

Phenomenology of Nano-Particle/Gas-Loading Experiments

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Outline of This Work

[Part-I] Brief Summary of the Kobe Group Experiments

- Anomalous data for D(H) absorption and heat-evolution by nano-Pd/ZrO₂ and Pd-Ni/ZrO₂ dispersed samples
- Recovery of Loading Ratio and Heat-level by Forced Oxidization (MO) and deoxidization of Used Samples
- Role of PdO surface coating of Pd nano-particle and Pd ad-atoms on binary nano-particle (Pd-Ni); what happens under D(H) charging

[Part-II] Modeling Anomalies

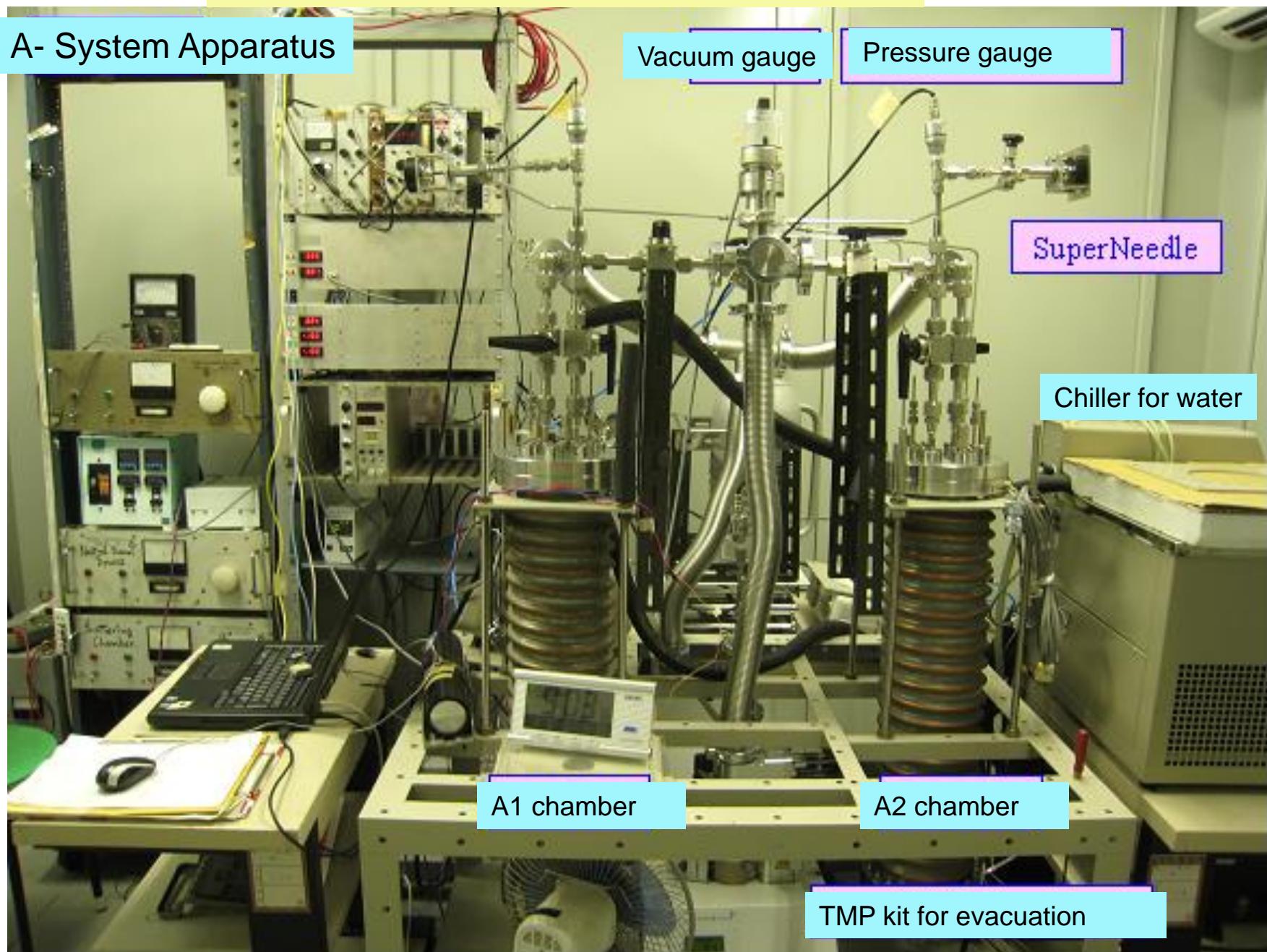
- Phenomenological Model for anomalous “chemical + nuclear” heat evolution
- Anomalous Chemical Heat by “Mesoscopic Catalyst”
- Link to D-cluster formation and 4D/TSC fusion

Anomalies observed by nano-Pd/ZrO₂ and Pd-Ni/ZrO₂

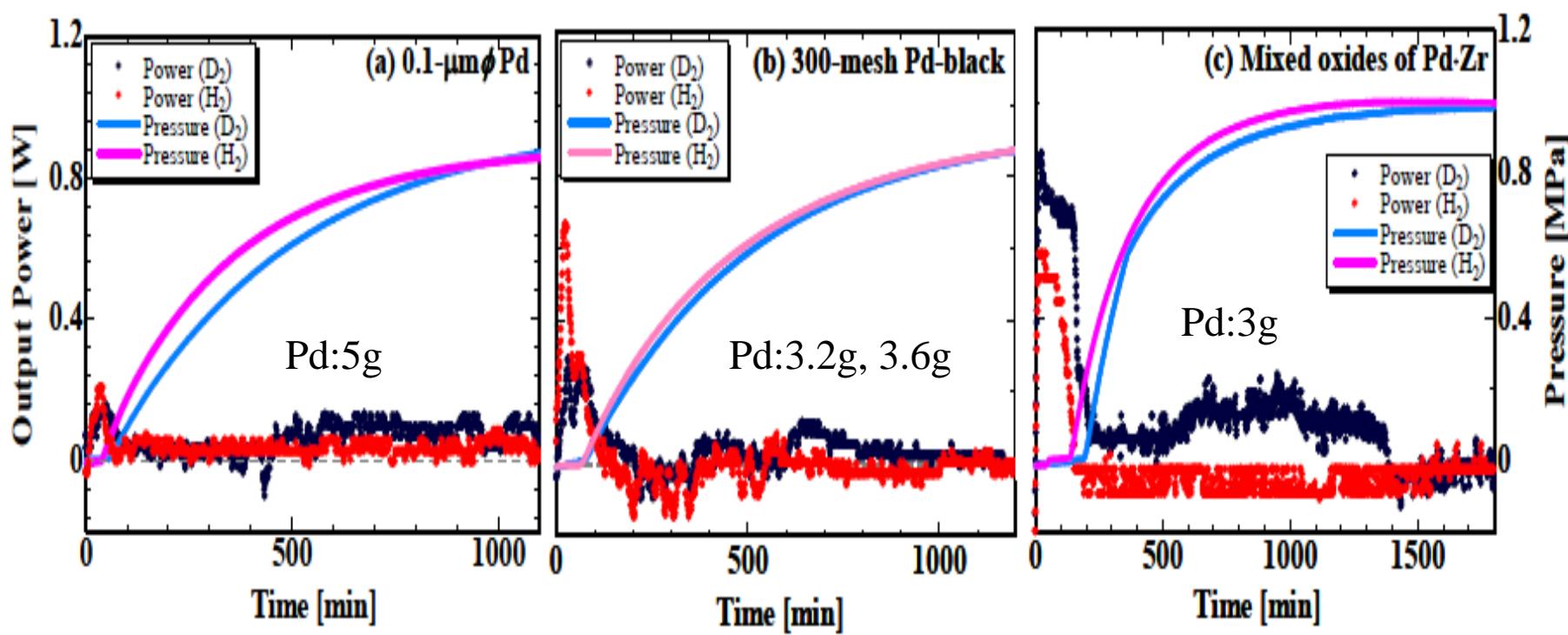
- Rapid over-loading ($D(H)/M \gg 1.0$) at near “zero” D(H)-gas pressure
- Large adsorption/absorption energy per D(H) and per M; 0.6 to 2.0 eV per D(H) and 1.2-2.5eV per M, c.f. 0.3eV for bulk metal; for the Phase-I
- Large gains:
 $(\text{Sorption Energy})/(\text{De-sorption Energy}) > 3 \text{ to } 30$
- Large and rapid heat evolution for D-gas loading in the beginning, c.f. slow and low heat for H-gas loading (Nuclear heat component?); anomalous dynamics of η -values
- Significant recovery of heat level and loading ratio by slight oxidization (PdO coating) of used samples
- Very large loading ratio ($x > 3$) and large heat release for PNZ (Pd₁Ni₇) sample at room temperature
- Continuous Excess Heat for D-gas in the Phase-II

