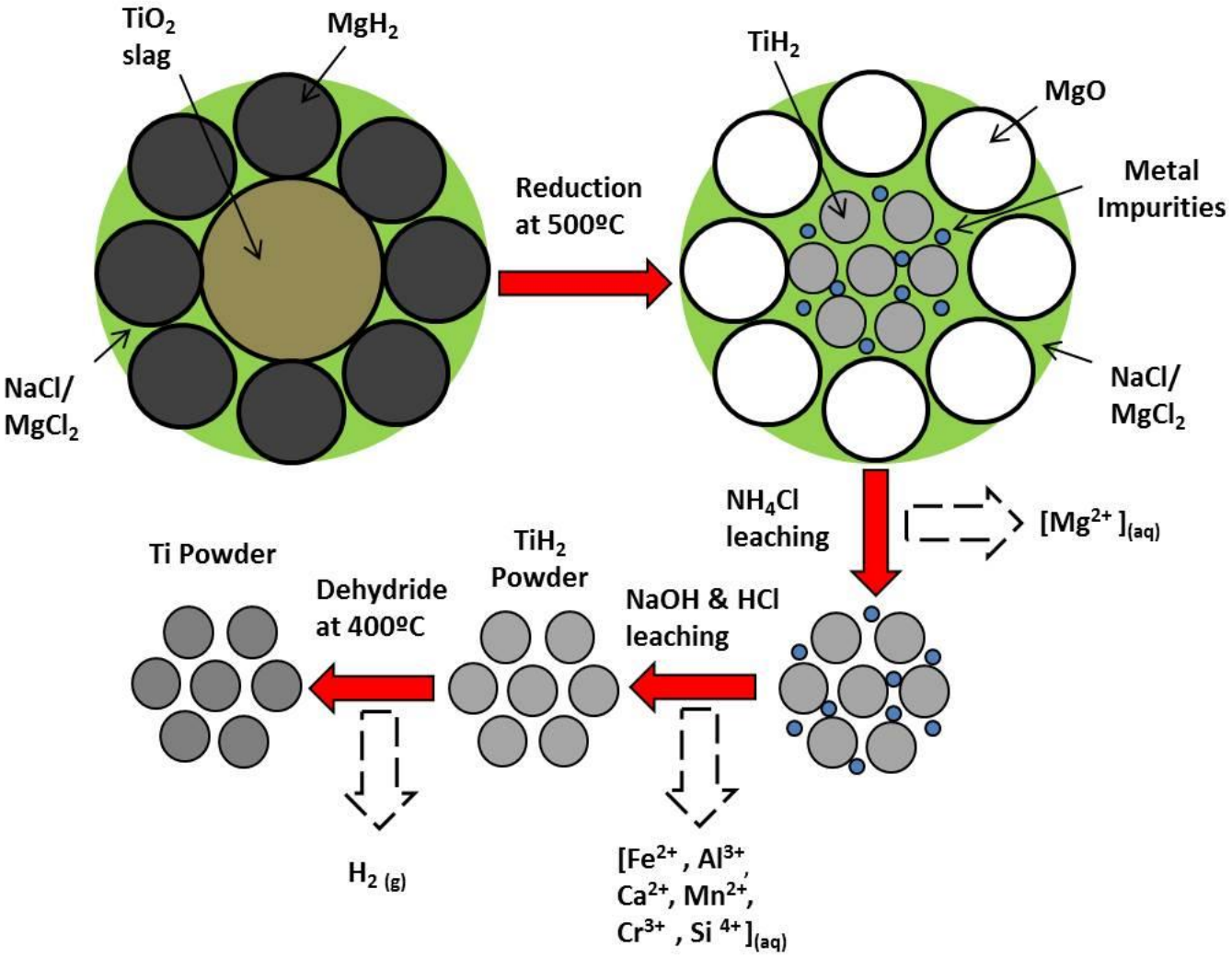
Pilot production furnace:

