

Neural Network Approach to Slag Viscosity / SlagVis



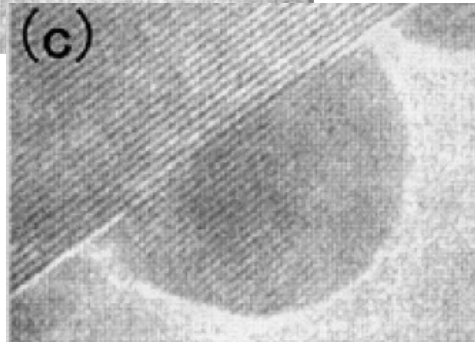
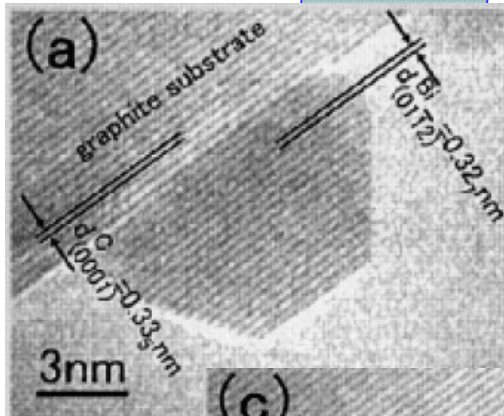
How our research works
have been related to GTT