Room Temperature is controlled to $22\text{-}25^{\circ}\pm0.1^{\circ}\text{C}$

A- System Apparatus



Comparison of heat-power evolutions for 100nm Pd,
Pd-black and 10nmPd/PdO/ZrO₂ samples:
Blue by D-charge cf. Red by H-charge



a) Bulk Character

b) Near-Nano
Character

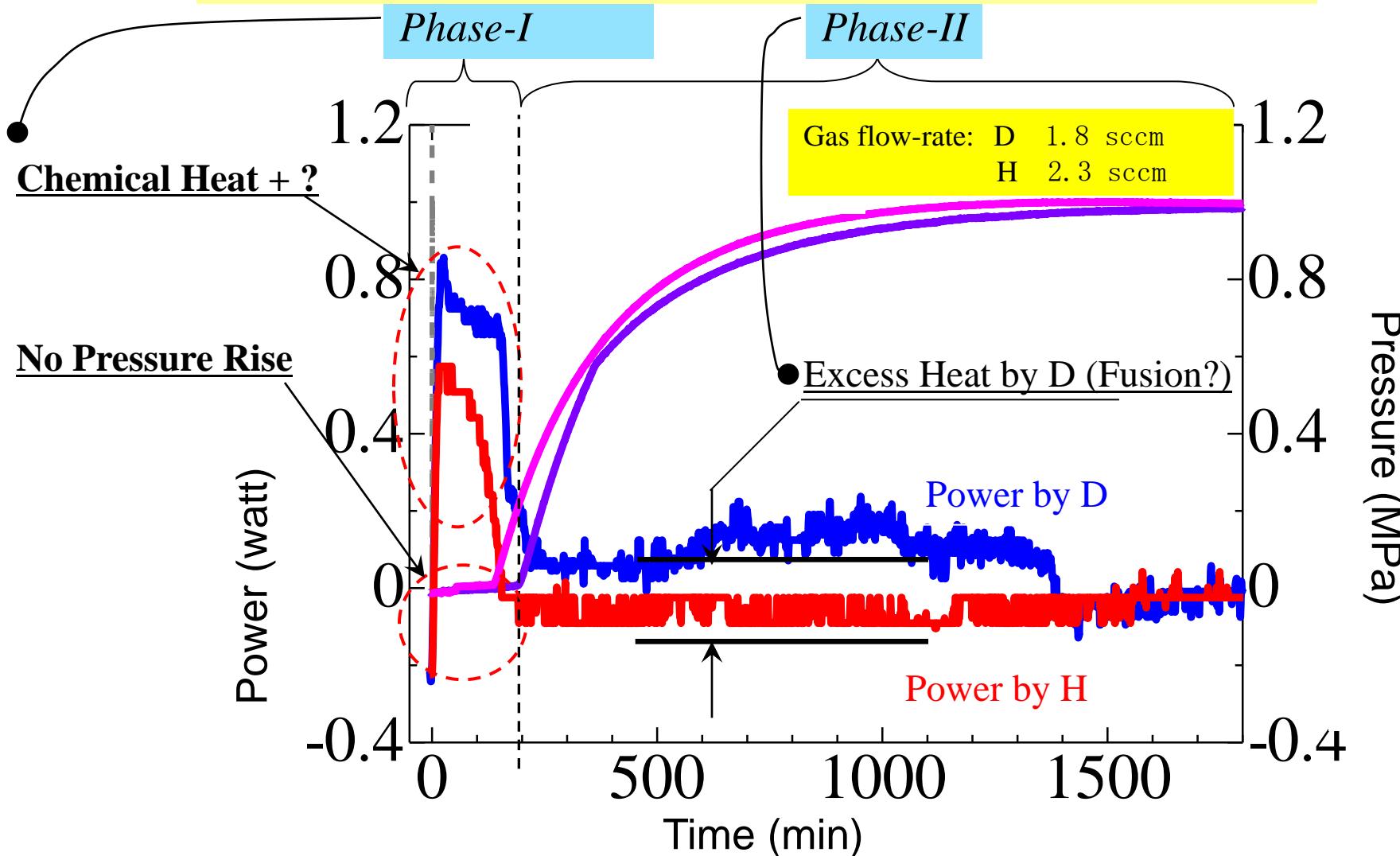
c) Mesoscopic
Character

Typical Data for Anomalous Heat Evolution by Nano-Pd/ZrO₂ Samples

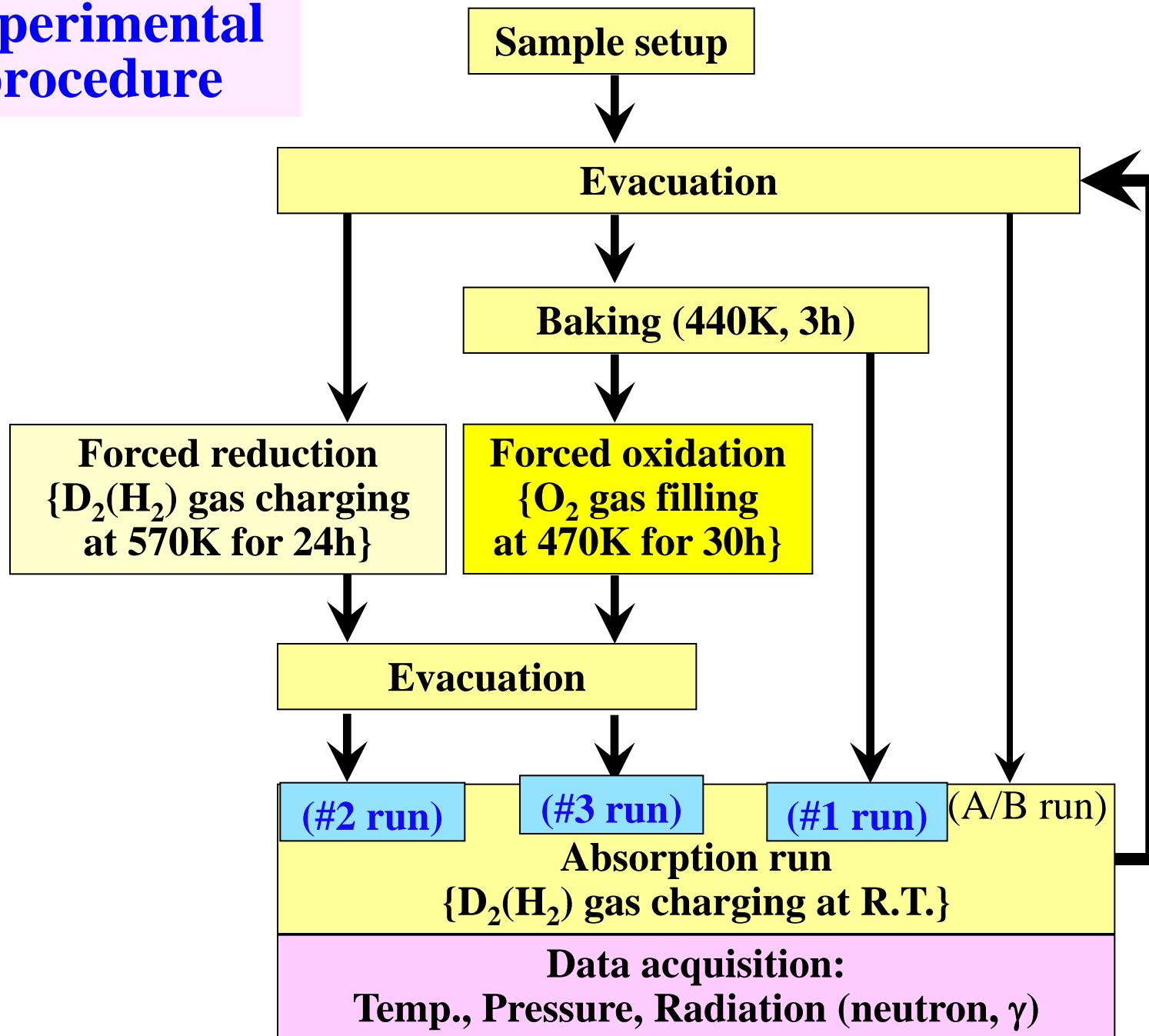
Heat Evolution appeared in Two Phases:

Phase-I: Heat by **Chemical** (+ some “**Nuclear**”: 10-50%) Process,

Phase-II: Some “**Nuclear**” Heat after PdD(H)x Formation ($x > 1.0$)



Experimental procedure



Tested Metal/Ceramics Powders and Results

	Pd	Ni	Zr	O	Supplier	Anomalies observed?
100nm ϕ -Pd PP	995%, 100nm ϕ	---	---	---	Nilaco Corp.	[1],[2] No, bulk metal data, but PdO
Pd-black PB	99.9%, 300mesh	---	---	---	Nilaco Corp.	[1],[2] Yes, a little large heat & D/Pd
8-10nm ϕ -Pd PZ	0.346	---	0.654	(1.64)	Santoku Corp.	[1],[2],[3], discussed Yes, Heat and D/Pd reproducible
mixed oxide NZ	---	0.358	0.642	(1.64)	Santoku Corp.	[2] No heat and loading
mixed oxide PNZ	<u>0.105</u>	0.253	0.642	(1.64)	Santoku Corp.	[2] Yes, but weak
2nm ϕ -PdNi PNZ2B	<u>0.04</u>	0.29	0.67	(1.67)	Dr. B. Ahern	Yes, very large heat and D(H)/M, reproducible

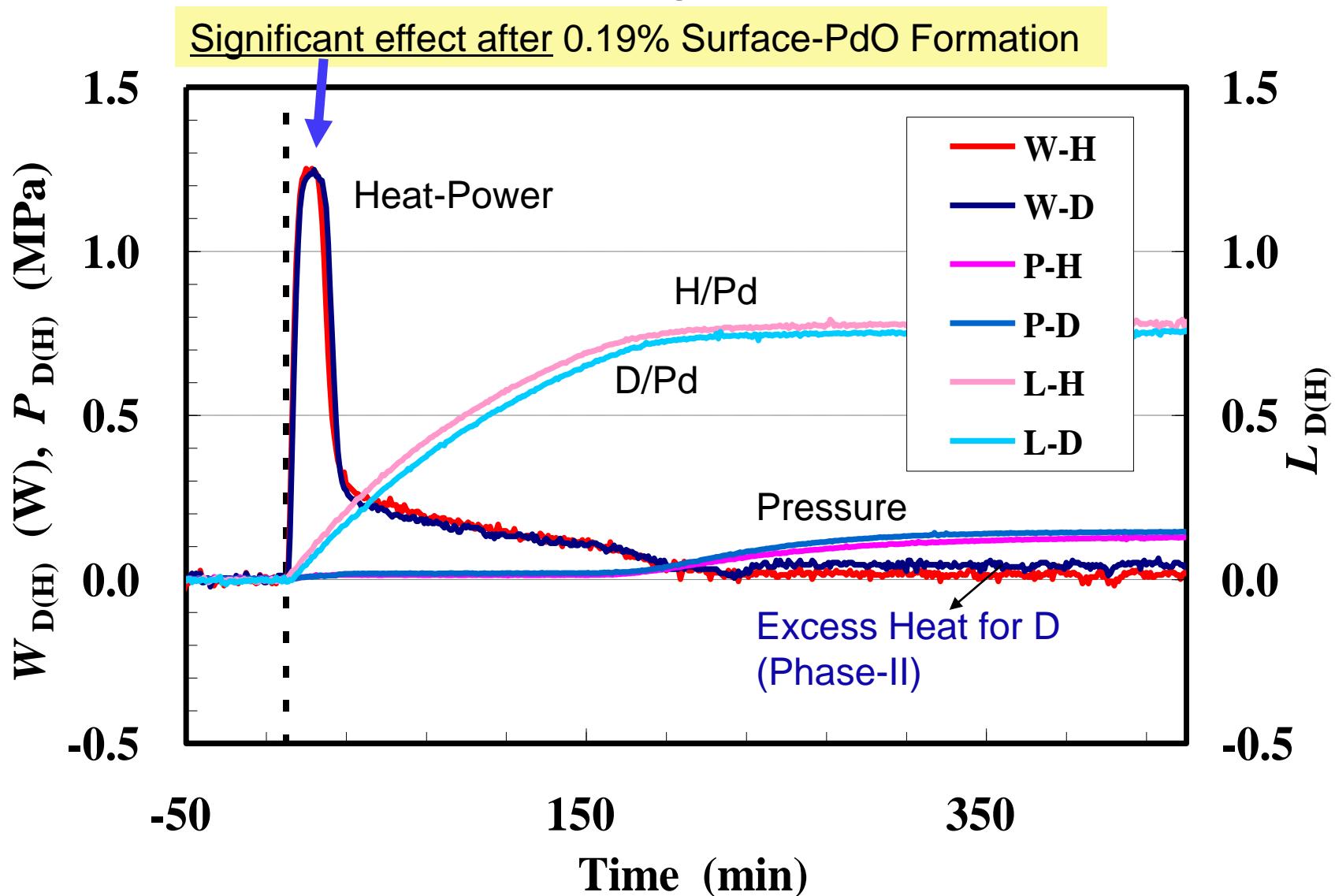
[1] Phys. Lett. A, 373 (2009) 3109-3112.

