Application of metallic foams

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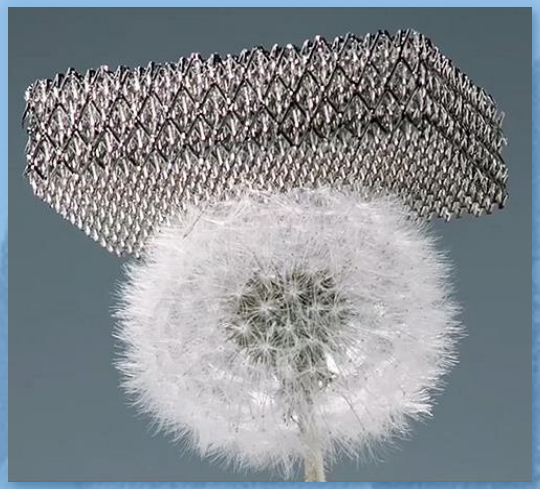
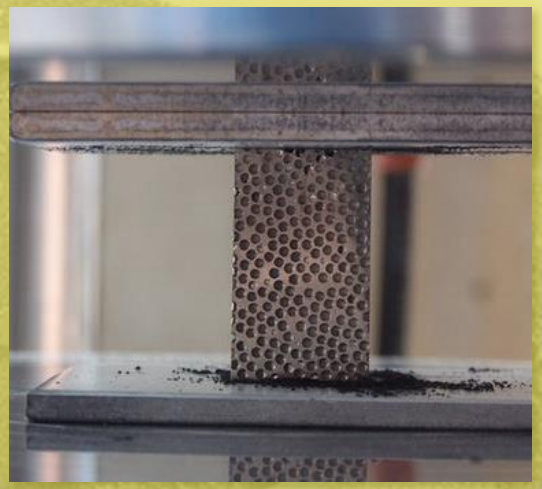
Current status of
structural materials on
02MAY2018

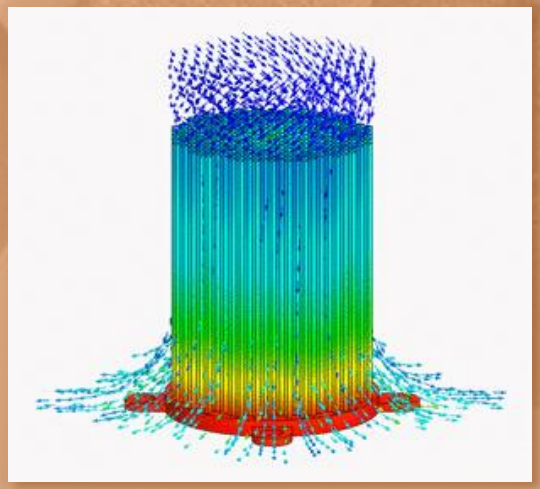
Metal foams

Light weight

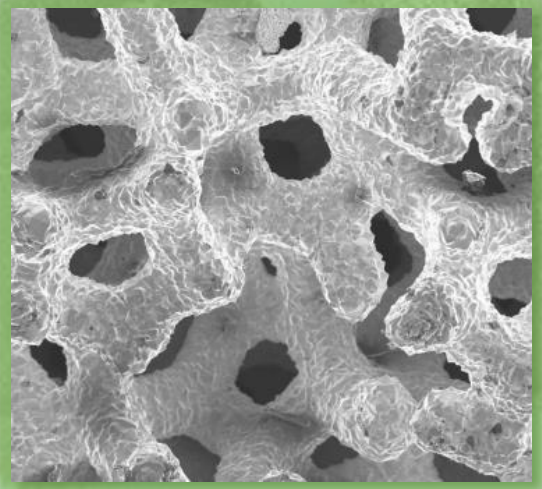


Energy absorption





Thermal conduction/insulation



Large surface area

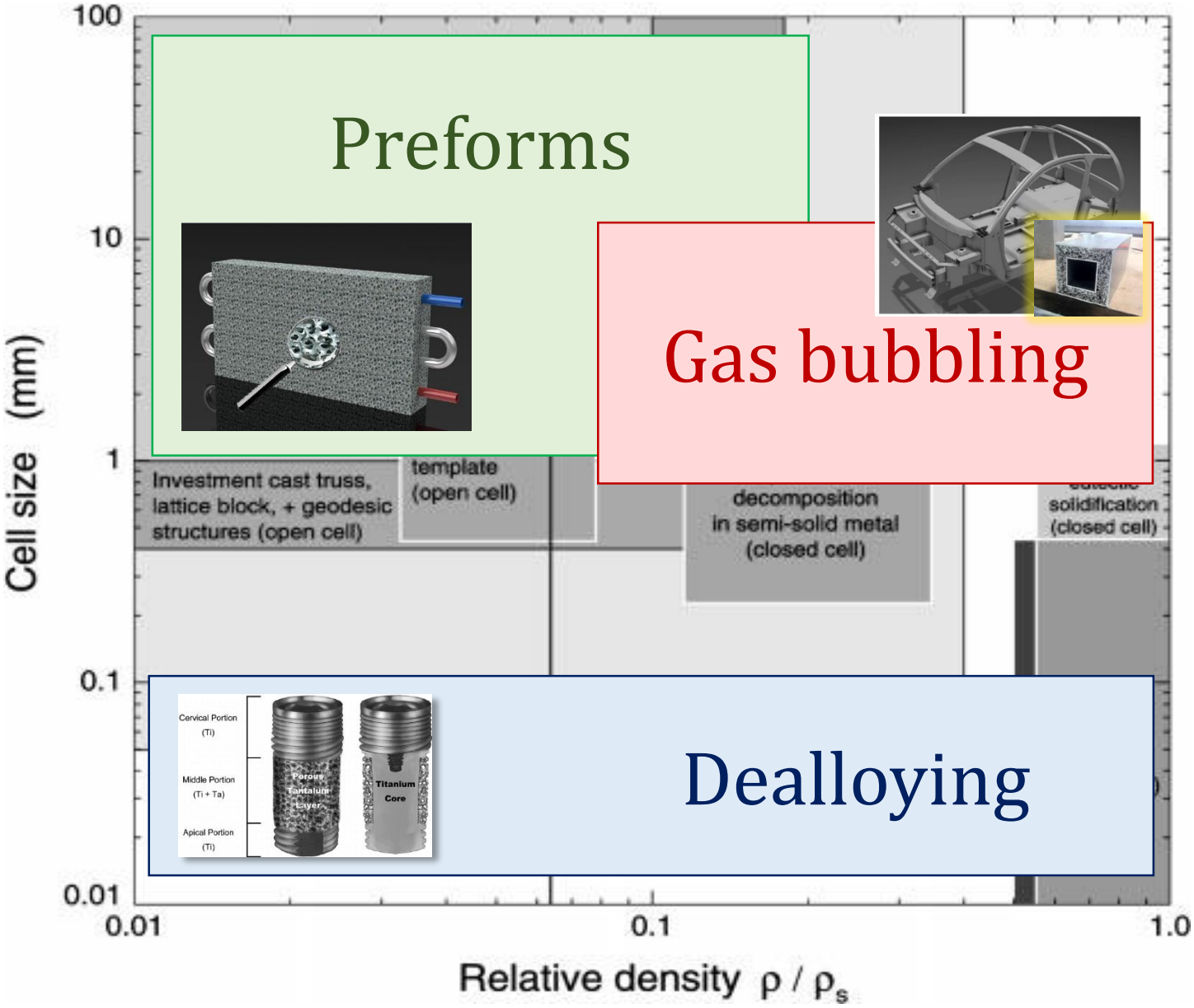
HOW can we make metallic foams ?