Toshihiro Tanaka,
Osaka University, Japan

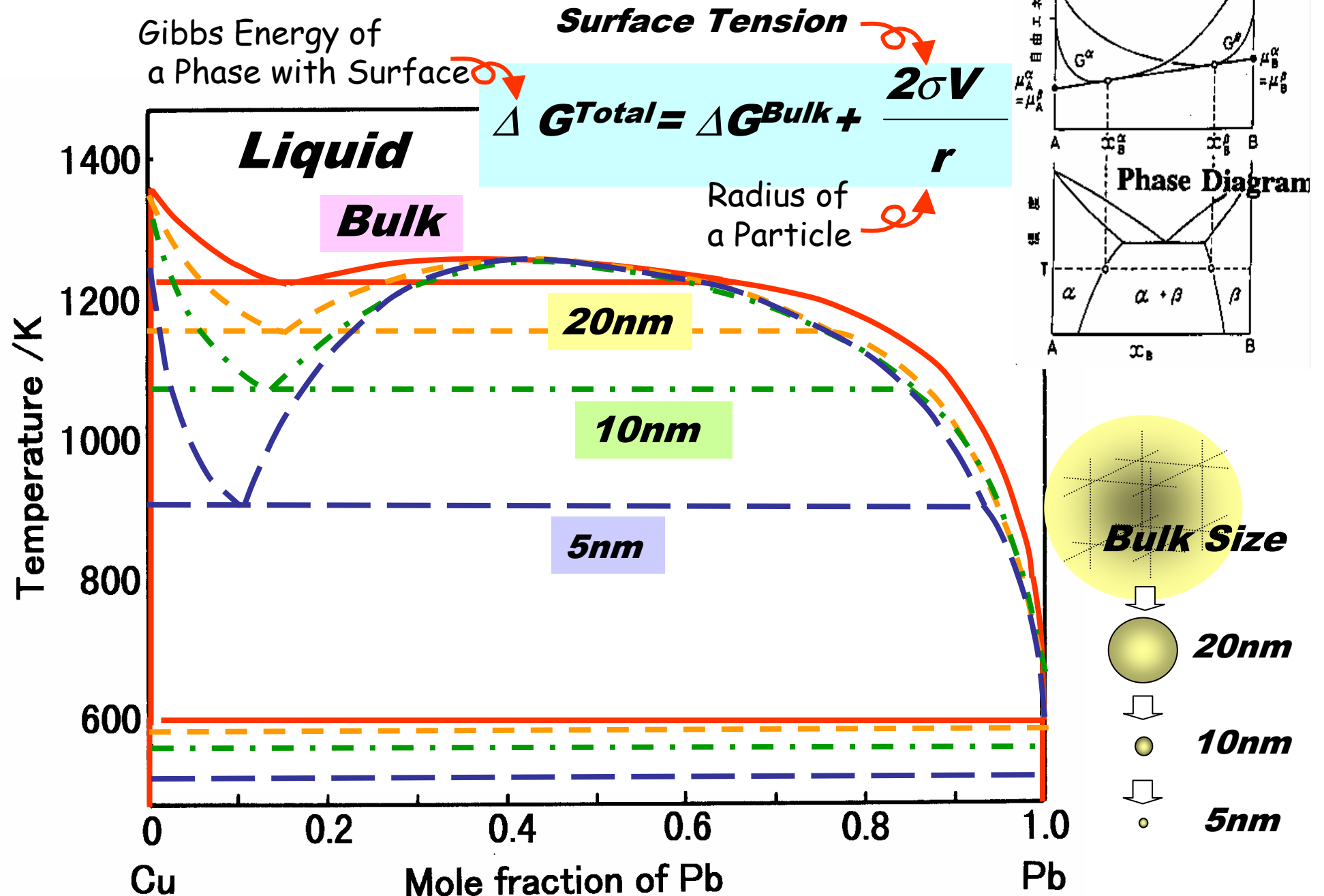
Physical Chemistry of Materials

(Thermodynamics, Surface Science etc.)