Drastic change happens! **Why?**

[2] **Low Energy Nuclear Reactions**, (AIP Conf. Proc. 1273, ed. Jan Marwan, 2010).

[3] **LENR Source Book 3**, (ed. Jan Marwan, ACS) to be published.

100nm diameter Pd (9.2g): PP3,4#3: Raw Data



Introduction of New Physical Quantity

Definition of $\eta(t)$: **Binding-E + Alpha**:

Time-Dependent Sorption Energy per D(H)-atom

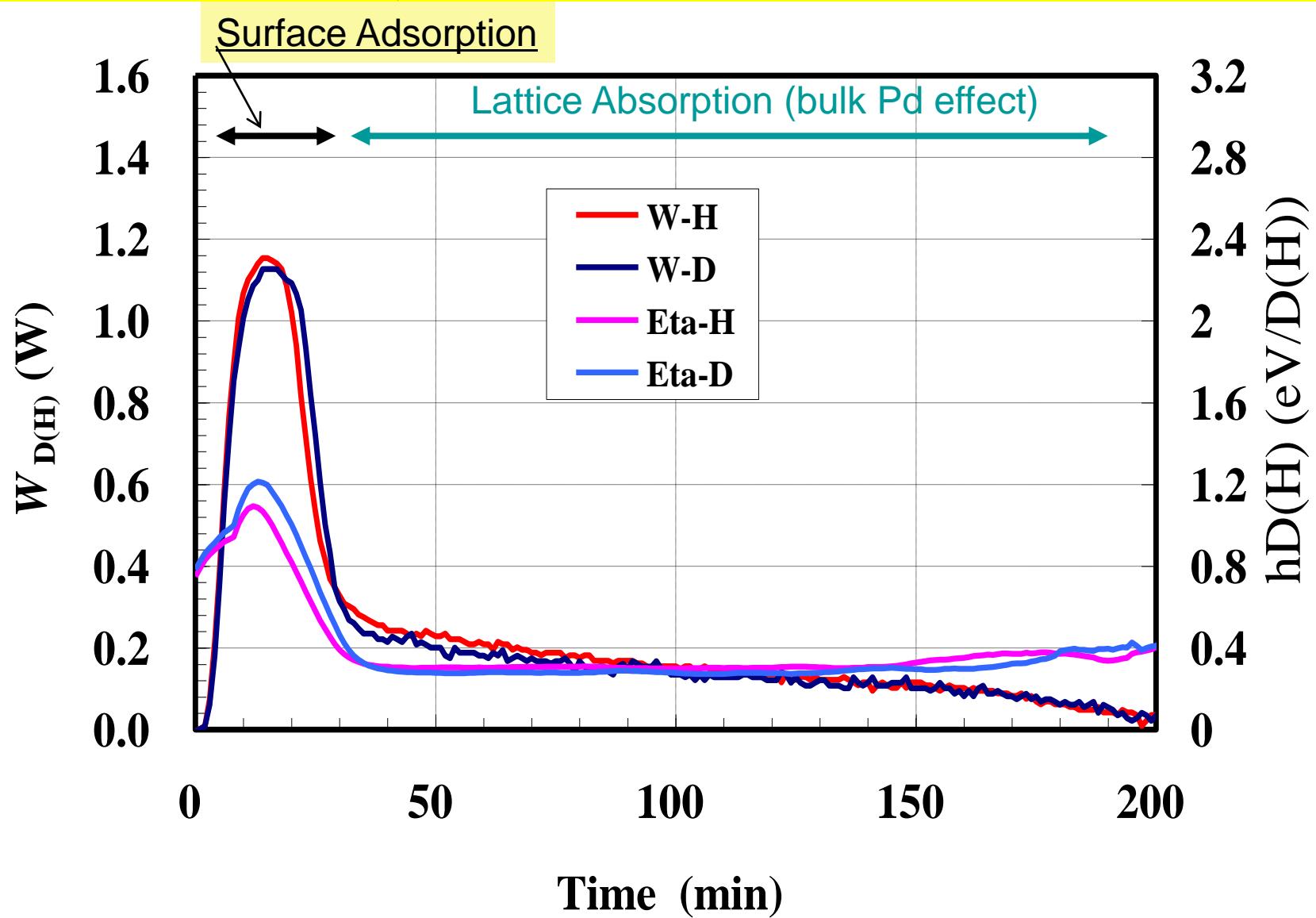
- $L(t)$: Evolution of Loading Rate (Convertible to D(H)/M)
- $W(t)$: Heat-Power Level in watt
- $E(t)$: Evolution of Released Heat

τ : Time Resolution of Calorimetry (5.2 min in Kobe Exp.)

$$E(t) = \int_0^t W(t) dt$$

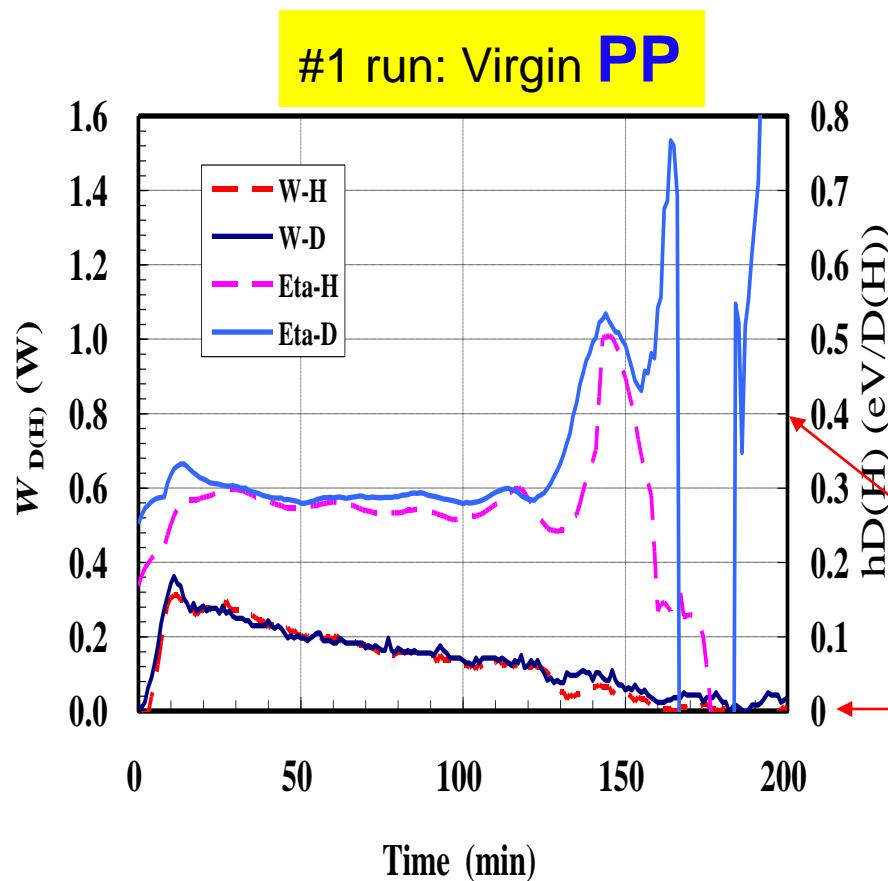
$$\begin{aligned}\eta(t) &= \frac{\overline{(dE/dt)}}{\overline{(dL/dt)}} = \left(\int_t^{t+\tau} \frac{dE}{dt} dt / \tau \right) / \left(\int_t^{t+\tau} \frac{dL}{dt} dt / \tau \right) = \int_t^{t+\tau} dE / \int_t^{t+\tau} dL \\ &= \frac{\Delta E(t, t + \tau)}{\Delta L(t, t + \tau)} = \frac{E(t + \tau) - E(t)}{L(t + \tau) - L(t)}\end{aligned}$$

Slight PdO layer on Pd Particle (100nm diam.) induces Strong Adsorption!
PP3,4#3: Heat and Eta values