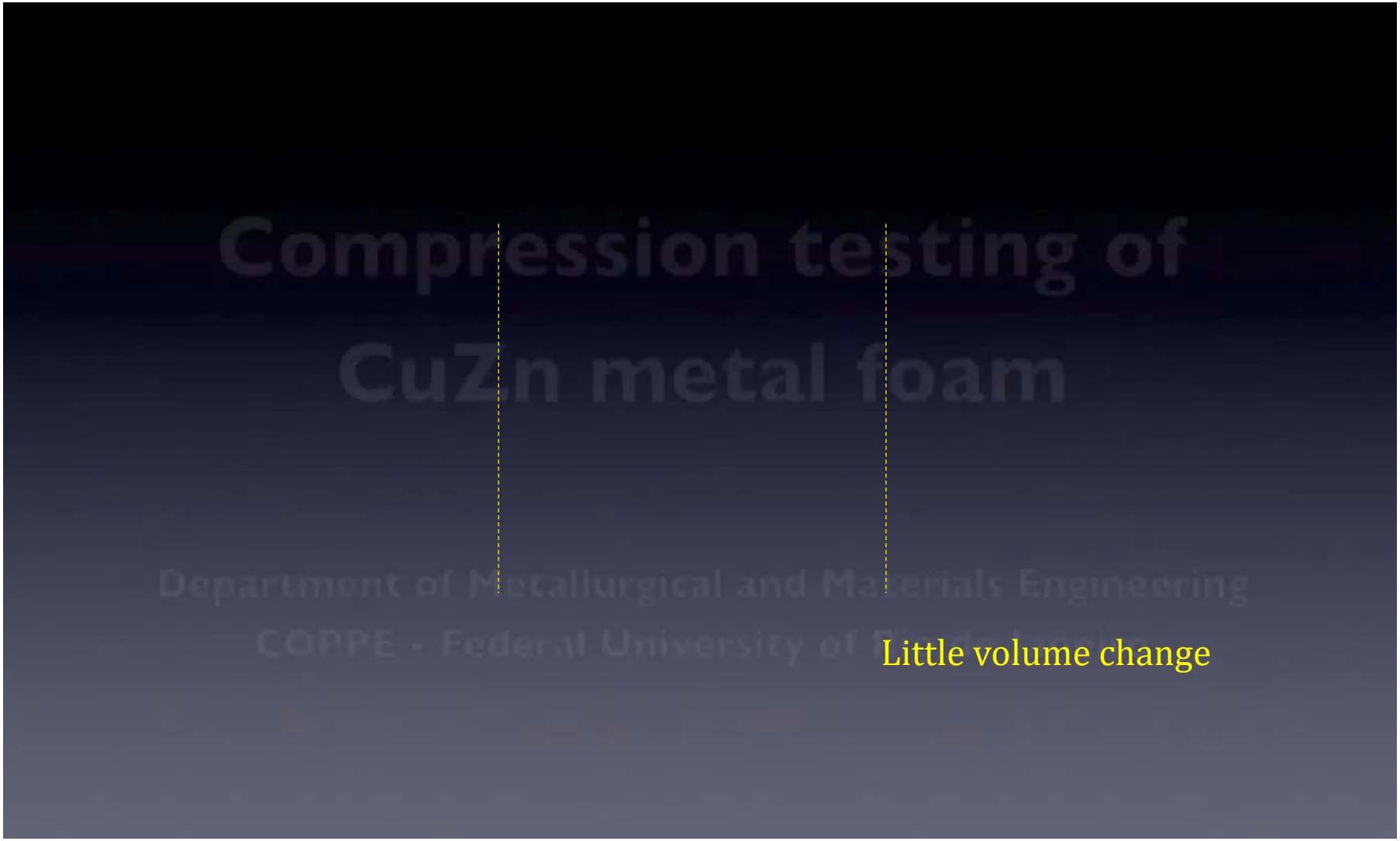
1) Gas **Bubbling** method
2) Foam fabrication with **Preforms**
3) **Dealloying** – Chemical etching process

WHAT are the further applications of metallic foams ?

1) Materials for **Hydrogen storage**
2) Military applications : **Ballistic amour**

How can we make metallic foams ?

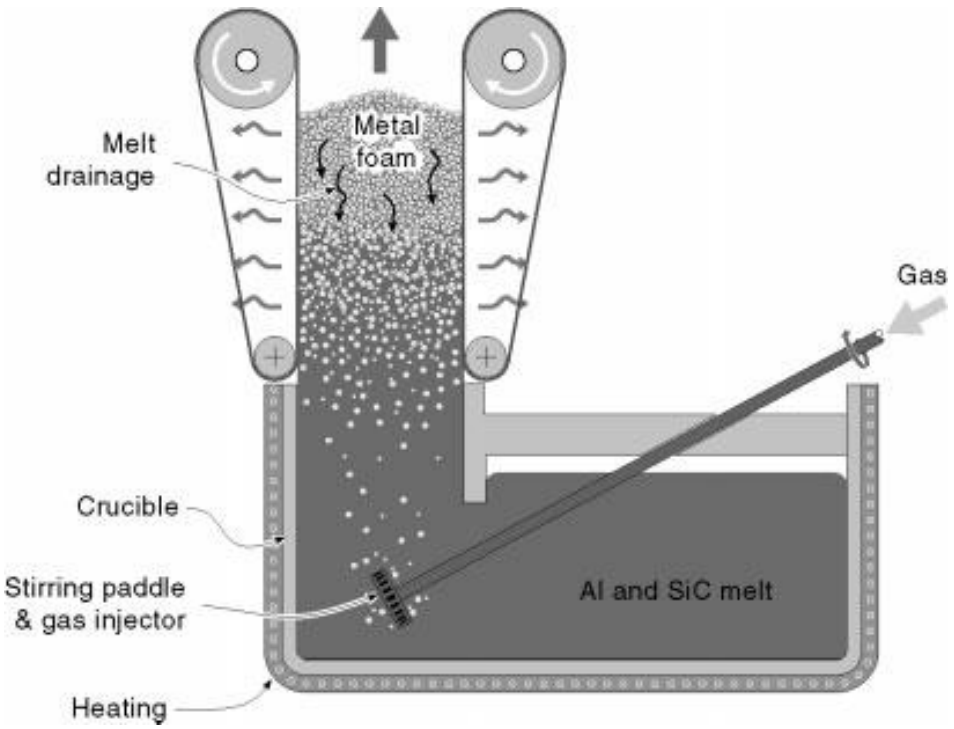

Preforms
Gas bubbling
Dealloying
Cervical Portion (Ti)
Middle Portion (Ti + Ta)
Apical Portion (Ti)
Porous Tantalum Layer
Titanium Core
Investment cast truss, lattice block, + geodesic structures (open cell)
template (open cell)
decomposition in semi-solid metal (closed cell)
solidification (closed cell)
Cell size (mm)
100
10
1
0.1
0.01
0.01
0.1
1.0
Relative density ρ / ρs



➢ **Metal foams can be good candidate for materials for vehicles !**

Air injection method

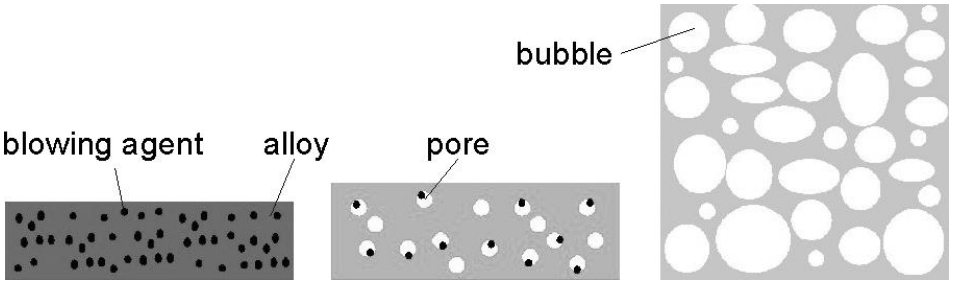
Cellular metals manufacturing (2002)