>50 kg WC-Co per run

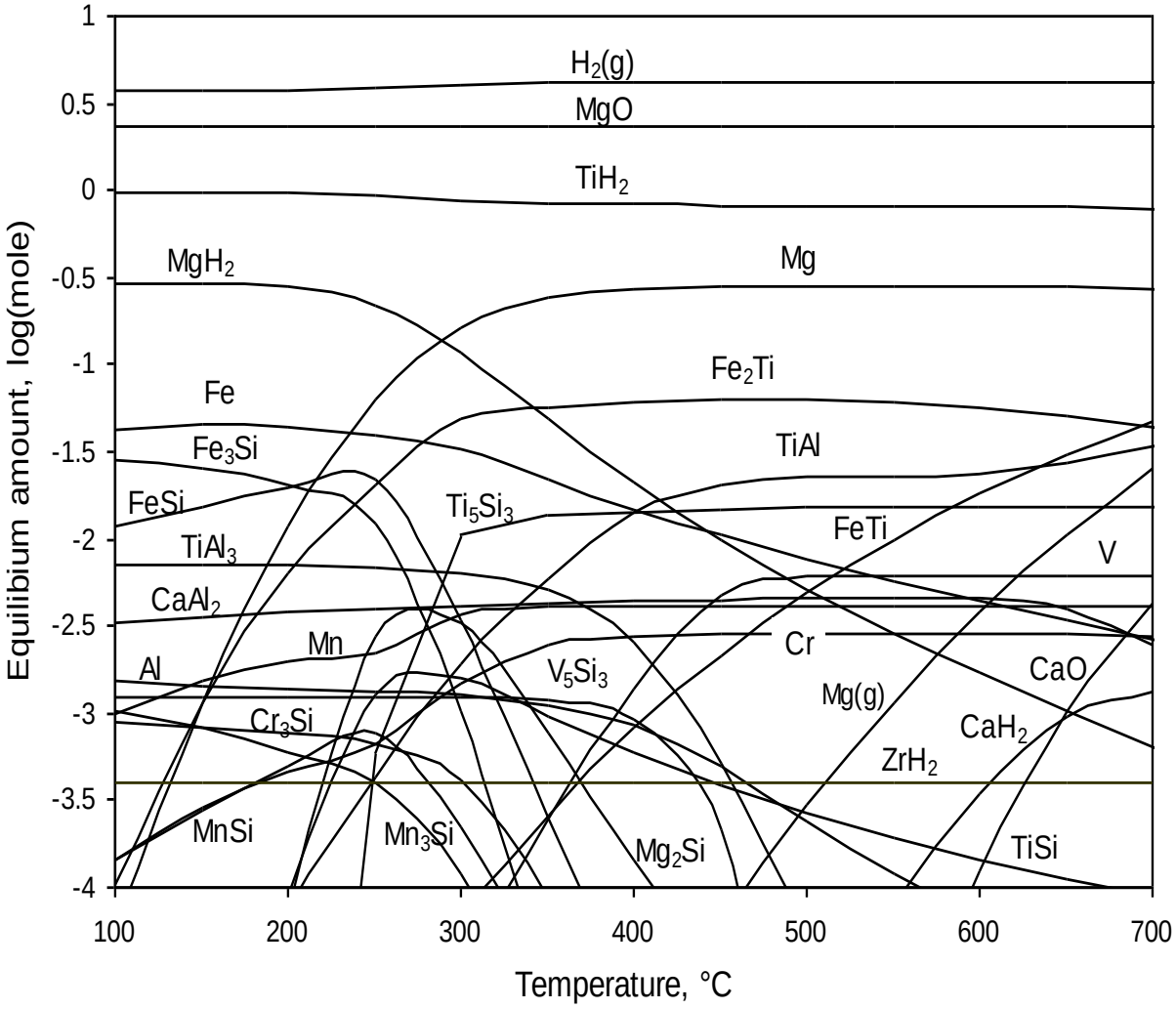
Direct reduction of Ti slag to make Ti



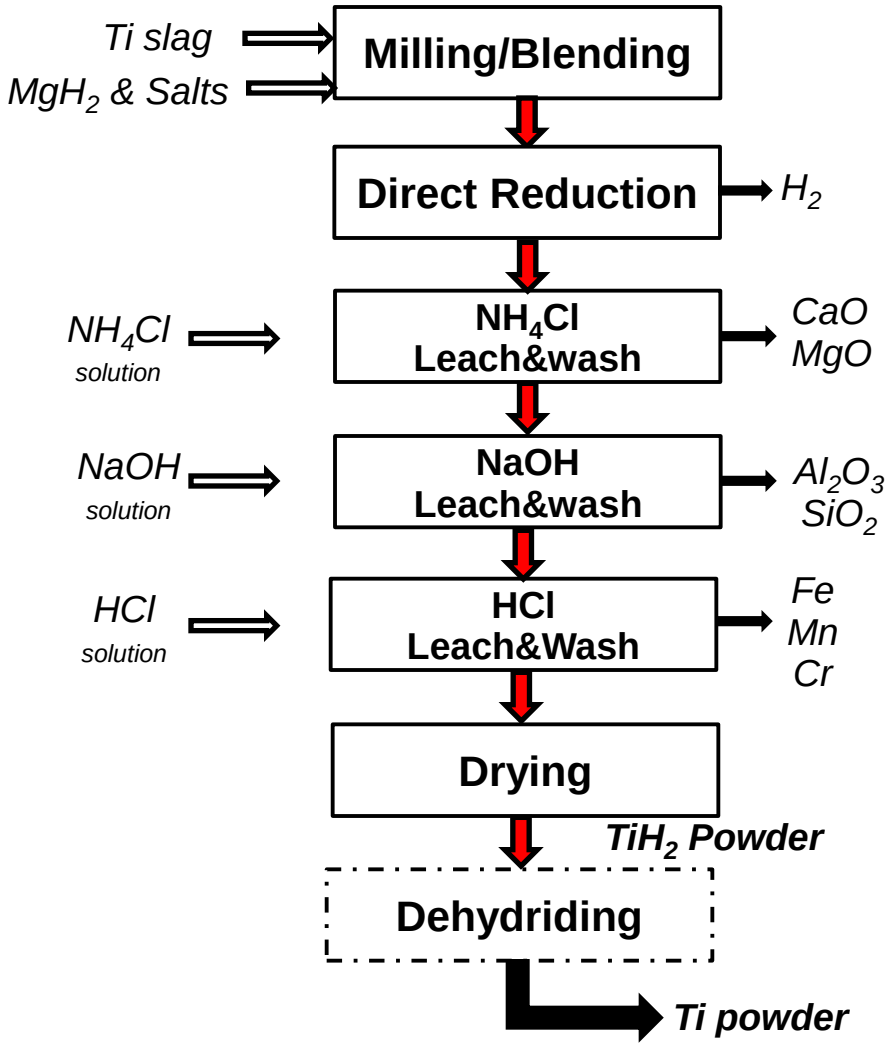
Mechanism of process



Thermodynamic feasibility analysis



Process flow chart



Removing nitrogen in molten steel

- Nitrogen in steel needs to minimized in view of its adverse effects on steel's properties.
- Two methods were attempted to remove nitrogen from molten steel – vacuum degassing and flux treatment.
- Prof. Fan and his colleagues invented a novel process to more effectively remove nitrogen from molten steel using titanium monoxide slag.