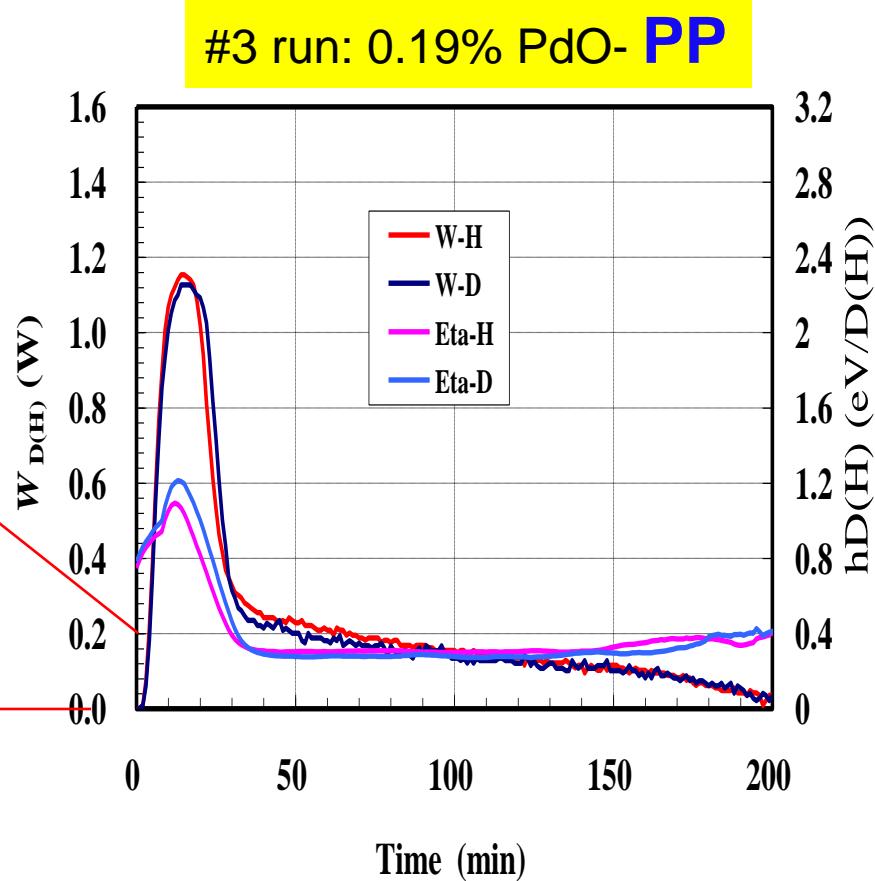
a) Bulk Pd Character

0.3eV per D(H)-sorption
: const. for #1 run of PP

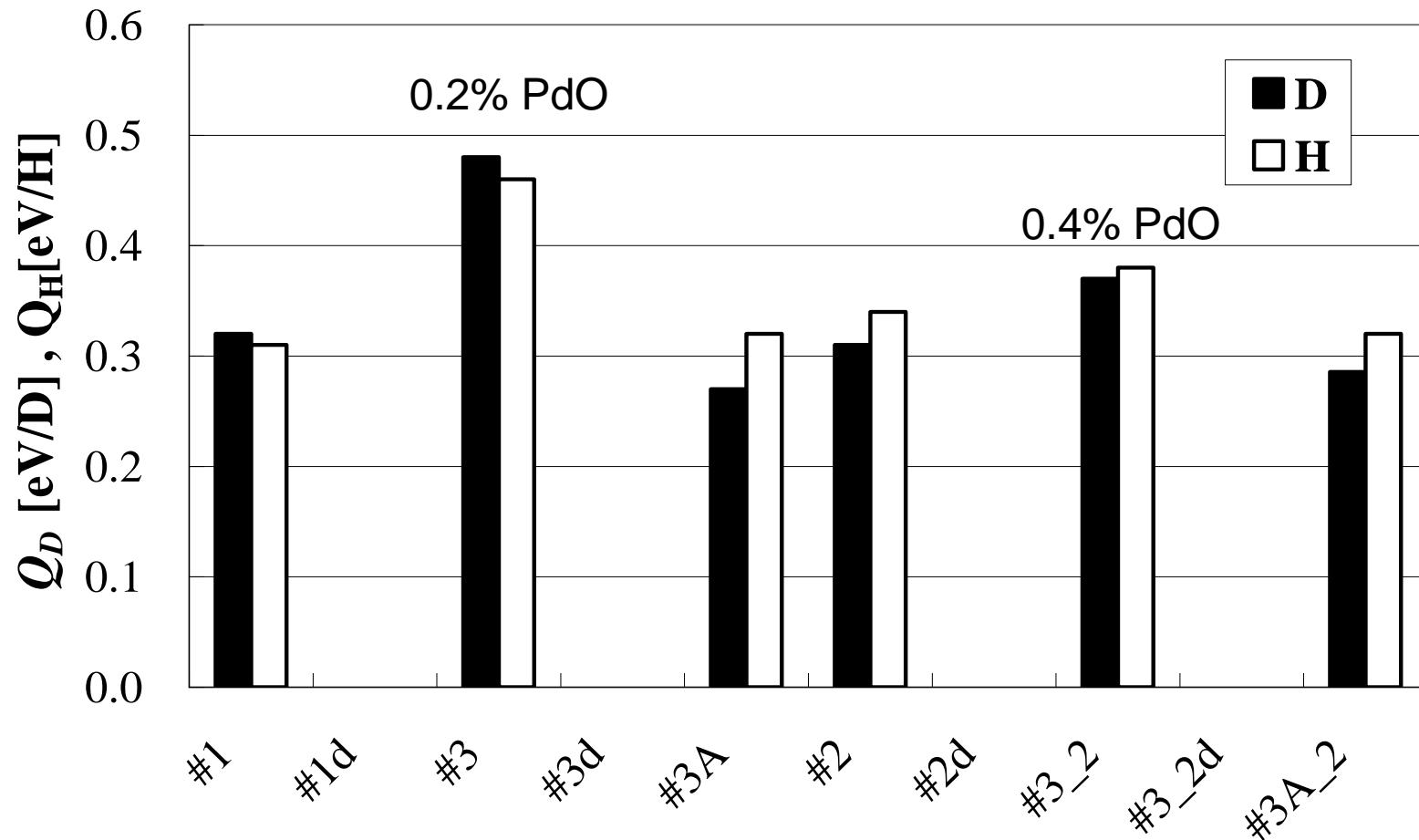


b) Nano-Catalysis on Surface of Bulk Pd

1.2eV per D(H)-sorption
: bump for #3 run of PP



Mean Energy per D(H)-Sorption: **PP3,4**
100nm Φ Pd-Powder (Bulk Character): 0.3eV

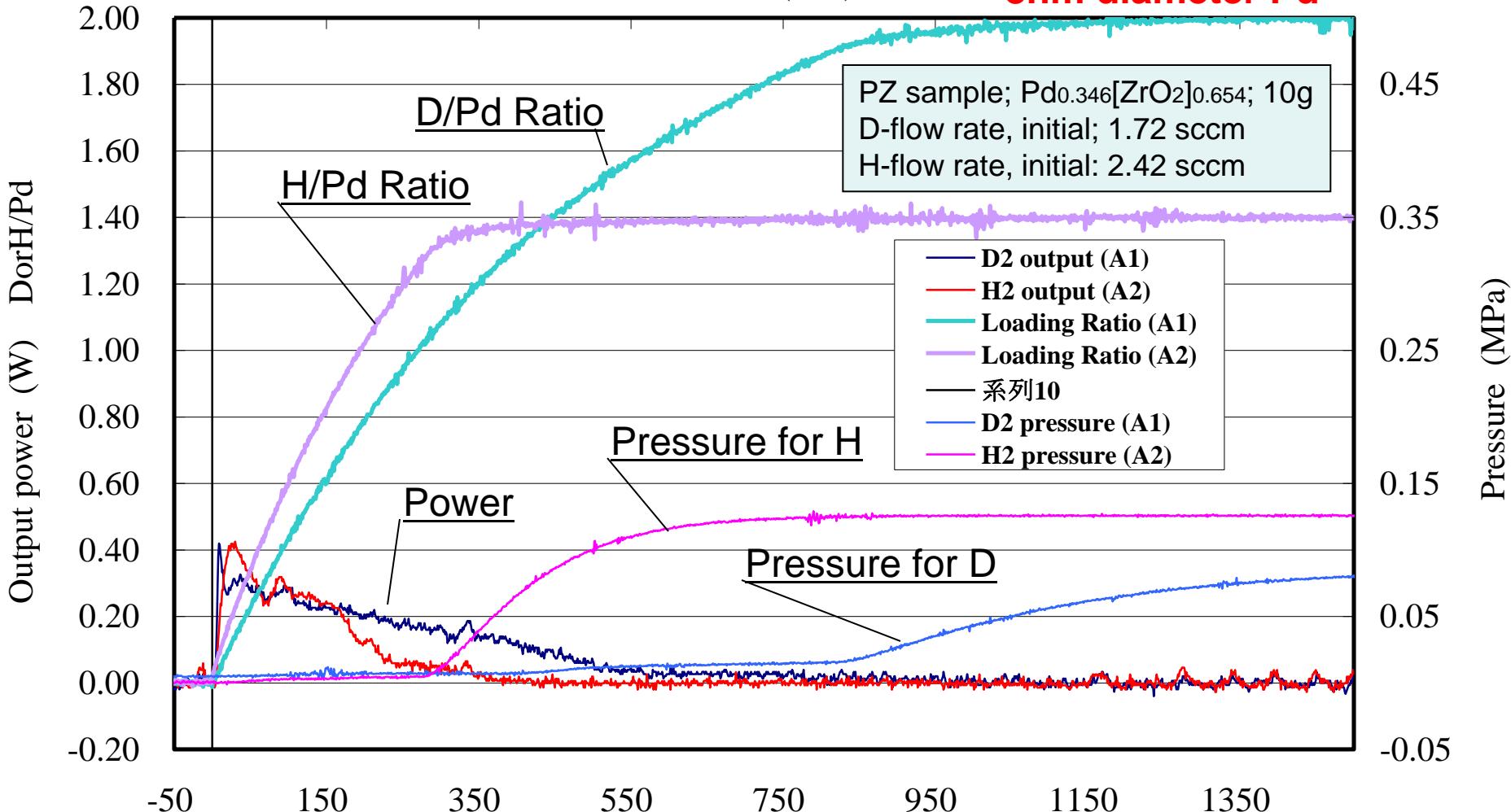


Recovery of D(H)/M ratio and Heat-Power level by **forced oxidation**.