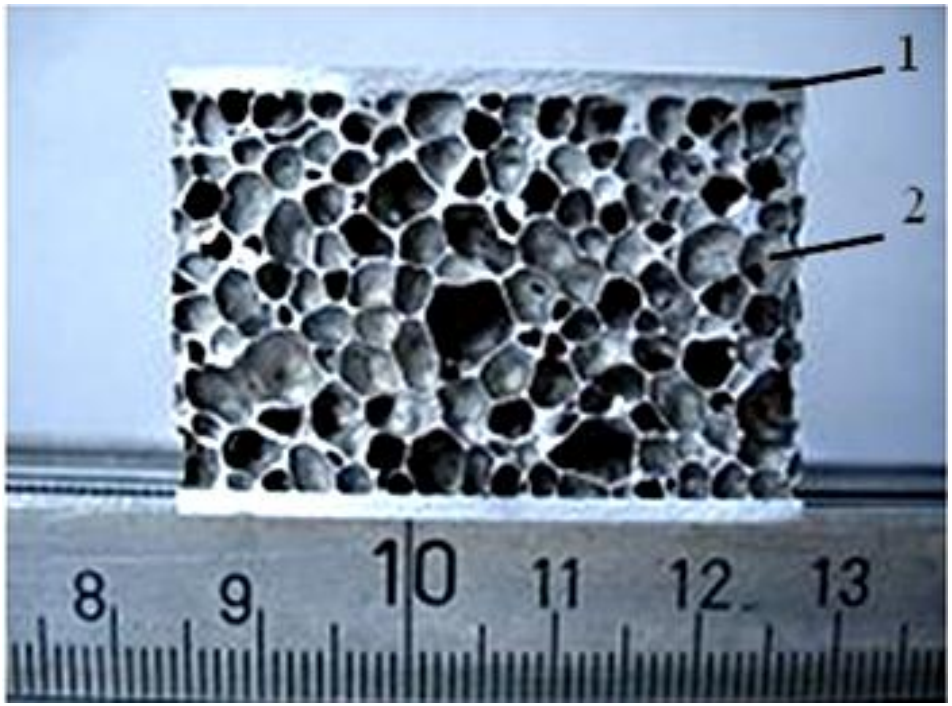


A method to bubble N_2 gas into metallic melt such as Al which has low T_m

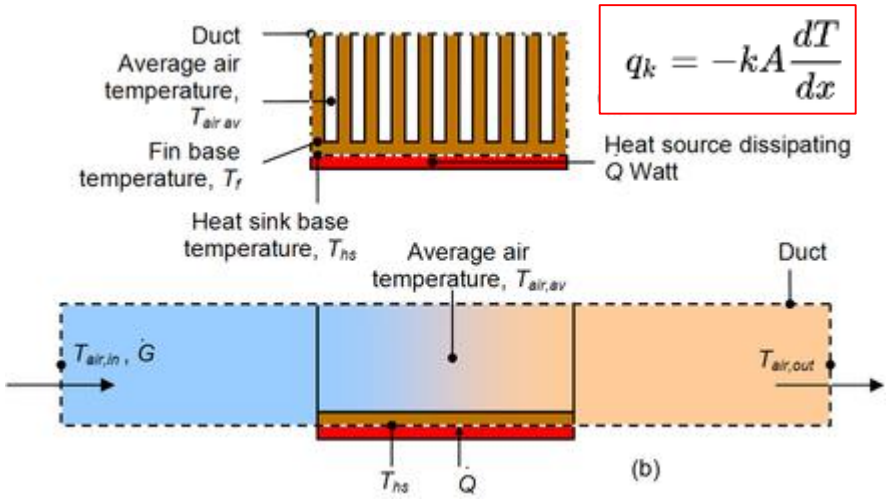
- Pros : **Easy and not expensive** way to fabricate closed-cell pores
- Cons : Too **heterogeneous** distribution of the pores

Casting with blowing agents





- A method to bubble H_2 gas by adding **blowing agents** such as TiH2 which **evaporates at 680°C**
- Since the TiH_2 powder can be **distributed homogeneously** during melting process, the pores spread much well

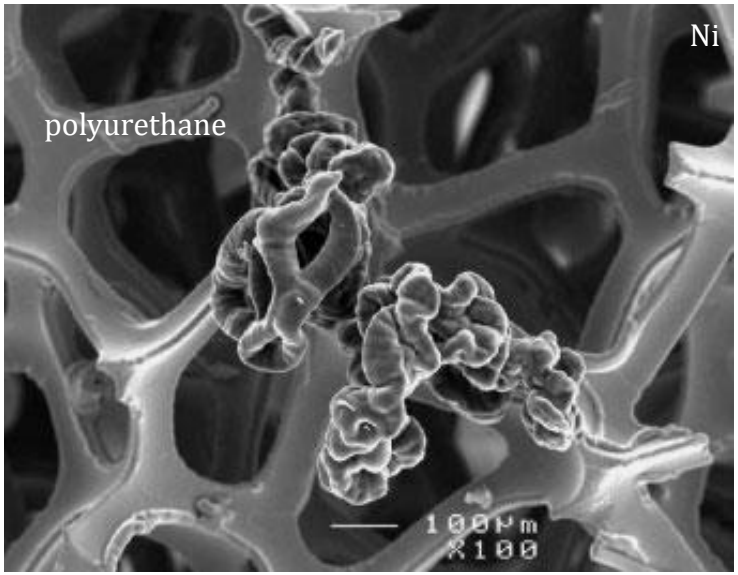


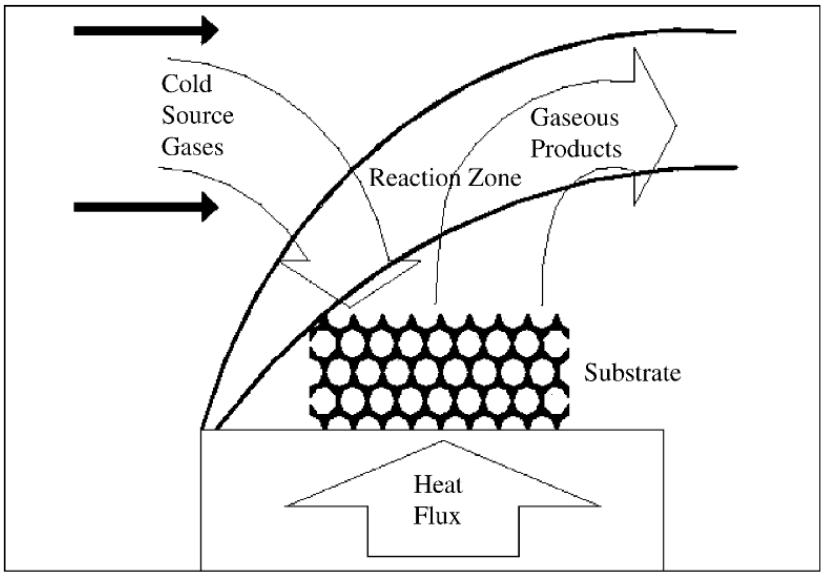
Pore size	Large (~ mm scale)
Pore structure	• Open cell • Well designed
Porosity	80 % <