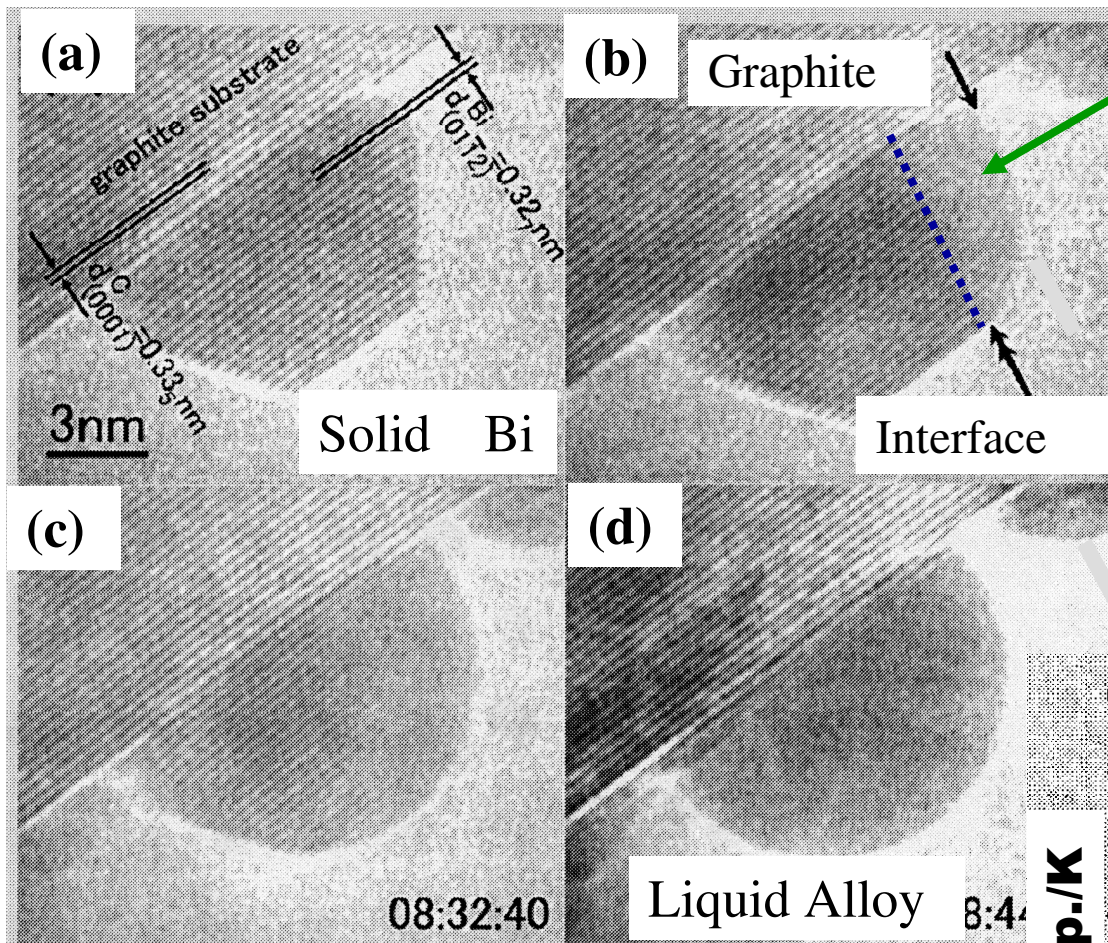
Target : From Nano to the Universe



Alloy Phase Diagram of Nano-Particle

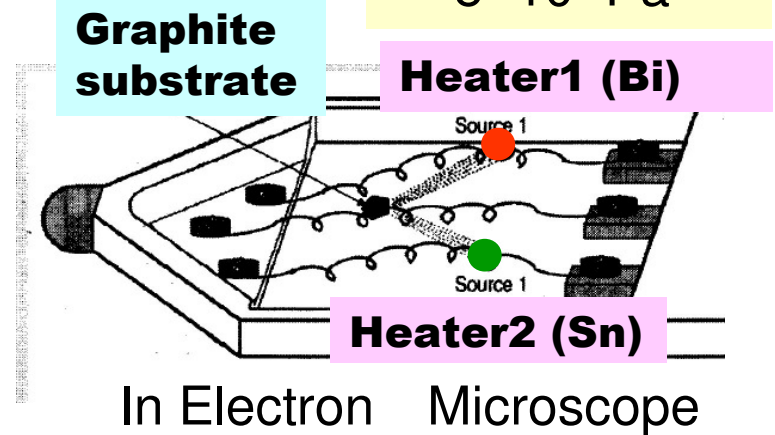


Melting behavior of Sn-Bi alloy on graphite substrate



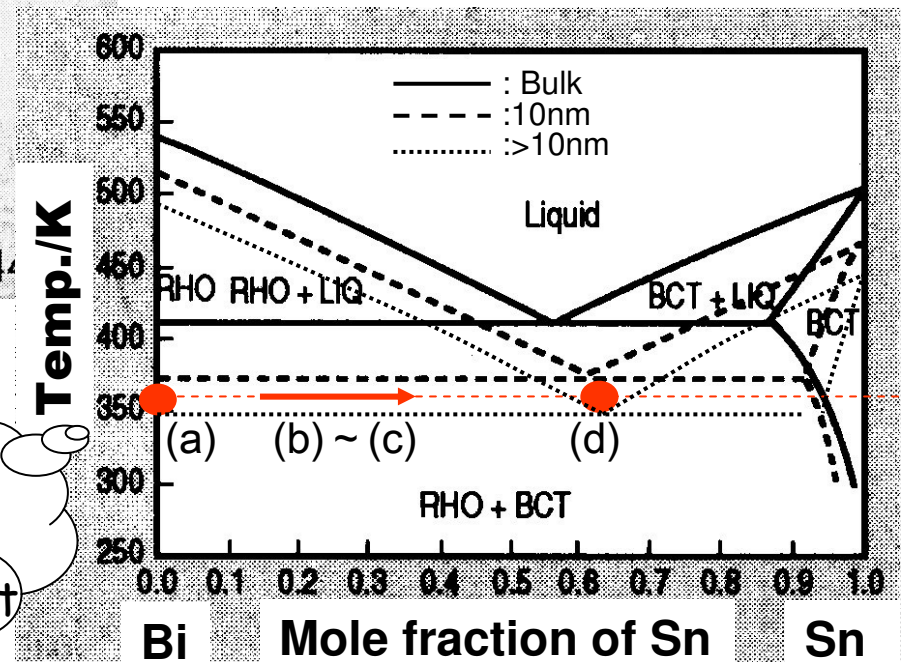
Sn vapor penetrates into solid Bi

- $80^\circ\text{C} = 353\text{K}$
- $5 \times 10^{-7} \text{ Pa}$



Junggoo Lee,
Joonho Lee
T. Tanaka & H. Mori
JOM (2005)