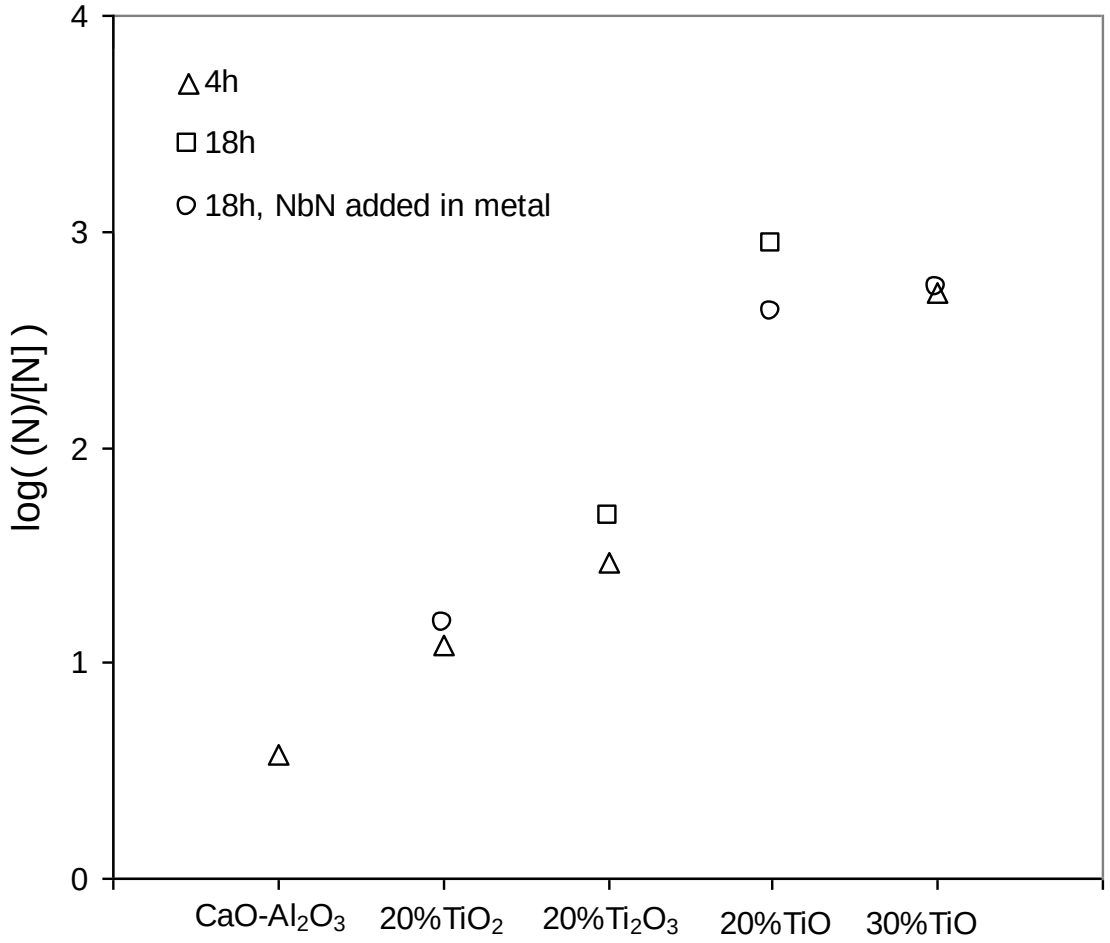
Experimental data using various slags

Table I Initial slag compositions, experimental methods, final metal and slag compositions

initial slag compositions	method	time, h	final metal, % (Ti)	(Al)	(Nb)	(N)	final slag (N), %	L_N = (N)/(N)
50%CaO-50%Al_2O_3	SA	4	0	0.035	0	0.0093	0.035	3.8
40%CaO-40%Al_2O_3-20%TiO_2	A	4	0.053	0.008	0	0.0023	0.028	12.2
40%CaO-40%Al_2O_3-20%TiO_2	LS *	18	0.145	0.021	0.62	0.0059	0.09	15.3
40%CaO-40%Al_2O_3-20%Ti_2O_3	SA	4	0.153	0.017	0	0.0069	0.2	29.0
40%CaO-40%Al_2O_3-20%Ti_2O_3	LS	18	0.256	0.024	0	0.0058	0.28	48.3
40%CaO-40%Al_2O_3-20%TiO	LS	18	0.51	0.04	0	0.0003	0.26	866.7
40%CaO-40%Al_2O_3-20%TiO	LS *	18	0.88	0.073	0.2	0.0006	0.25	416.7
35%CaO-35%Al_2O_3-30%TiO	SA	4	0.42	0.035	0	0.0005	0.26	520.0
35%CaO-35%Al_2O_3-30%TiO	LS *	18	0.44	0.034	1.4	0.0012	0.66	550.0

LS: liquid sealing; SA: static atmosphere; A: flowing Ar; * : NbN added below steel