1. **Large surface area** to contact the cold atmosphere such as air, water etc.
2. The **pore structure** can hider the heat transfer as well as give path to conduct

➢ **Al or Cu foams are good for heat radiating applications**

CVD technique for Inco Nickel Foam production (2004)





ex) $Ni(CO)_4 \rightarrow Ni + 4CO$

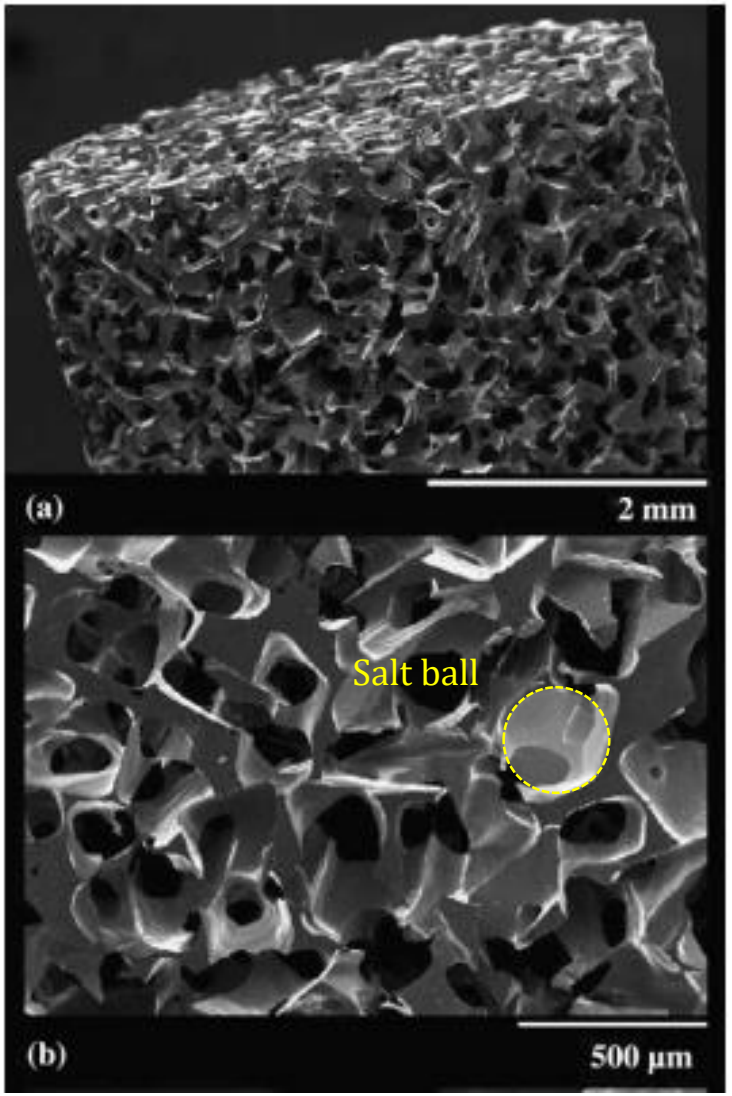
Metals can be deposited on polymer/ceramic/metal templates to fabricate well-ordered foam structure

- Pros : **Easy to control** the foam structure
- Cons : **Remaining templates** can degrade the mechanical properties

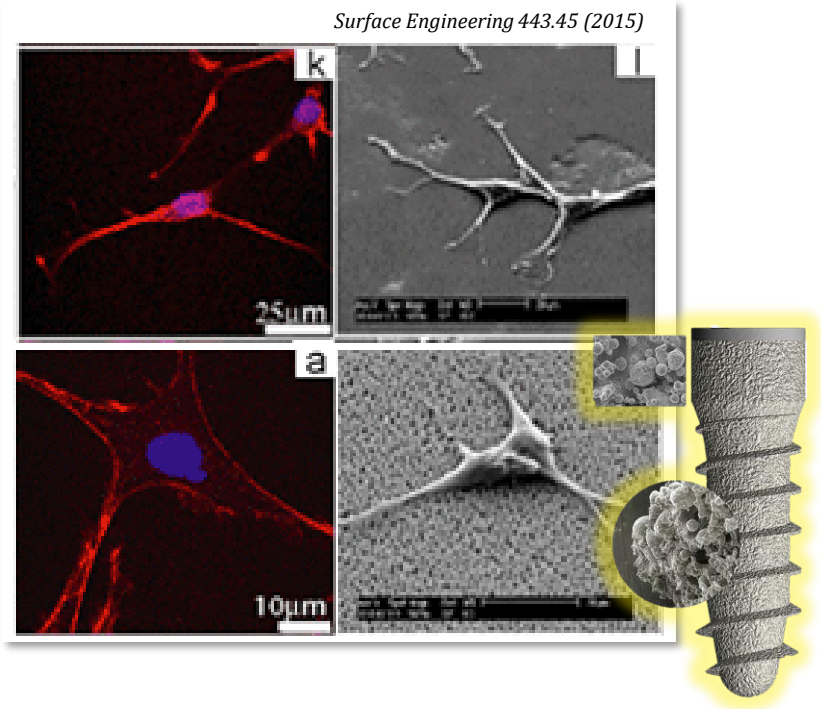
Ductile bulk metallic glass foam (2015)

Porosity can be created by infiltration of a bed of hollow spheres to create syntactic foams and infiltration of salt space-holder particles which are removed by dissolution in acidic solutions

- Pros : **Easy to form the open-cell structure** whose pores are homogeneously distributed
- Cons : The space holders can **contaminate** the materials



Metal foams with large surface areas



1. **Large surface area** can enhance not only the bio-compatibility, but also catalytic efficiency
2. The pores should be **connected**: open-cell type

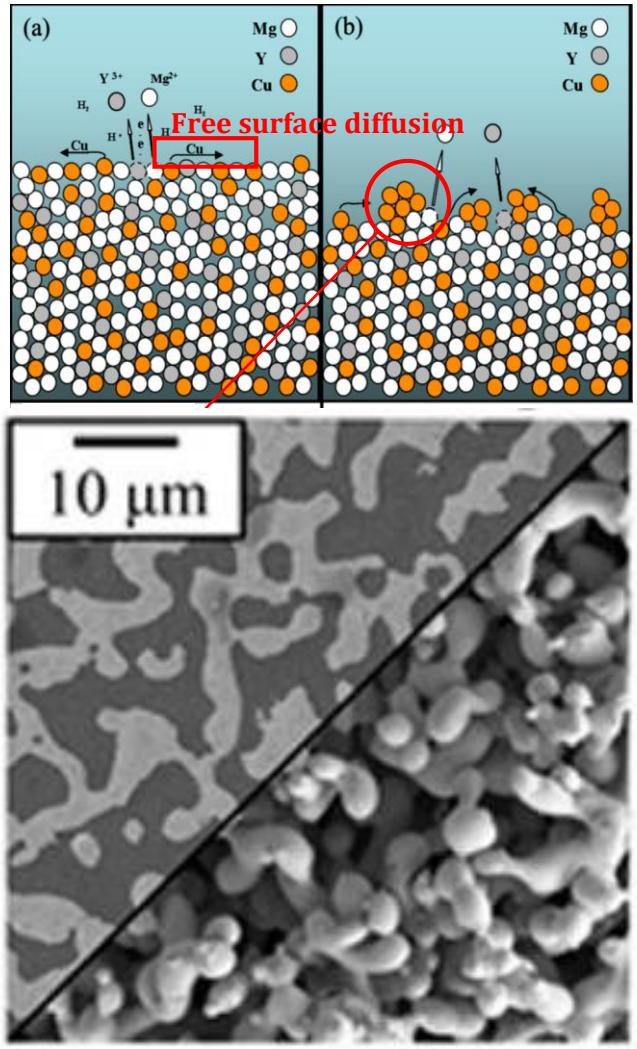
Pore size	Small (nm ~ um scale)
Pore structure	Open cell
Porosity	20 ~ 99 %