By using
ChemApp
/ ChemSheet



Metallurgy on the Moon

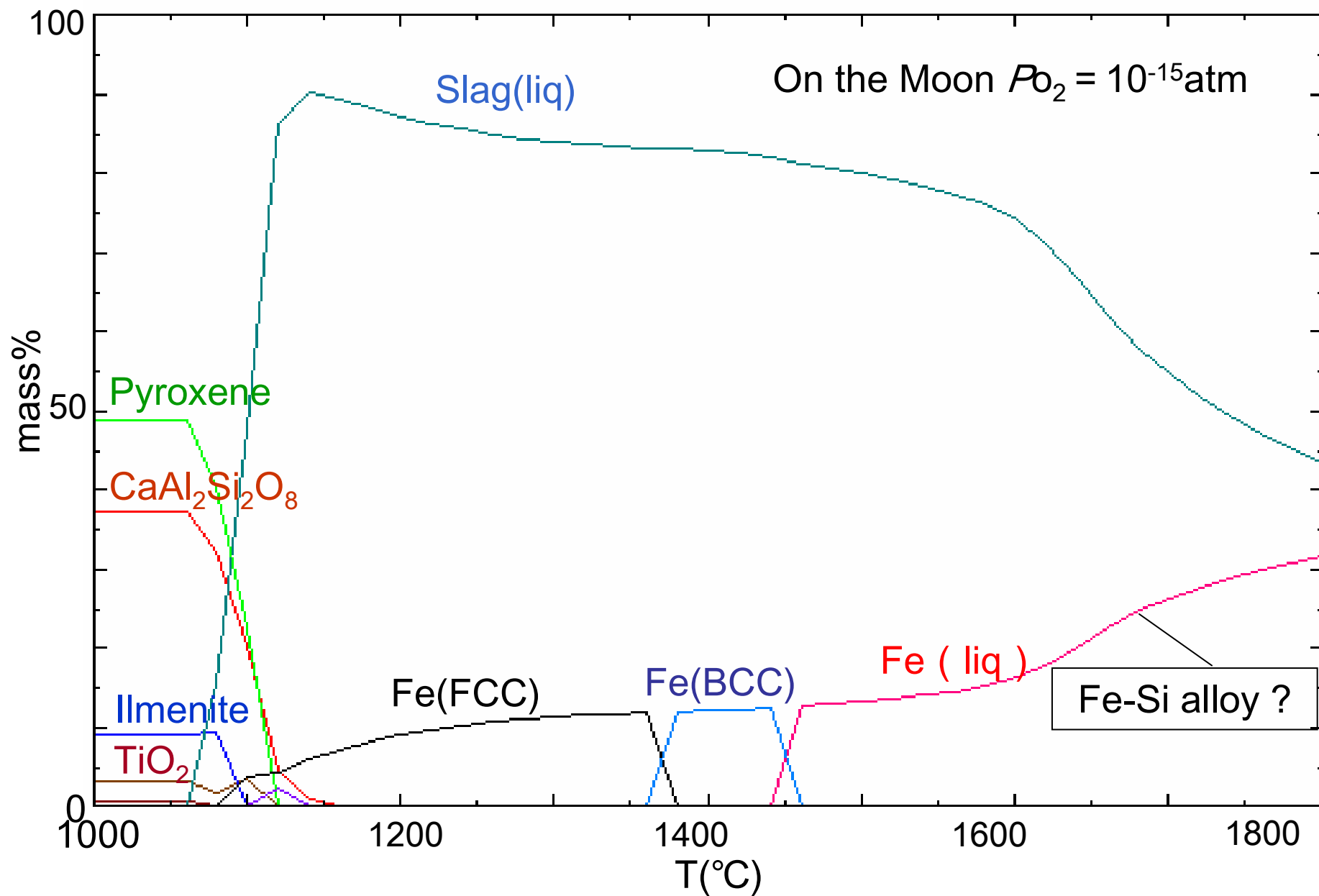


Lunar Soil

(Regolith) mass%
One example :

SiO ₂	42.2
Ti O ₂	7.8
Al ₂ O ₃	13.6
FeO	15.3
MgO	7.8
CaO	11.9
Na ₂ O	0.47

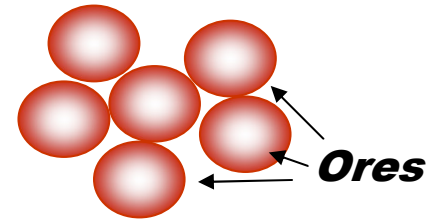
Calc. in FactSage: Reduction of Lunar Soil



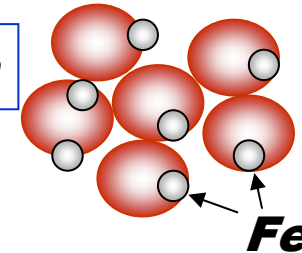
Lunar Soil mass%
(One example)

SiO_2	42.2
TiO_2	7.8
Al_2O_3	13.6
FeO	15.3
MgO	7.8
CaO	11.9
Na_2O	0.47

Ore dressing

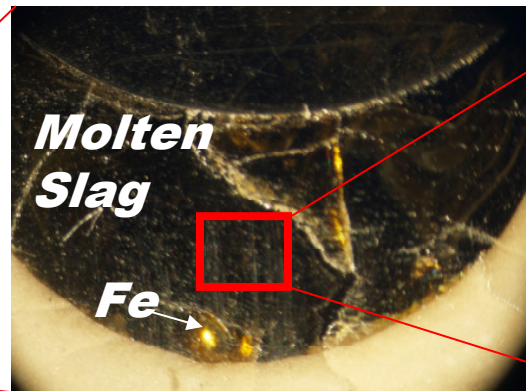
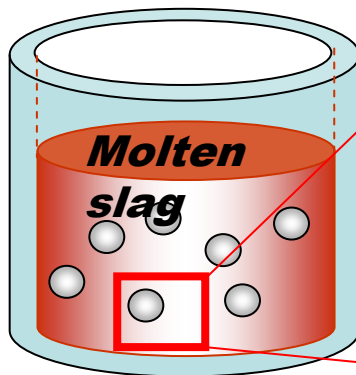