D-PZ11#3 vs. H-PZ12#3 ; After Forced Oxidization (8-5% PdO)

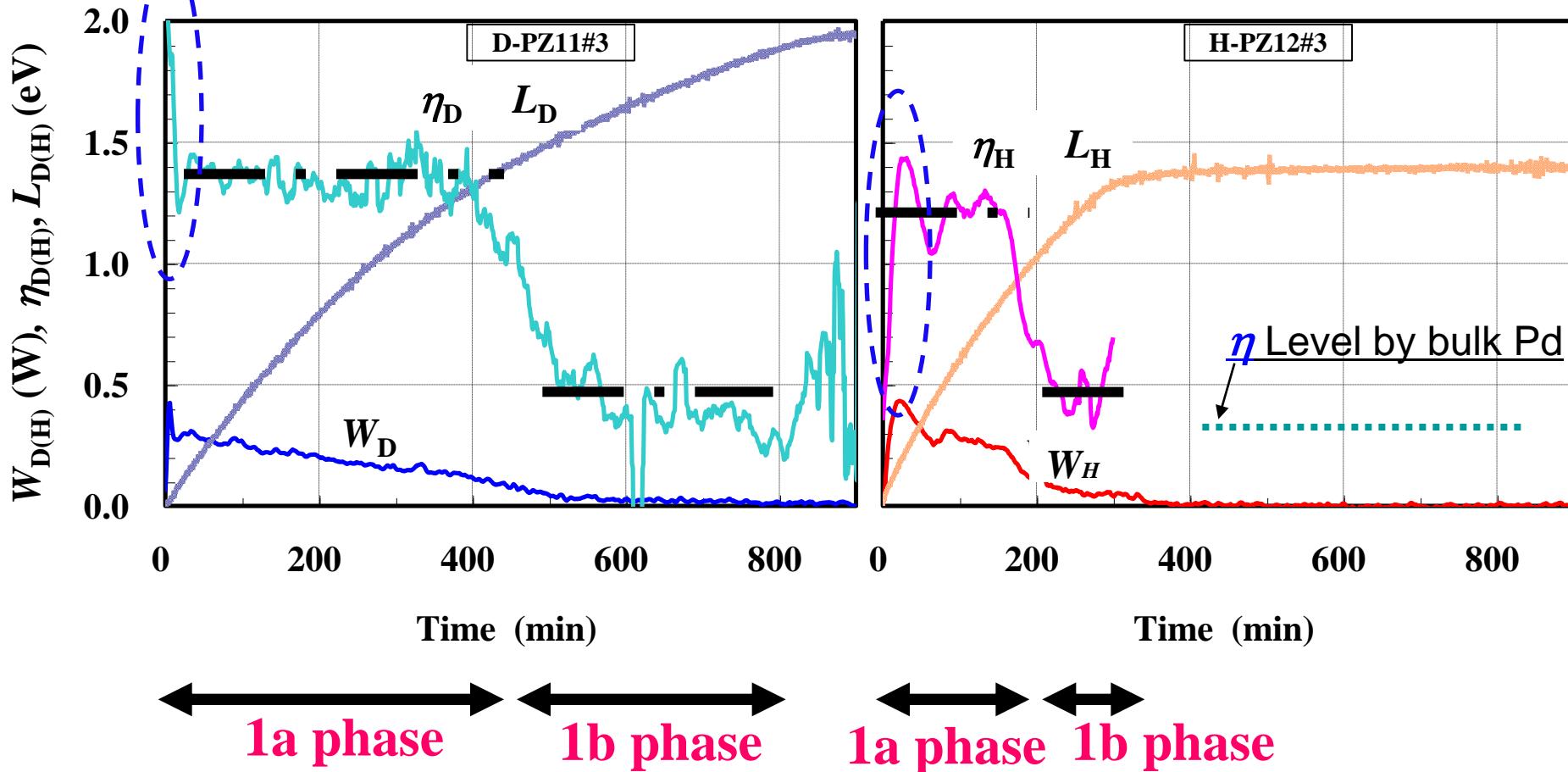
Time (min)

8nm diameter Pd



At the beginning, large heat-power appears for D-charging only!

Two components appear in Phase-I, by PdO effect?

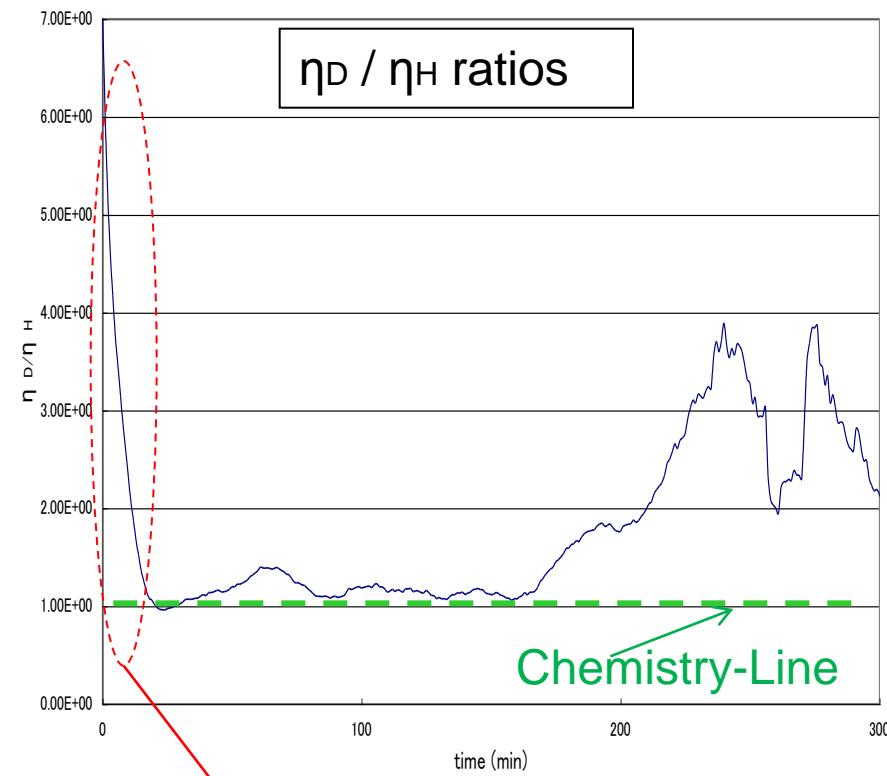


Typical variation of the specific sorption energy, η_D (η_H), compared with the power, W_D (W_H), and pressure, P_D (P_H), in the #3 run for the PZ11(12) sample: 8nm diam. Pd.

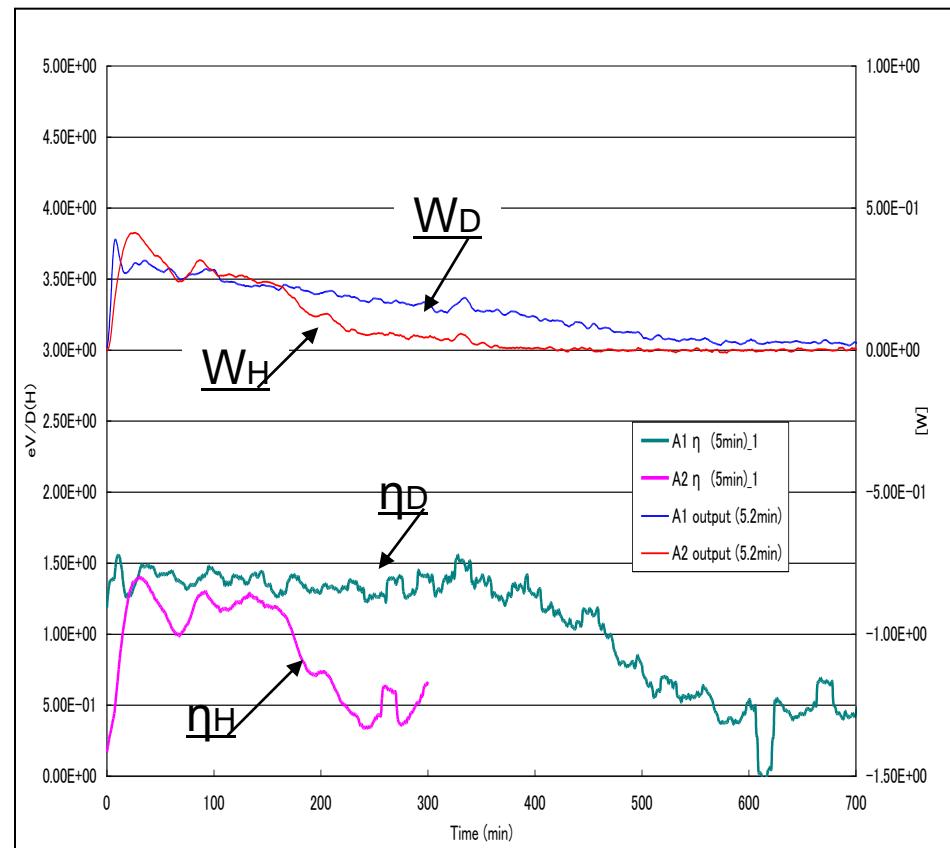
D-vs.-H Isotopic Effect for heat evolution (W), energy per D(H) sorption = η ,
 η_D / η_H ratios

:D-PZ11#3 vs. H-PZ12#3: after forced oxidization (5-8% PdO) for used **PZ** sample