➢ **Metal foams provide even larger surface area than bulk materials**

Thermal shielding property : Resistance to thermal flux

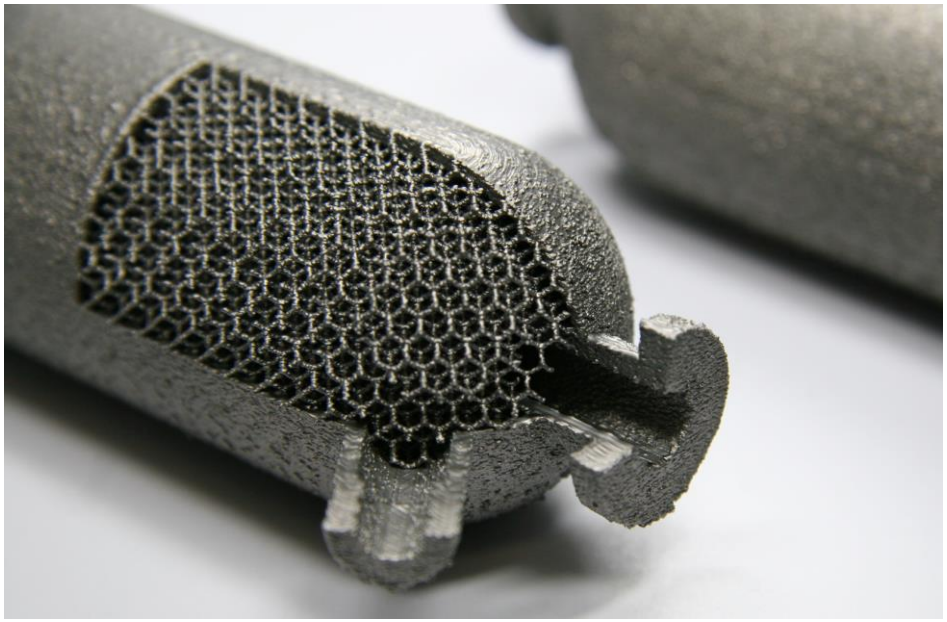
Nucleation and growth of nanoporous copper ligaments during electrochemical dealloying of Mg-based metallic glasses , Xuekun Luo et al. (2013)

- **Dealloying is a common corrosion process during which an alloy is 'parted' by the selective dissolution of the most electrochemically active of its elements.**
- **This process results in the formation of a nano-porous sponge composed almost entirely of the more noble alloy constituents.**
- Cons : It is **hard to get exact target composition** of metal foams



3D printed metal foams

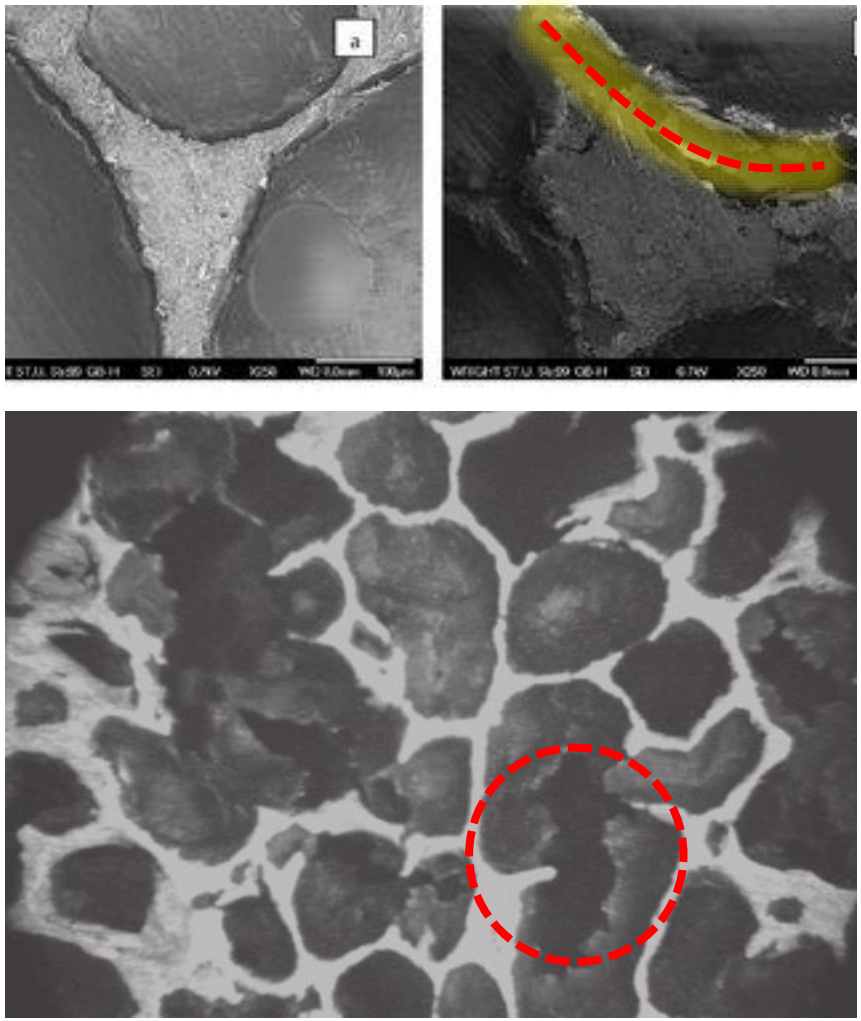
Synthesis of TiC/Ti–Cu composites by pressureless reactive infiltration of TiCu alloy into carbon preforms fabricated by 3D-printing(2005)



- The use of additive manufacturing for serialized production of orthopedic implants (metals) is also increasing due to the ability to efficiently create porous surface structures that facilitate bio-compatibilty.

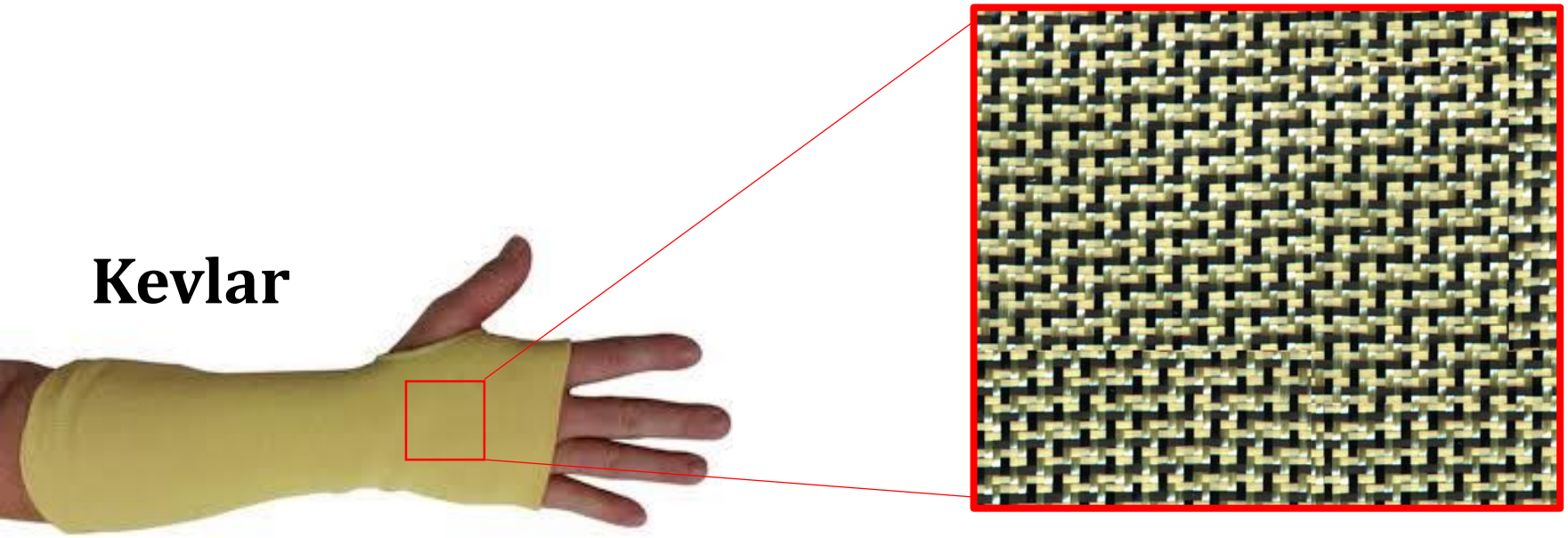
➢ **3D printing technique offers new opportunity for metal foam markets**