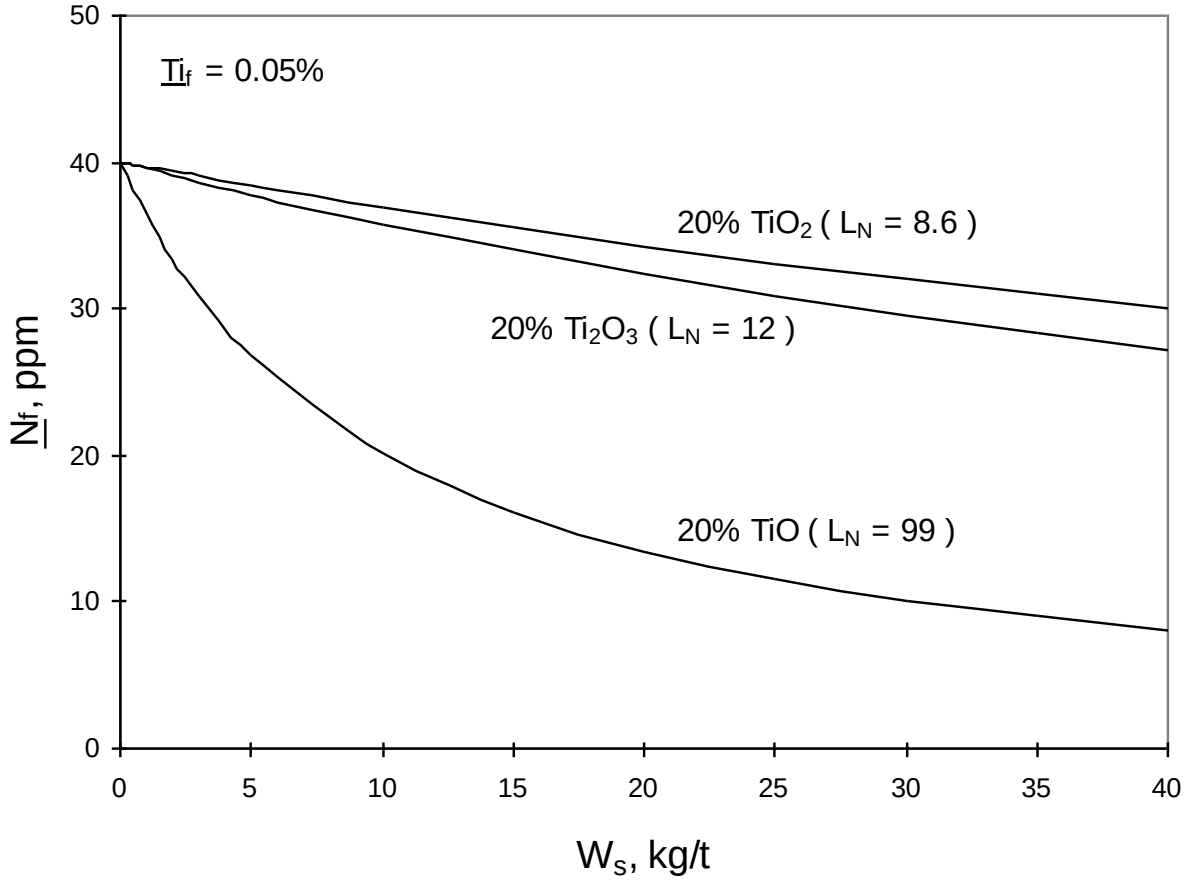
Effective N removal using TiO slag



Nitrogen distribution ratio between slag and molten steel using various slags at 1673K

High values of nitrogen distribution ratio using titanium monoxide slag indicated more effective removal of nitrogen from molten steel.