8nm diameter Pd with PdO Surface Layer

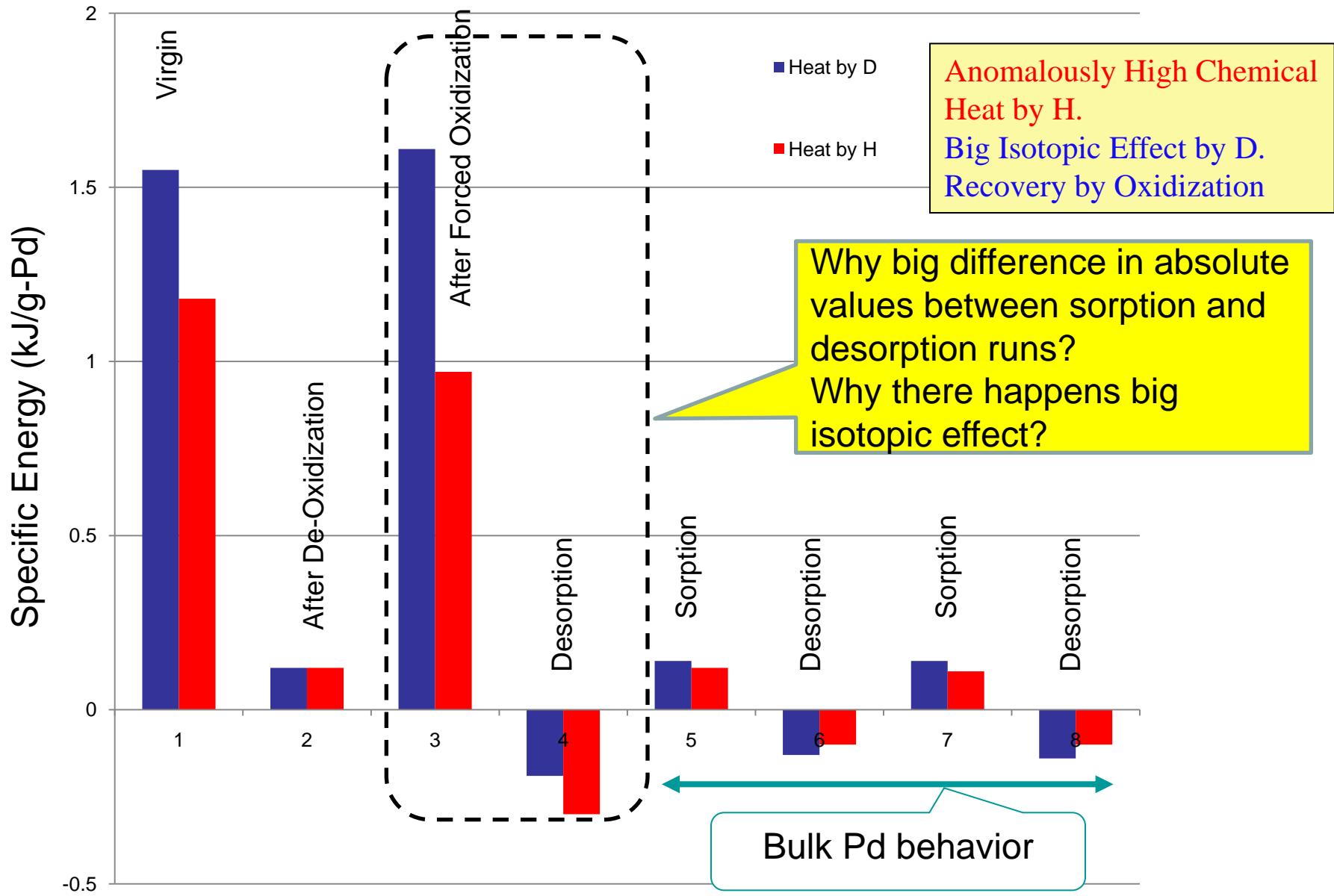


For η_D / η_H ratios $>> 1.0$,
Nuclear Effect!(?)



Integrated Heat Data (Phase-I) for PZ11 and PZ12

8nm diameter Pd



	D-PZ11		vs.	H-PZ12		
Run #	D-Sorption Energy	D-De-Sorption Energy	Gain for D	H-Sorption Energy	H-De-Sorption Energy	Gain for H
	(kJ/g-Pd)	(kJ/g-Pd)		(kJ/g-Pd)	(kJ/g-Pd)	
1 Virgin	1.55			1.18		Why so? There remain many D(H)s in nano-particle, still after desorption?
2 De-Ox.	0.12			0.12		
3 F-Ox. (8-5 %)	1.61	-0.19	<u>8.5</u>	0.97	-0.30	3.2
4-1 No-baking	0.14	-0.13	1.1	0.12	-0.10	1.2
4-2 No-baking	0.14	-0.14	1.0	0.11	-0.10	1.1

PNZ(10%Pd): heat and loading are proportional to Pd amount. NZ: No effect

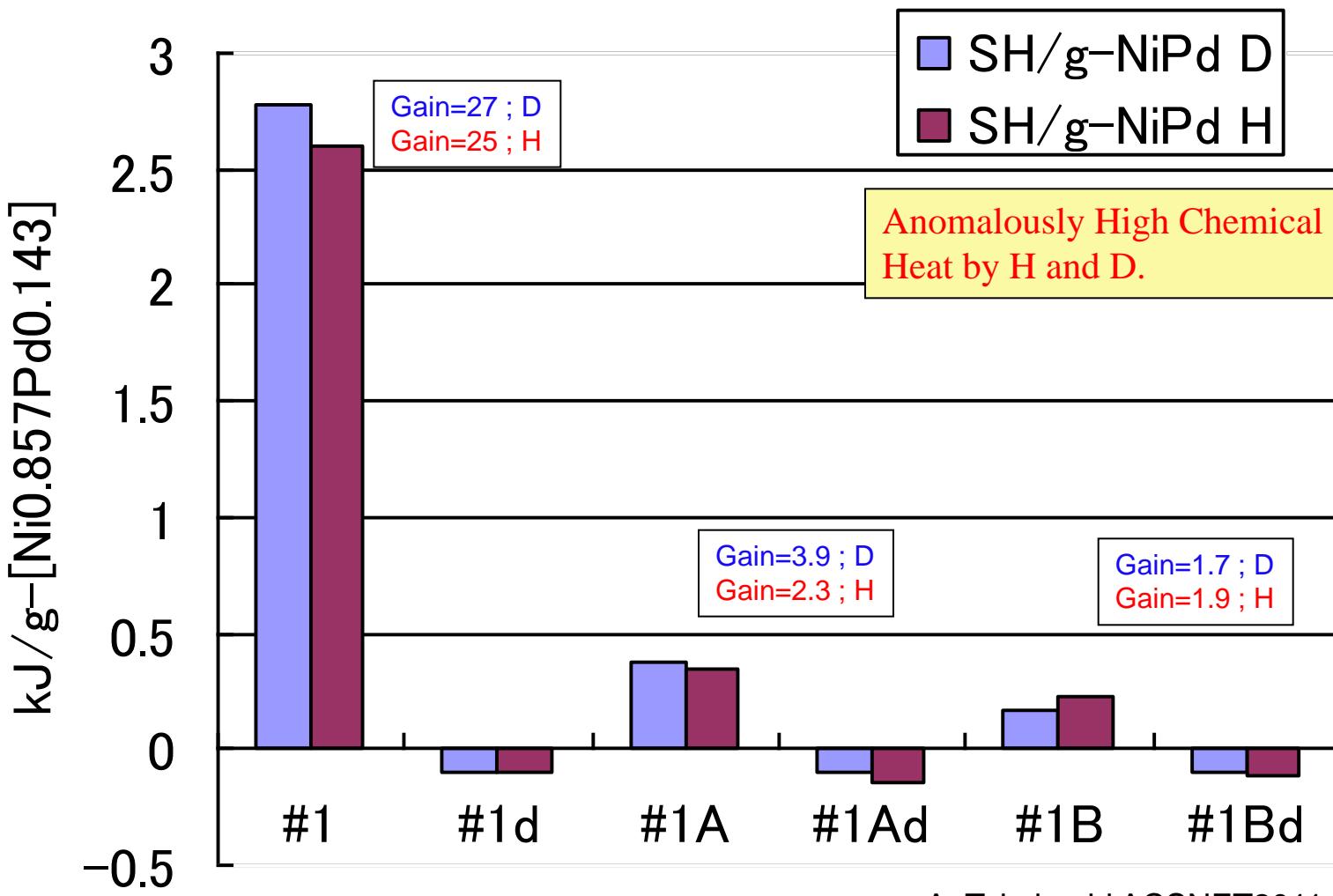
Run	1st phase						2nd phase	Remarks $Q_D (Q_H)$ assumed to calcu- late x
	Flow rate [sec m]	Specific output energy E_1 [kJ/g- Pd]	D/Pd or H/Pd (=y)	$E_{1\text{st}}$ per D/H atom [eV]	O/Pd (=x)	Q_D or Q_H [eV/D(H)]		
D-PNZ1#1	5.57	1.74±0.03	0.94 (m)	2.05 (m)	0.156 (c)	1.77 (a)	1.01±0.45	
H-PNZ2#1	11.12	1.86±0.03	0.94 (m)	2.19 (m)	0.262 (c)	1.73 (a)	0.10±0.45	
D-PNZ1#2	5.37	0.12±0.03	0.10 (m)	1.28 (m)	-0.029 (c)	1.77 (a)	5.78±3.18	
H-PNZ2#2	11.37	0.14±0.03	0.11 (m)	1.44 (m)	-0.019 (c)	1.73 (a)	2.18±3.18	
D-PNZ1#3	5.21	0.73±0.02	0.39 (m)	2.09 (m)	0.044 (m)	1.89 (c)	0.91±0.72	
H-PNZ2#3	11.14	0.75±0.02	0.41 (m)	2.01 (m)	0.032 (m)	1.89 (c)	-0.66±0.72	
D-PNZ1#4	5.43	0.84±0.03	0.50 (m)	1.85 (m)	0.063 (m)	1.64 (c)	-0.31±1.83	
H-PNZ2#4	12.01	0.87±0.02	0.56 (m)	1.72 (m)	0.047 (m)	1.58 (c)	-0.03±1.85	
D-NZ1#2	7.01	0.0 (Ni)	0.0 (/Ni)	---	---	---	0.0 (/Ni)	No Effect
H-NZ2#2	13.05	0.0 (Ni)	0.0 (/Ni)	---	---	---	0.0 (/Ni)	No Effect

Ni only makes very small D(H) loading and negligible heat.