What are the further applications of metallic foams ?

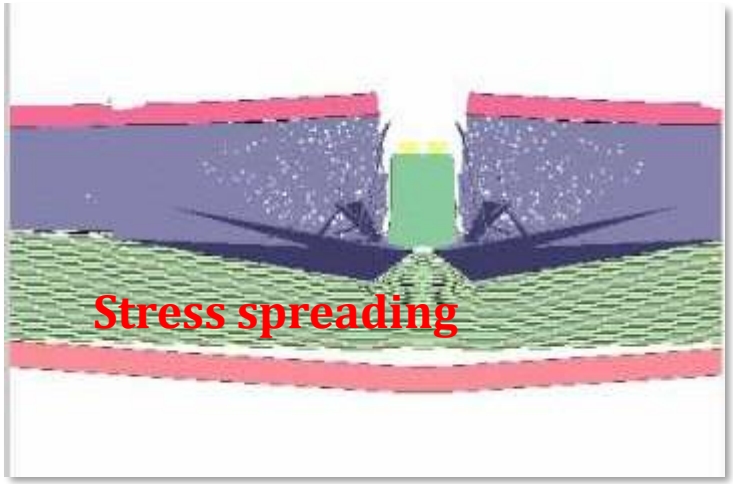


- **Dealloying is a common corrosion process during which an alloy is 'parted' by the selective dissolution of the most electrochemically active of its elements.**
- **This process results in the formation of a nano-porous sponge composed almost entirely of the more noble alloy constituents.**

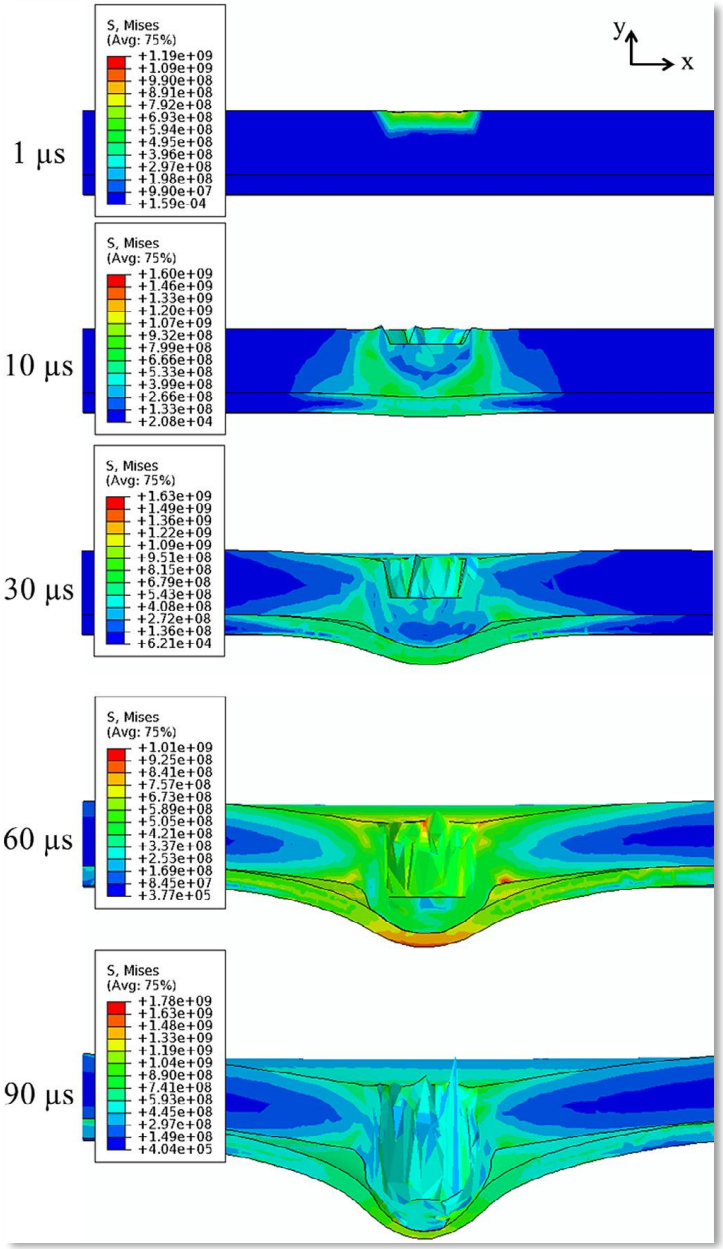
➢ **Composites fabricated from metal foam have disadvantages against dynamic stress**



- Fiber-reinforced composite materials have become important engineering materials used such as marine bodies, aircraft structures and **light-weight armor for ballistic protection** in military applications.