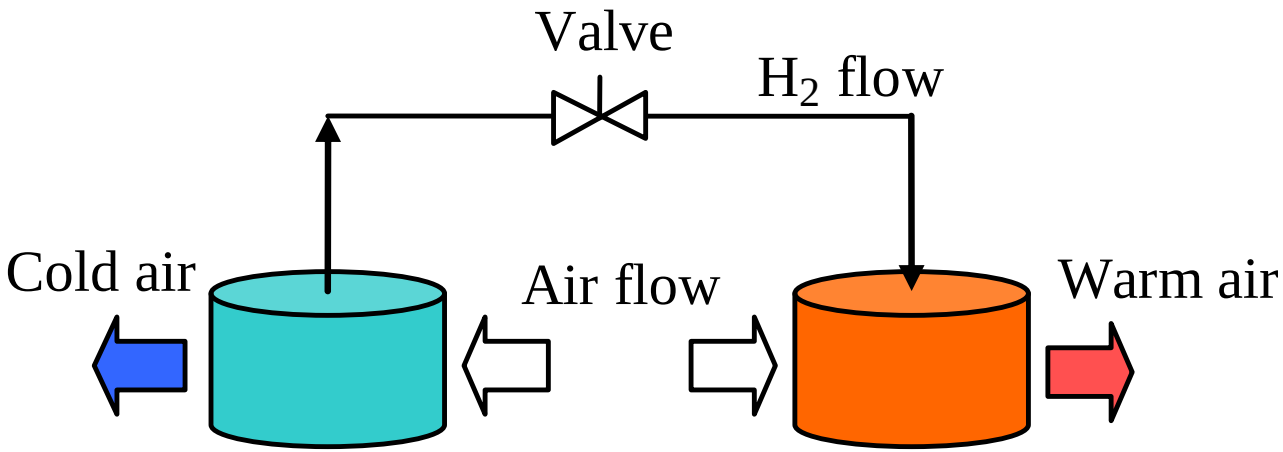
N removal limit using various slags



Nitrogen removal limit vs slag amount using various slags

Thermal energy battery

Application: provide heating and cooling for electric vehicles