PNZ2B: Ca. 2nm diameter Pd-Ni Particle

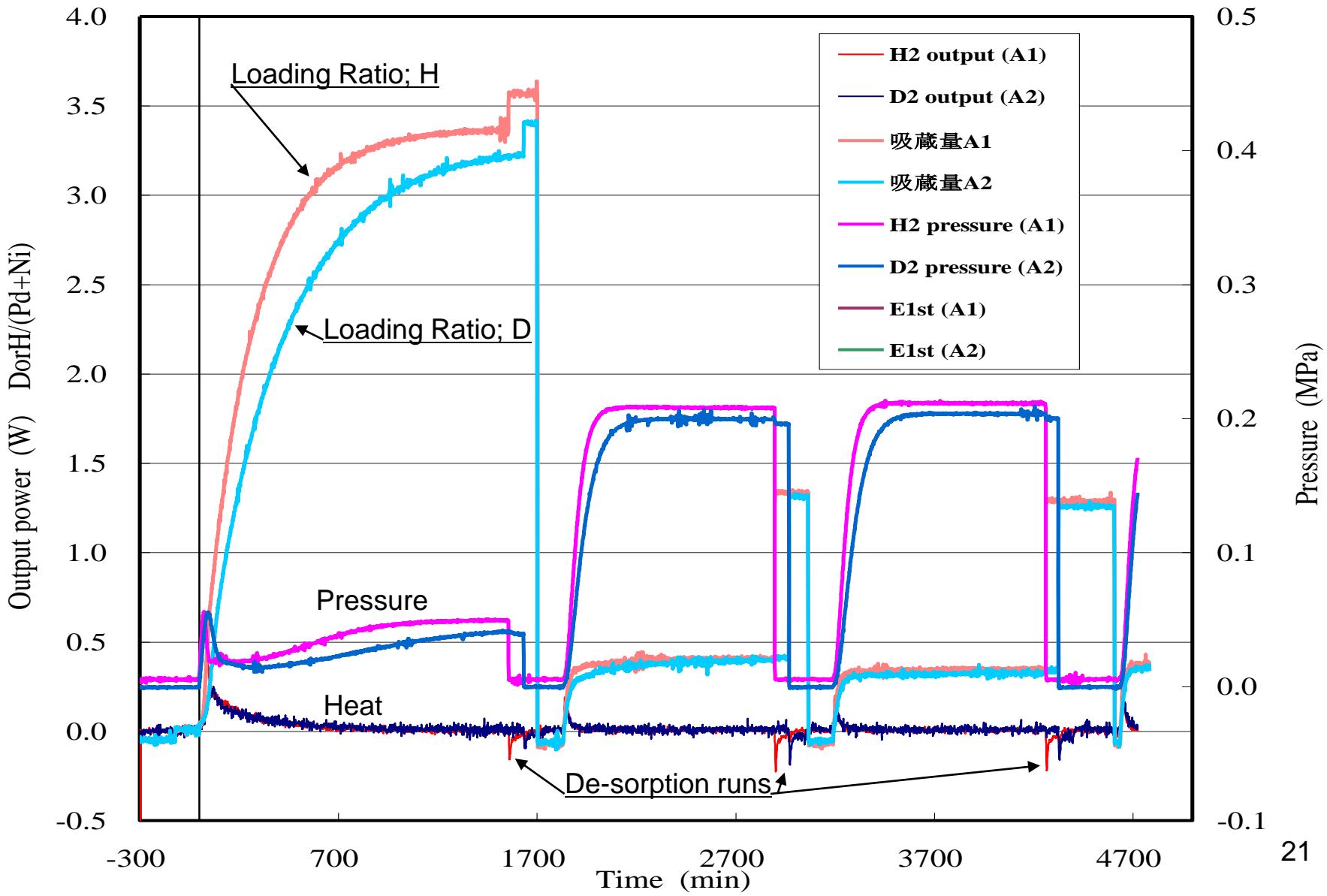
Binary-Alloy Nano-sample: Pd_{0.04}Ni_{0.24}Zr_{0.72}O₂ Sample by Brian Ahern

PNZ2B 1st Phase Heat Data



PNZ2B1,2#1; Virgin; loading ratio, pressure, heat

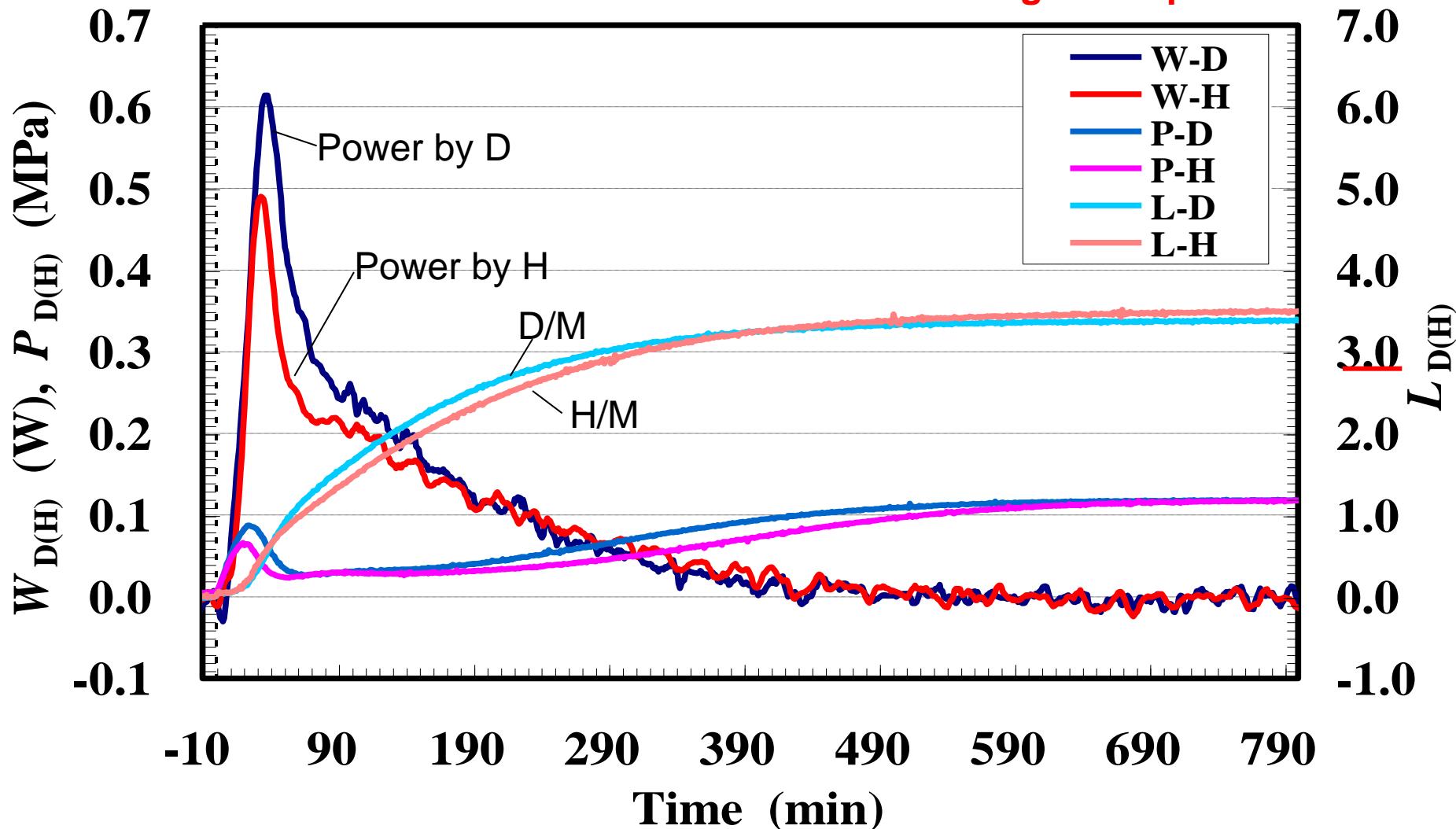
Very Large Loading Ratios, $D(H)/M > 3$, in this PNZ sample: $M = [Pd-Ni]$



Raw Data for **PNZ2B**_{3,4#1}: 5.1sccm (H), 5.9sccm (D)

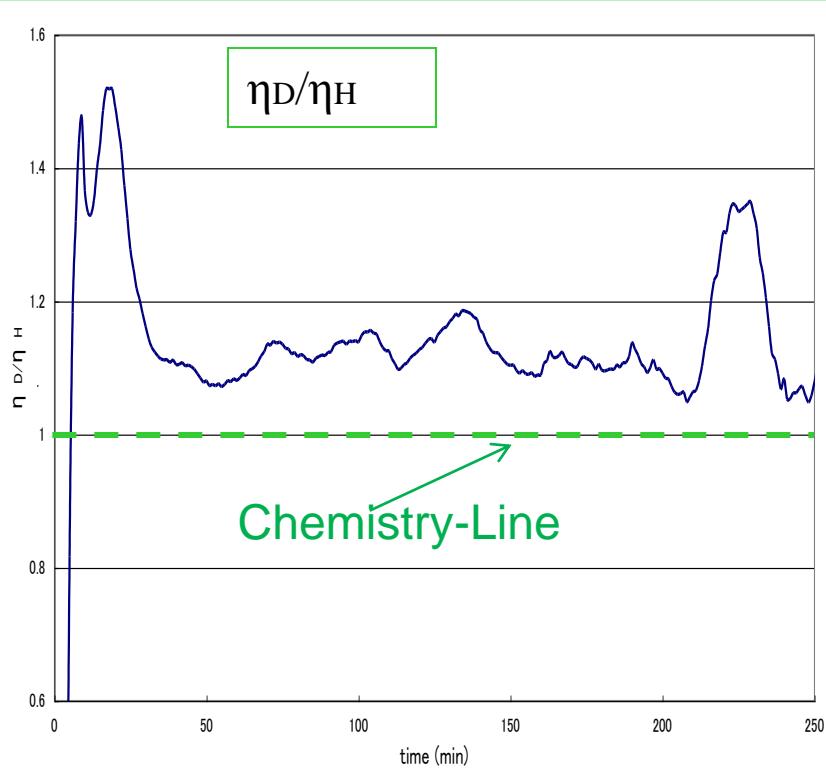
Heat-Power W, Pressure P and Loading Ratio D(H)/M

Ca. 2nm diameter Pd-Ni Particle: Virgin Sample

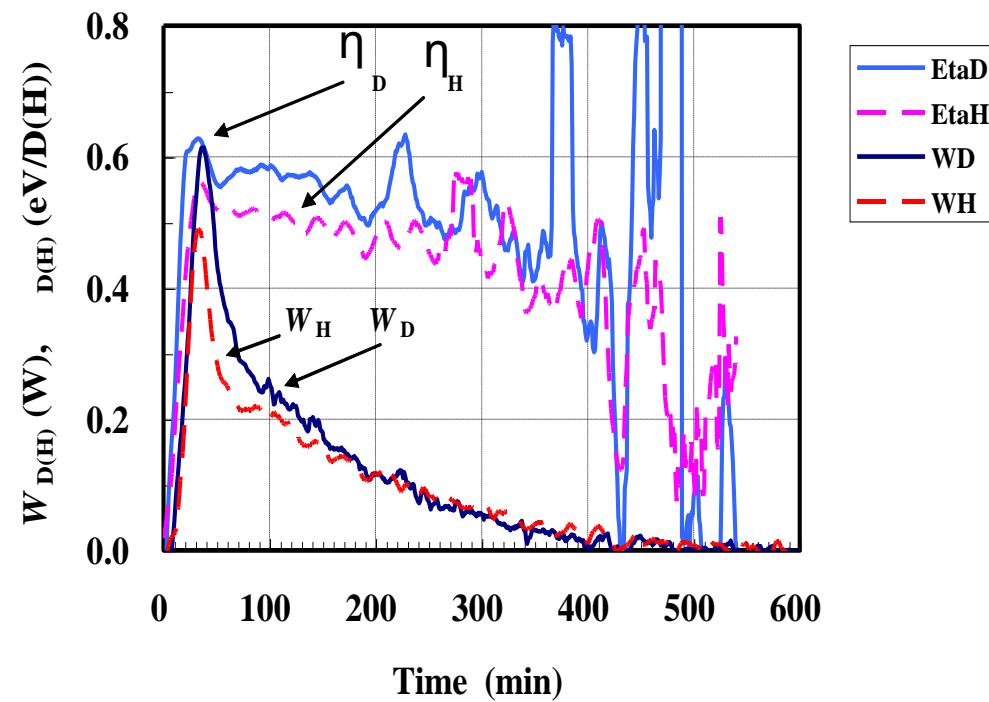


D-vs.-H Isotopic Effect for heat evolution (W), energy per D(H) sorption = η ,
 η_D / η_H ratios
:H-PZ2B3#1 vs. D-PNZ2B4#1: **Virgin runs**

For η_D / η_H ratios > 1.0,
Nuclear Effect!(?)