**Reduction of solid iron oxide
by H_2**

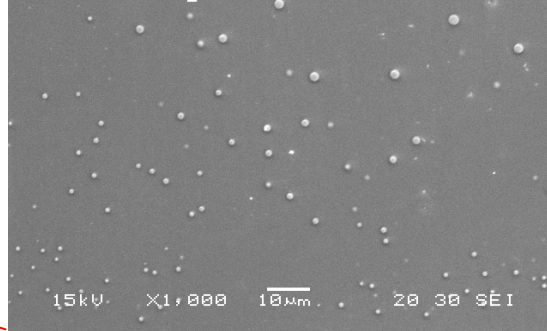


Melting of Slag

Separation of Iron particles from molten slag

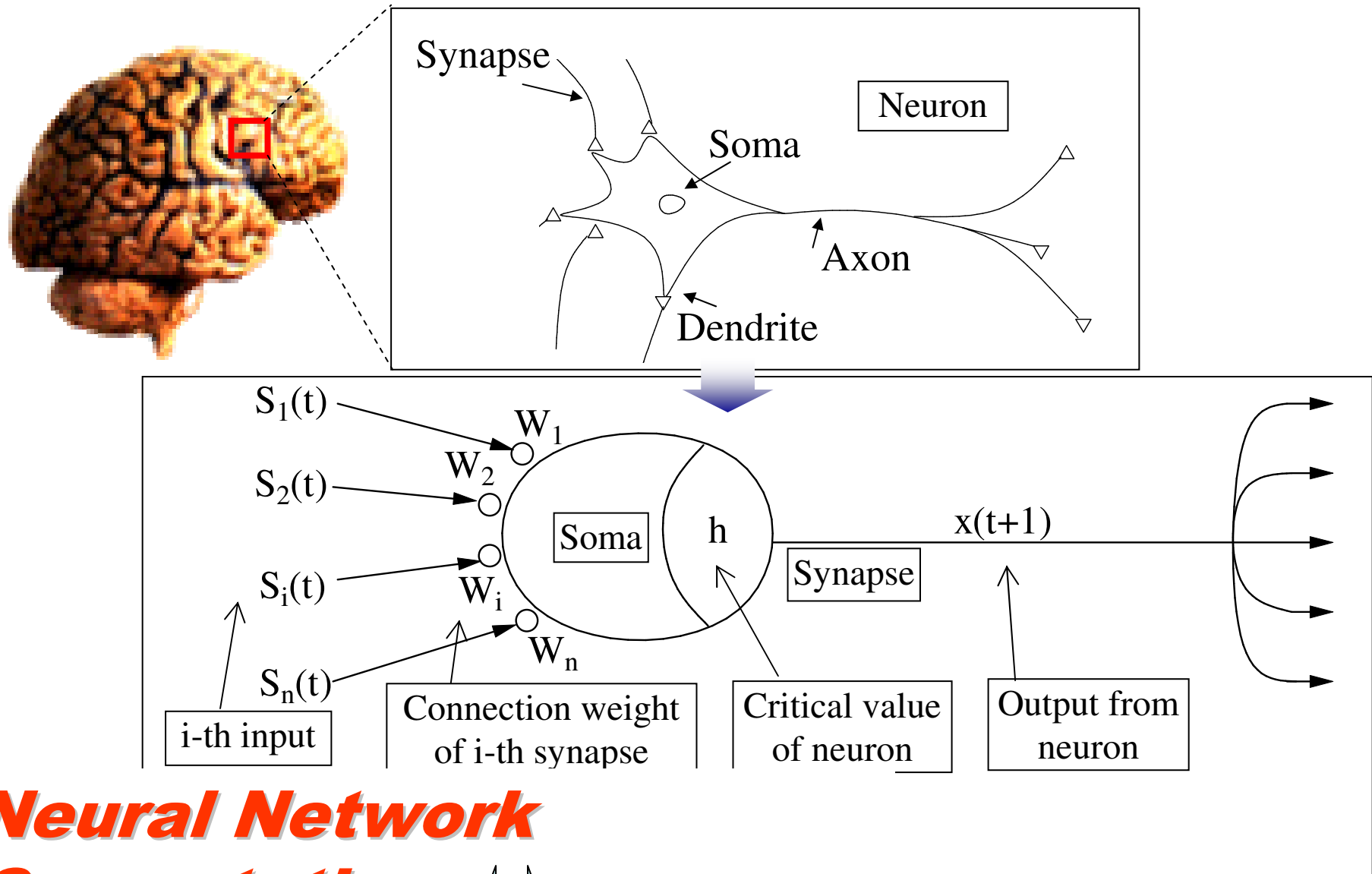


Small particles : Fe



**To separate Fe particles from molten slag,
Viscosity of molten slag is a Key !**

How to evaluate viscosity of molten slag made of Lunar soil ???