M_1H + heat => M_1 + H_2

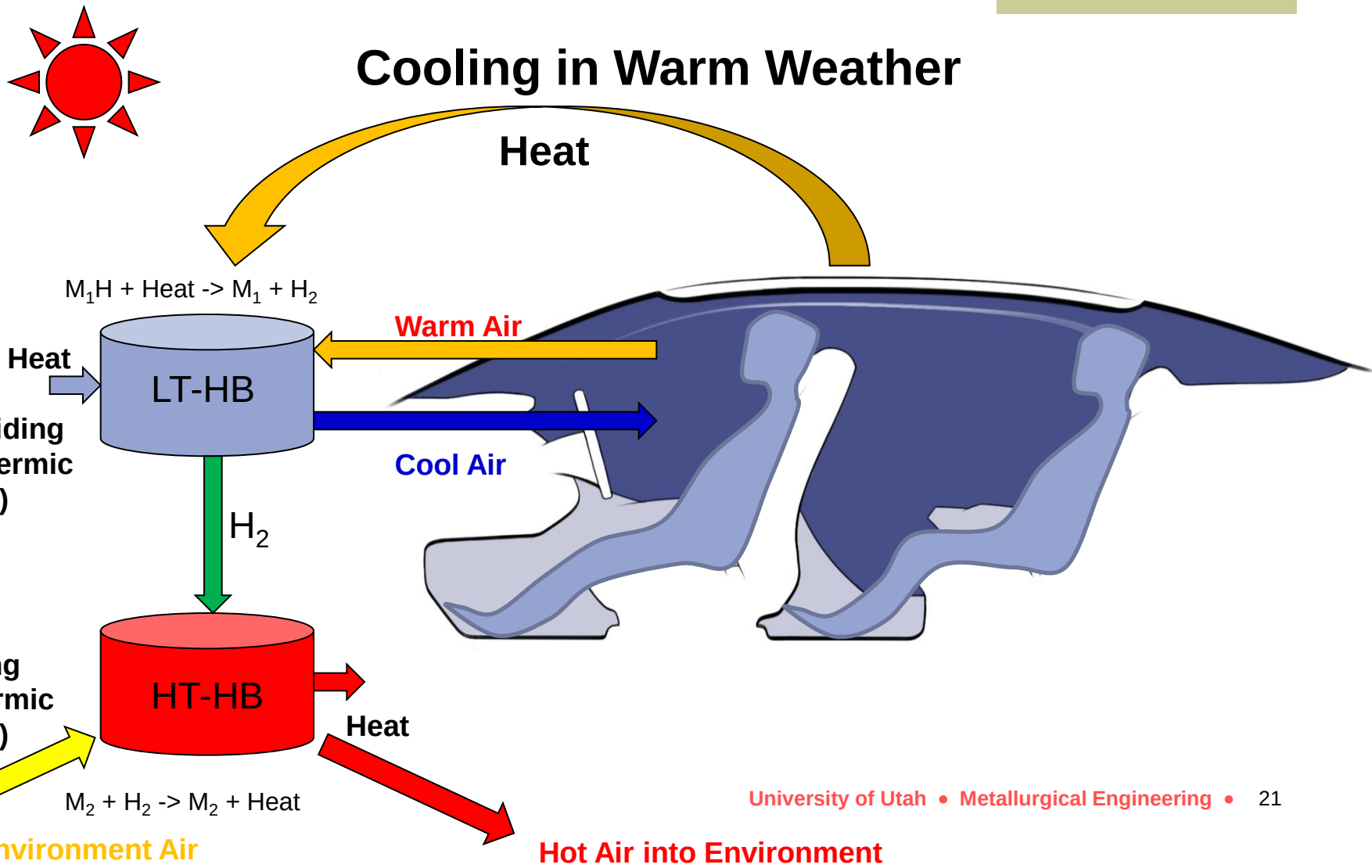
M_2 + H_2 => M_2H + heat

Thermal energy battery

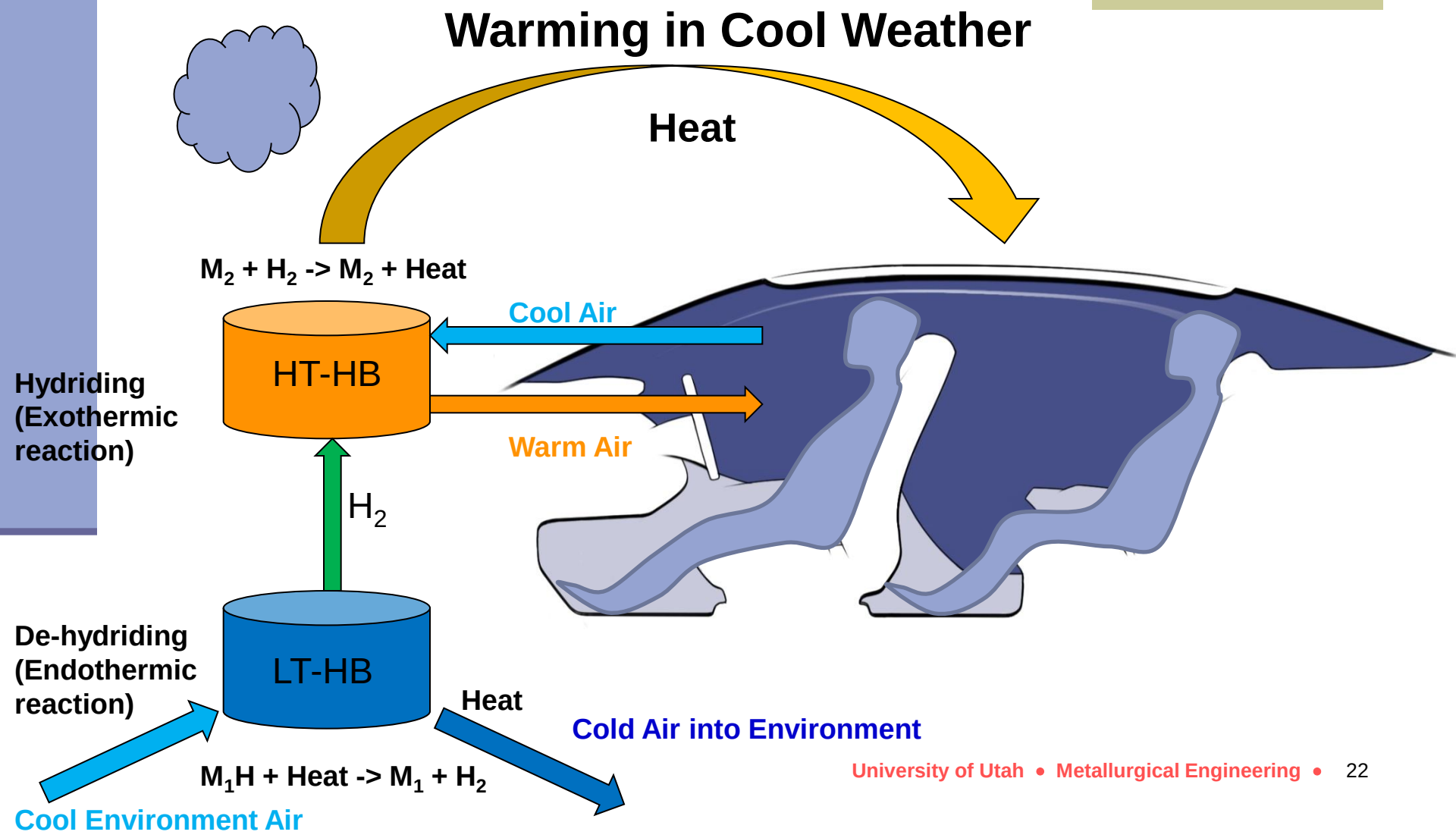
Operating principles of thermal energy battery