Sandwich panels : Composite materials for damping properties

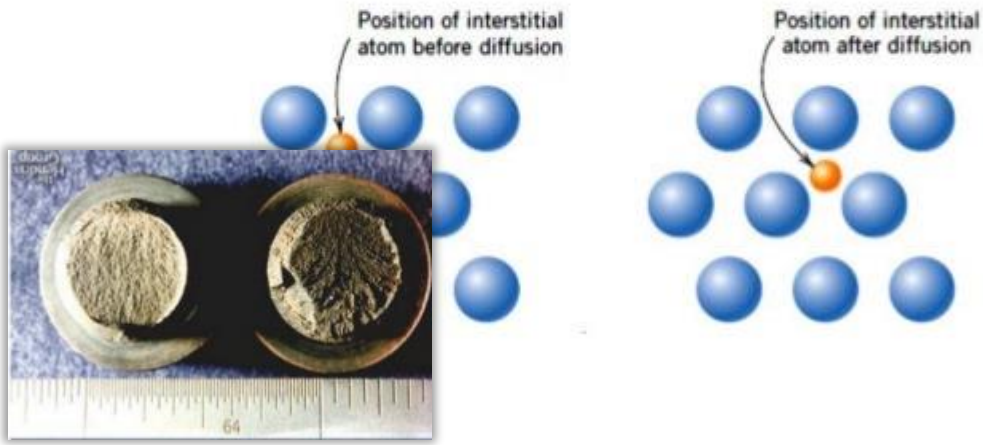


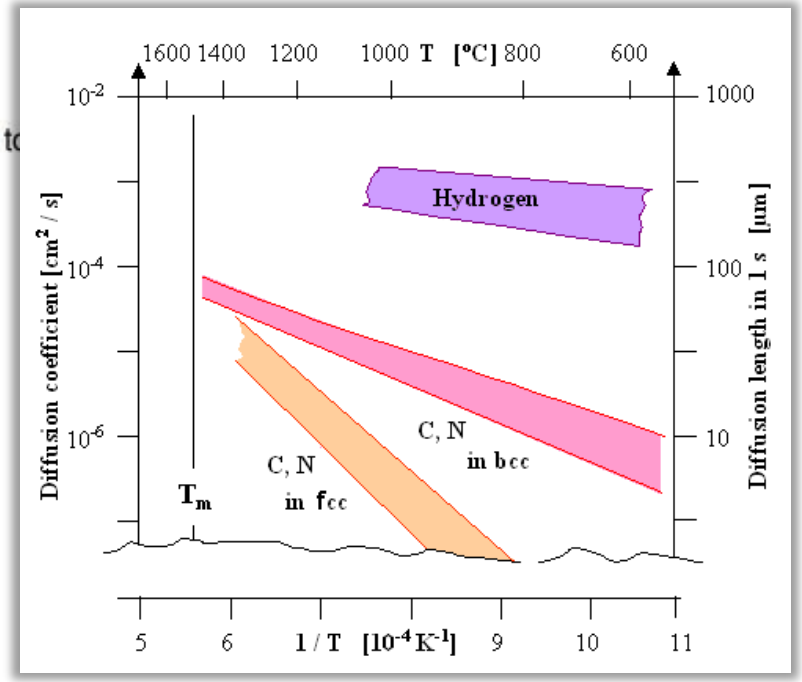
- Due to its light-weight and high impact energy absorption capabilities, composite metal foams have shown **good potential for ballistic armor**
- Composite metal foam processed by powder metallurgy technique as a **bullet kinetic energy absorber interlayer**

Hydrogen diffusion into alloys

❑ Interstitial Diffusion

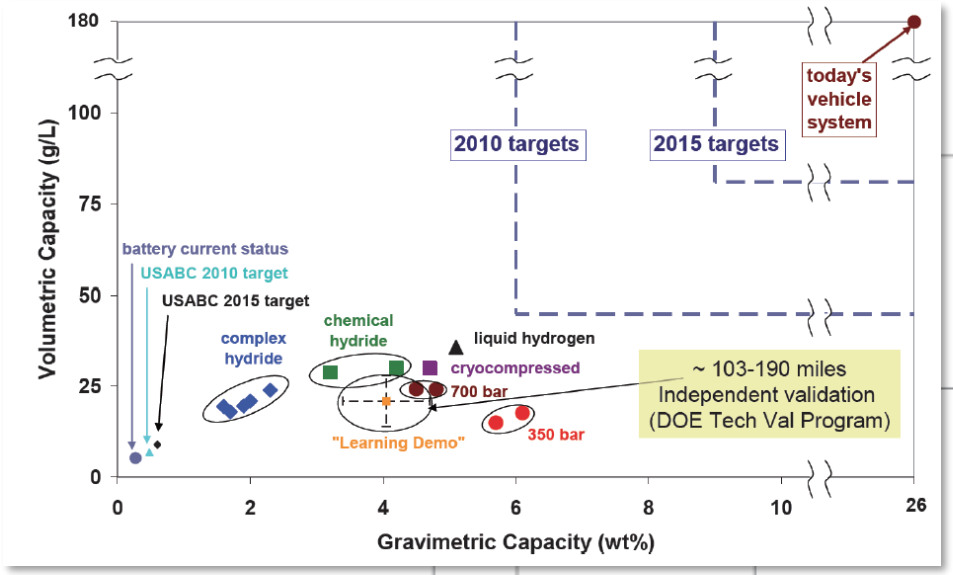
- Diffusion involves atoms that migrate from an interstitial position t
  neighboring position that is empty.



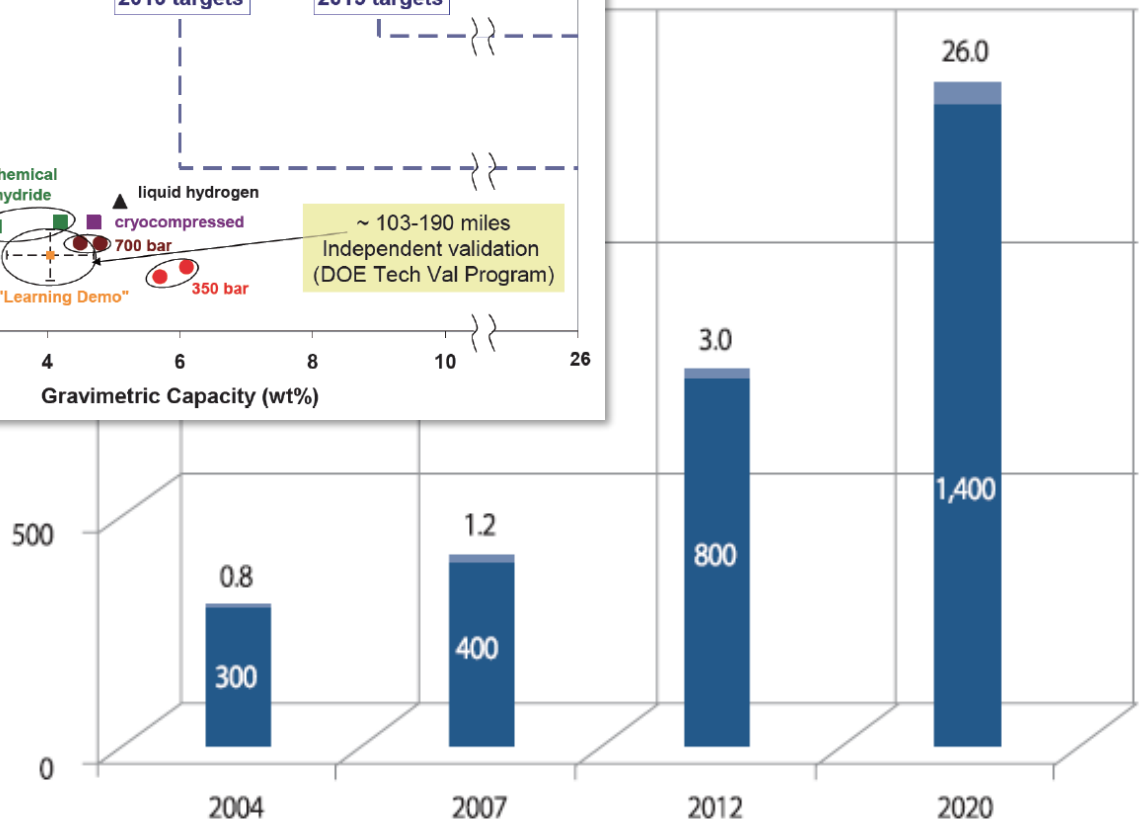


- Hydrogen is the **smallest atom** in the nature
- Hydrogen molecules have **large tendency to diffuse** in the alloy matrix
- Since the interstitial hydrogen atom can hinder the movement of dislocations, it can **embrittle the commercial alloys** such as steels