***Neural Network
Computation***

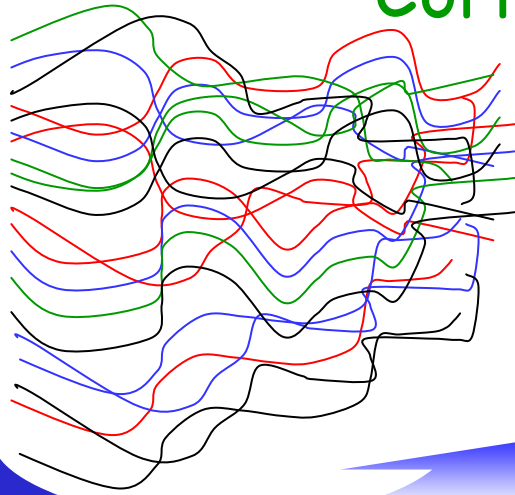


Control Engineering (e.g. Robotics etc.)

Correlation ?!

Input

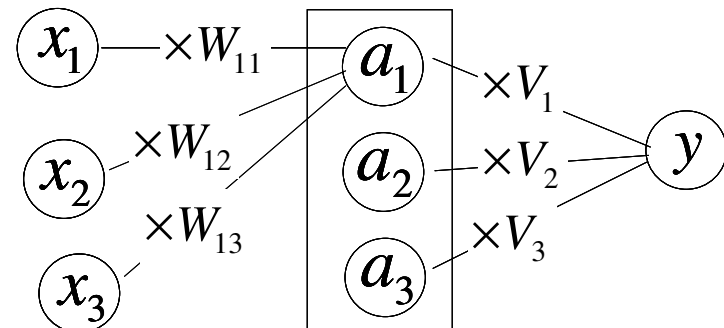
e.g.
Compositions
& Temp.



Output

e.g. Viscosity
of Multi-component
Molten Slag

- **Linear regression ?**
- **Logarithm ?**
- **Exponential ?**



**Neural
Network
Computation**



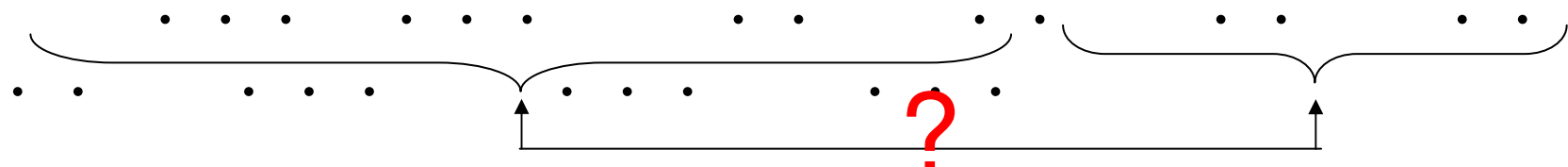
Output $a_k = f\left(\underbrace{\sum_{i=1}^n \overset{\text{Input}}{x_i} \cdot \overset{\text{Parameters}}{W_{ki}} - W_{k0}}\right)$

Fundamental function: $f(x) = \frac{1}{1 + e^{-\eta \cdot x}}$

Recommended Experimental Data on Viscosity with Comp. & Temp. of Molten Slag in Round-Robin Project by Prof. Seetharaman & Dr. Mills etc.

e.g. Molten Flux for Continuous Casting in SteelMaking

	Composition/mass%							Expe. Viscosity/Pa·s		
	SiO ₂	CaO	Al ₂ O ₃	MgO	Na ₂ O	F	T.Fe	1573K	1623K	1673K
A	45.9	39.3	4.3	2.9	1.6	3.7	1.6	0.680	0.517	0.397
B	46.0	39.3	4.1	2.6	1.6	5.1	2.0	0.509	0.352	0.253
C	45.7	38.8	3.9	2.5	1.7	6.3	1.3	0.348	0.256	0.195
D	46.2	39.9	4.1	2.4	1.7	6.0	1.1	0.483	0.340	0.257
E	47.7	38.5	5.0	2.5	1.7	5.1	1.2	0.440	0.327	0.259
F	46.9	40.9	5.0	3.9	1.7	1.9	0.8	0.666	0.392	0.352