- Thermal chemical energy storage
- Charging by plugging into the wall
- Discharging – converting stored energy into heat / cold
- Heating (or cooling) of cabin through heat exchanger

HVAC system based on thermal battery

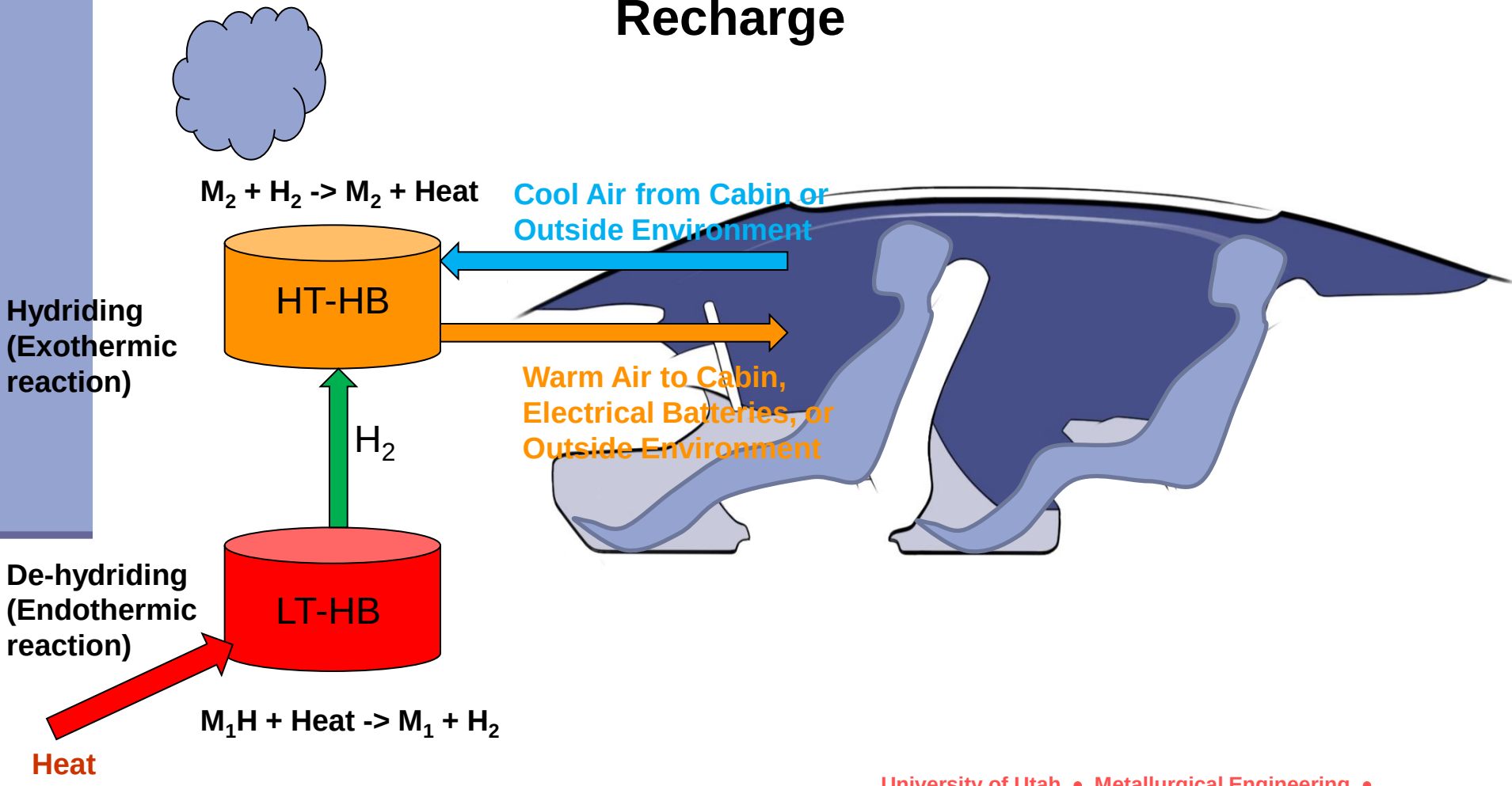


HVAC system based on thermal battery



HVAC system based on thermal battery

Recharge



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