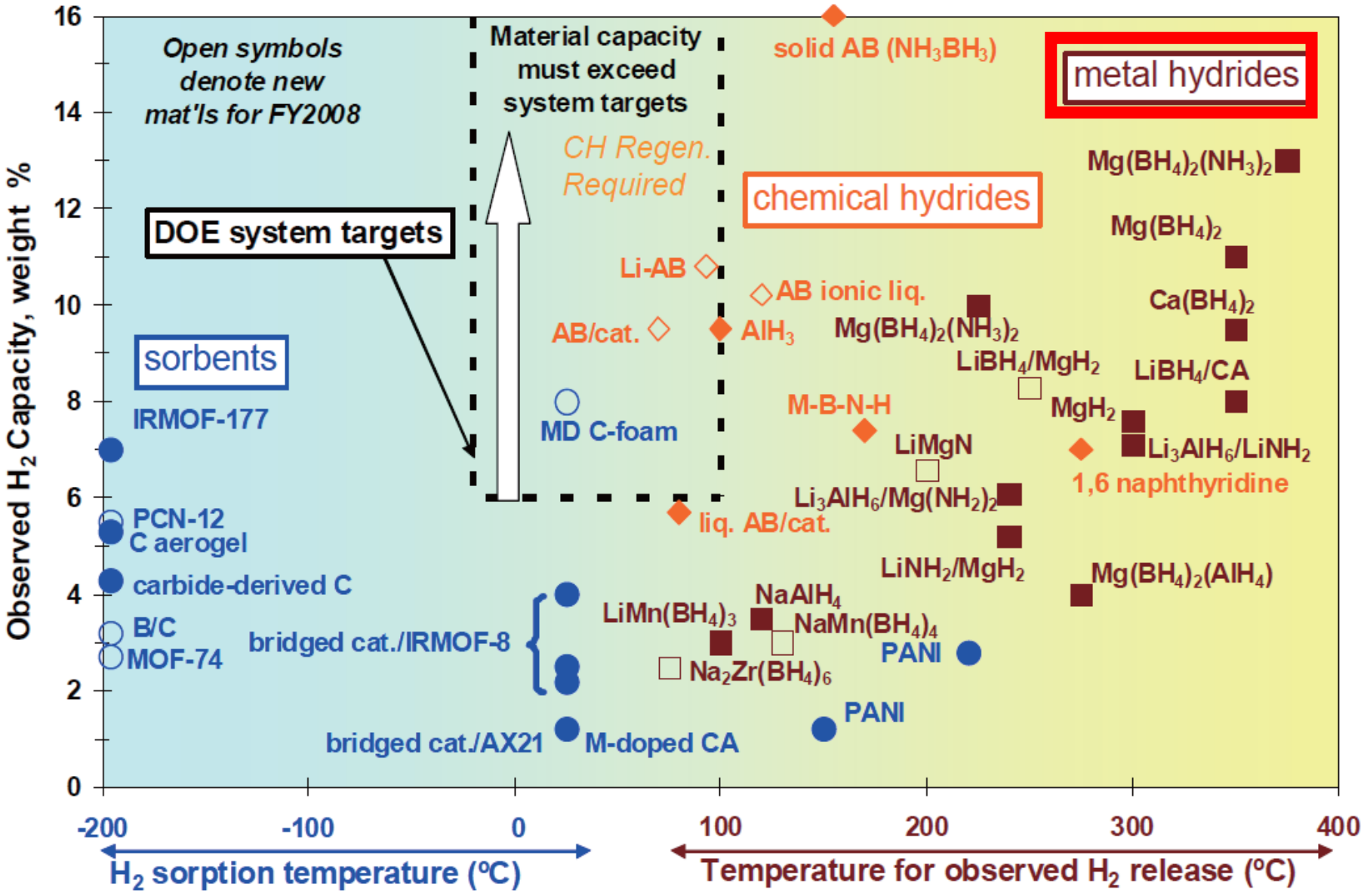
Hydrogen storage in metallic materials



(단위: 억 달러)



The global market for hydrogen storage is expected to witness a CAGR of 7.6% during the forecast period due to the increasing focus of **key players to produce alternative renewable energy** from fuel cells, hydrogen and oxygen.


Observed H_2 Capacity, weight %
16
14
12
10
8
6
4
2
0
-200
-100
0
100
200
300
400
H_2 sorption temperature (°C)
Temperature for observed H_2 release (°C)
Open symbols denote new mat'ls for FY2008
Material capacity must exceed system targets
CH Regen. Required
DOE system targets
metal hydrides
chemical hydrides
sorbents
solid AB (NH_3BH_3)
$Mg(BH_4)_2(NH_3)_2$
$Mg(BH_4)_2$
$Ca(BH_4)_2$
Li-AB
AB ionic liq.
AB/cat.
AlH_3
$Mg(BH_4)_2(NH_3)_2$
$LiBH_4/MgH_2$
$LiBH_4$/CA
M-B-N-H
MgH_2
LiMgN
$Li_3AlH_6/LiNH_2$
1,6 naphthyridine
IRMOF-177
MD C-foam
$Li_3AlH_6/Mg(NH_2)_2$
liq. AB/cat.
PCN-12
C aerogel
$LiNH_2/MgH_2$
$Mg(BH_4)_2(AlH_4)$
carbide-derived C
$NaAlH_4$
$LiMn(BH_4)_3$
$NaMn(BH_4)_4$
B/C
MOF-74
bridged cat./IRMOF-8
PANI
$Na_2Zr(BH_4)_6$
PANI
bridged cat./AX21
M-doped CA

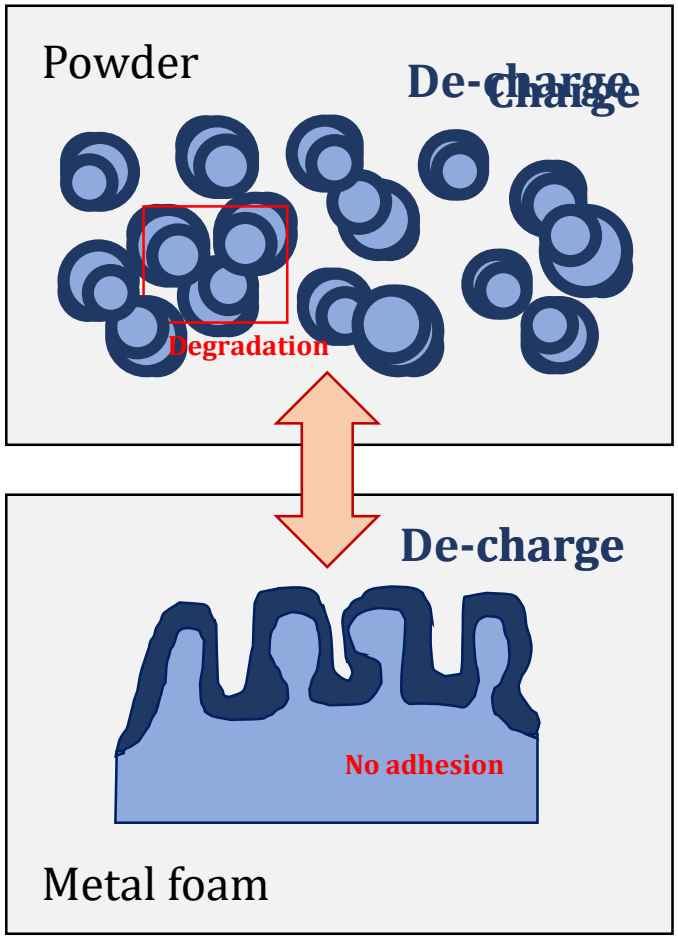


그림 2-3 Ti-Cr-V-Fe계 수소저장합금[18]

TiFe 합금
나듐을 부분
전극으로서
(주)한국에
티타늄계 수
회 생산량 1
의 최대 수
의 순수한 수
인 바나듐(V
력을 확보하

- **Metal foam is a good candidate for hydrogen storage materials by forming hydride**

THANK YOU FOR

YOUR KIND ATTENTION