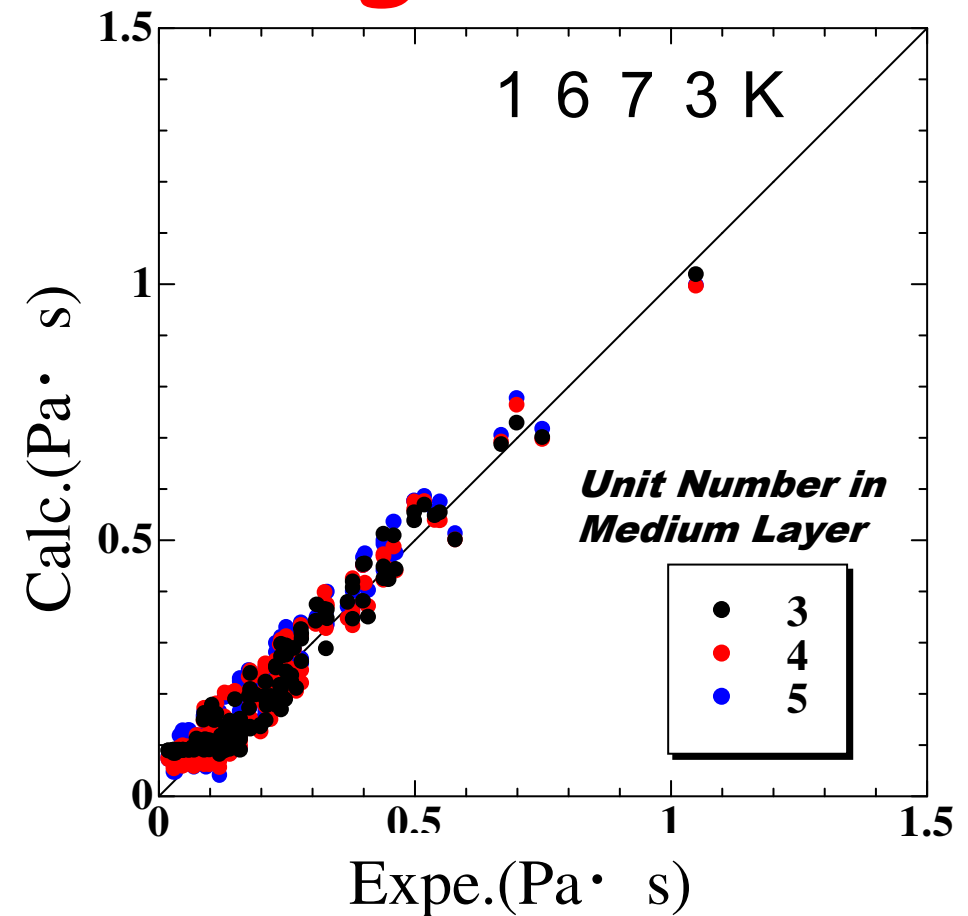
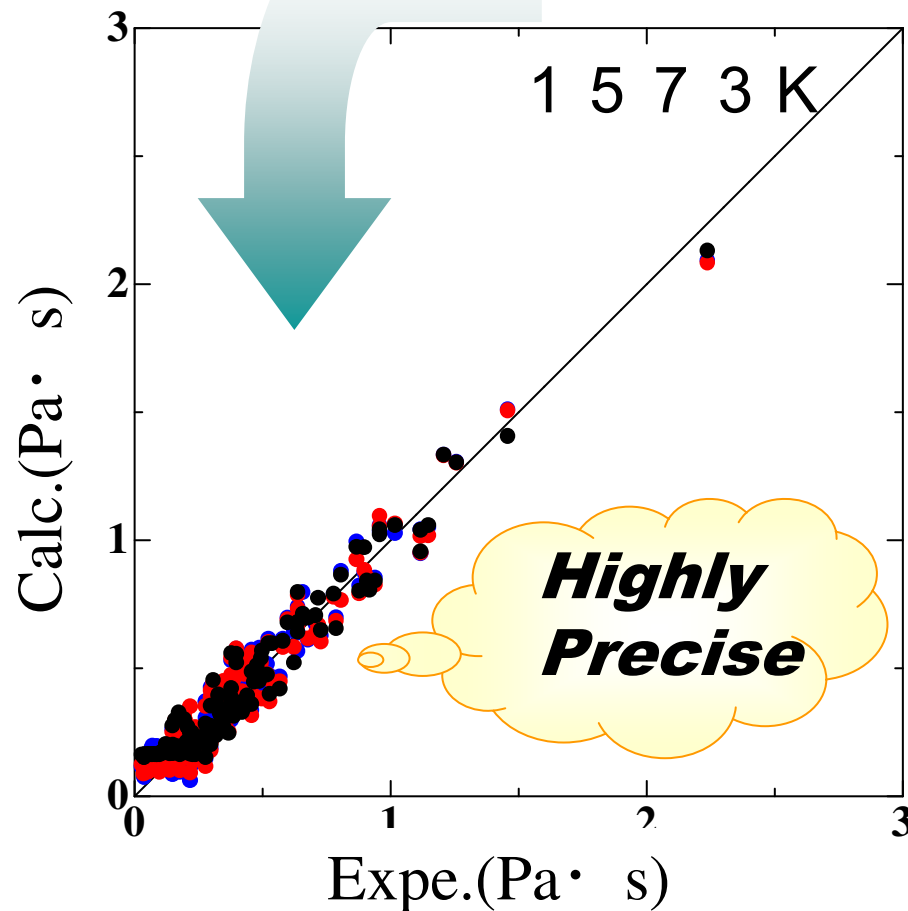
*Correlation of **Viscosity** at each temp. with **Compositions**
in multi-component molten slag?*

Predicting Viscosity of molten $\text{SiO}_2\text{-CaO-Al}_2\text{O}_3\text{-Na}_2\text{O-CaF}_2\text{-}$

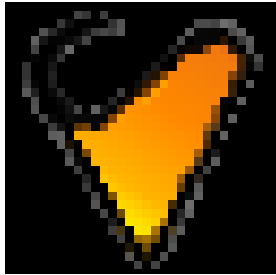
• • •

(14 inputs Systems)

Neural Network Regression



- ★ Correlation of Viscosity with Comp. & Temp. is completed.
- ★ Input of New Comp.& Temp. $\Rightarrow$ Estimation of Viscosity



SlagVis

RCCM
(Research Center of
Computational Mechanics, Inc.)

: An agency of GTT Technologies
in Tokyo/Japan

SlagVis

Open(O) Mold Flux(M) Clear(C) NeuOpt(N) Help(H) Exit(X)

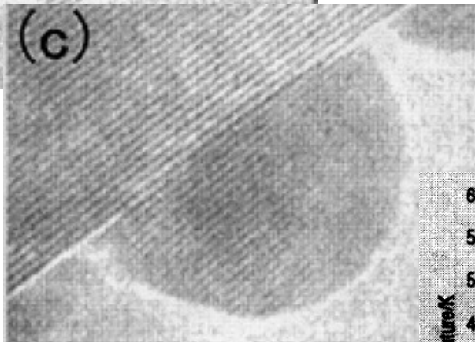
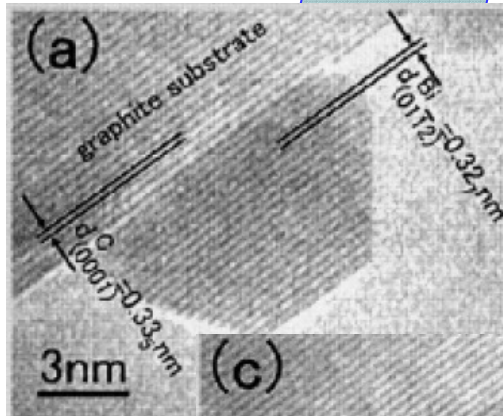
Estimate 0.211 [Pa-s] Unit of Temperature: [C]

	[wt%]		[wt%]
SiO2	40.5	K2O	0.77
Al2O3	5.53	MnO	0.04
CaO	20.39	P2O5	0
CaF2	14.07	TiO2	0.21
Na2O	15.5	Temperature	1300
MgO	1.24		
Fe2O3	1.8		
FeO	0		
B2O3	0		
Li2O	0		

Network File Name: -- Mold Flux --

Summary

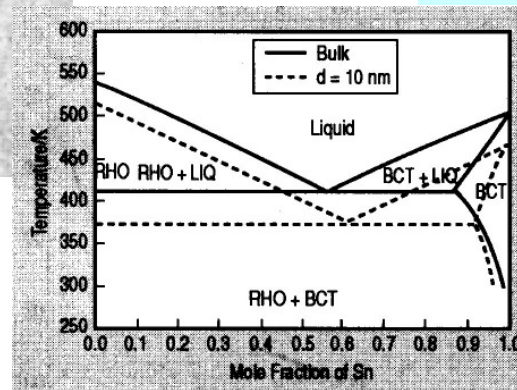
Target : From Nano to the Universe



Lunar Metallurgy



Nano-particle phase diagrams



ChemApp

FactSage

with Thermodynamic Databases.

by GTT Technologies

SlagVis