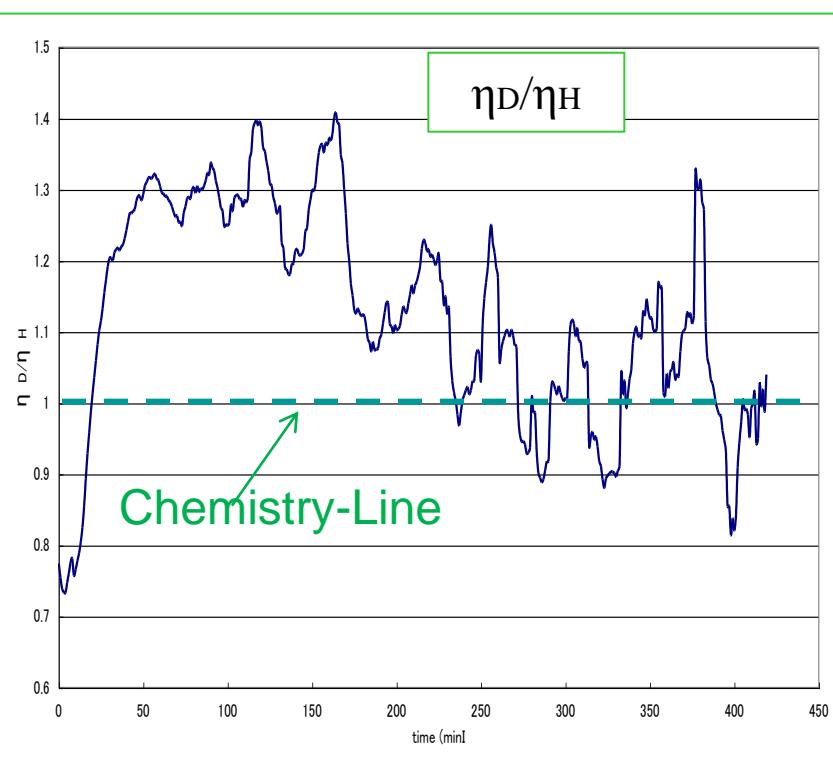
Ca. 2nm diameter Pd-Ni Particle



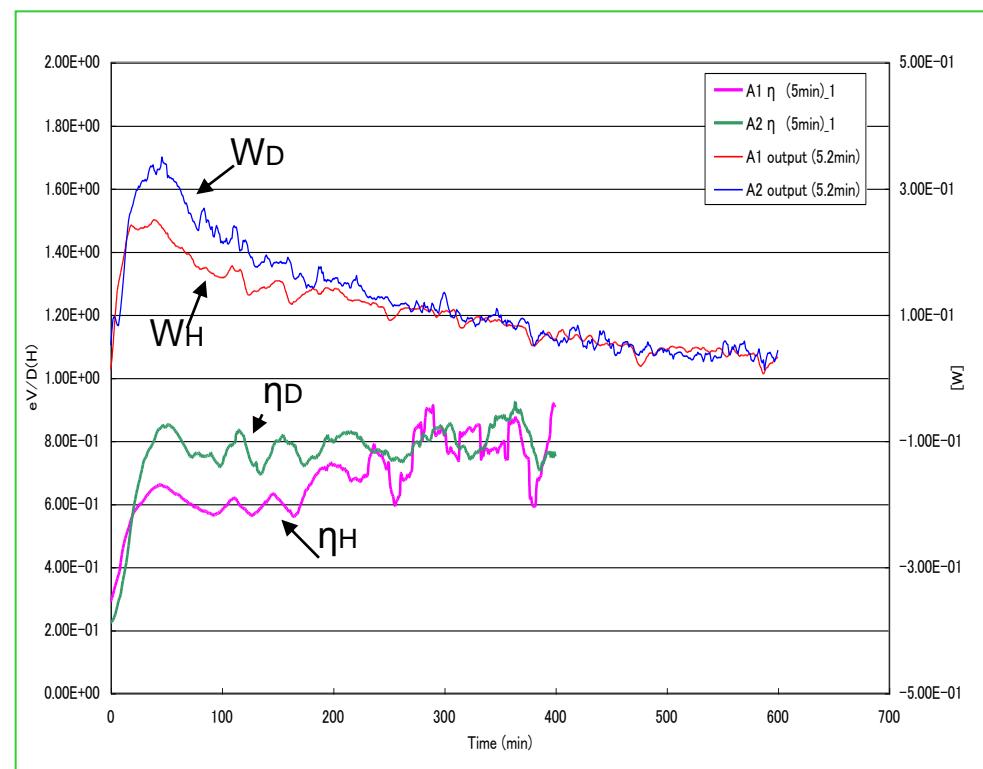
PNZ2B sample gave anomalously large heat and isotopic effect even after the **Forced Reduction of Oxygen**

: Heat-Power (W), Energy per D(H)-sorption (η) and η_D/η_H

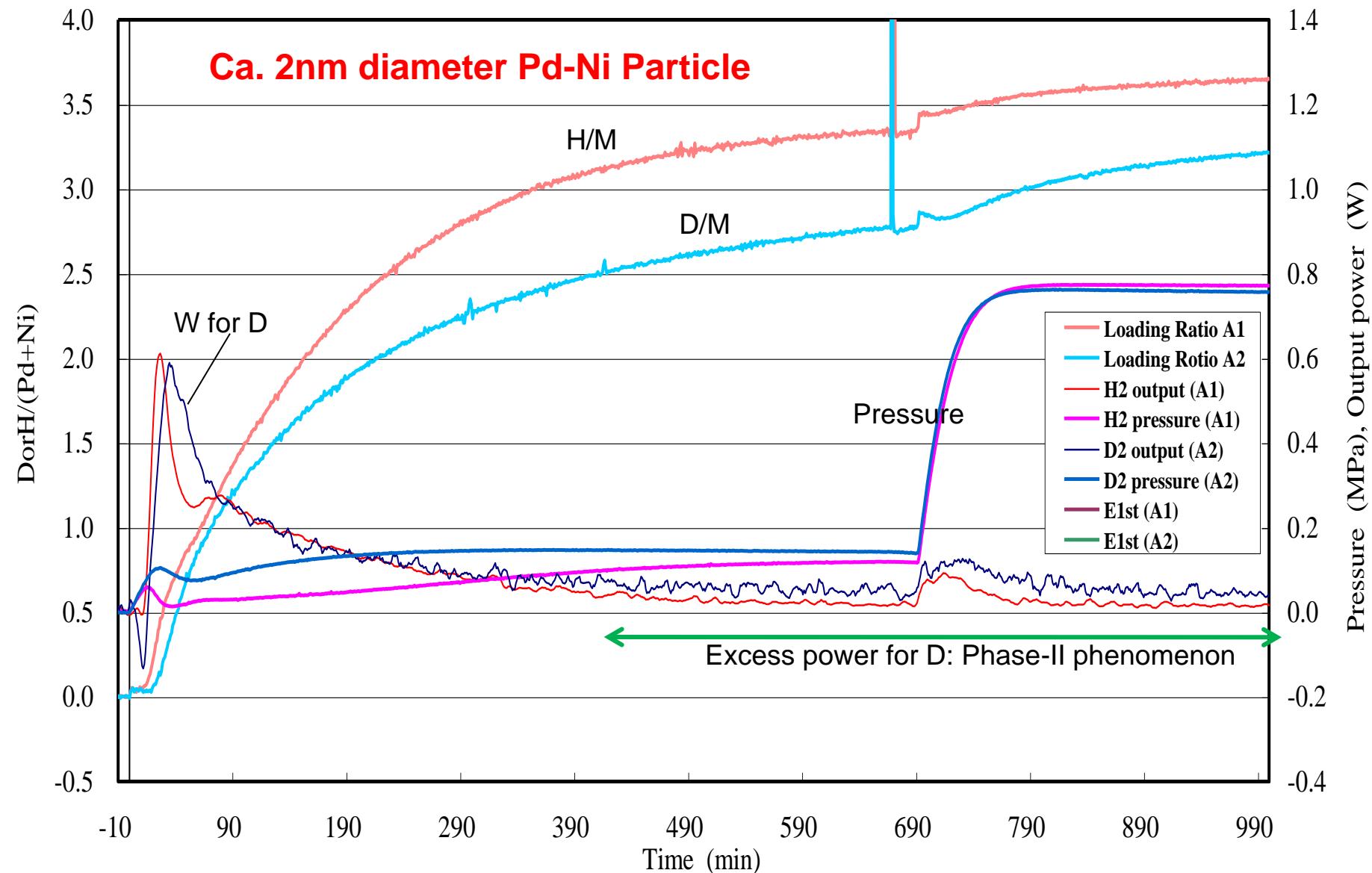
D-PNZ2B#2 vs. H-PNZ2B#2



Ca. 2nm diameter Pd-Ni Particle



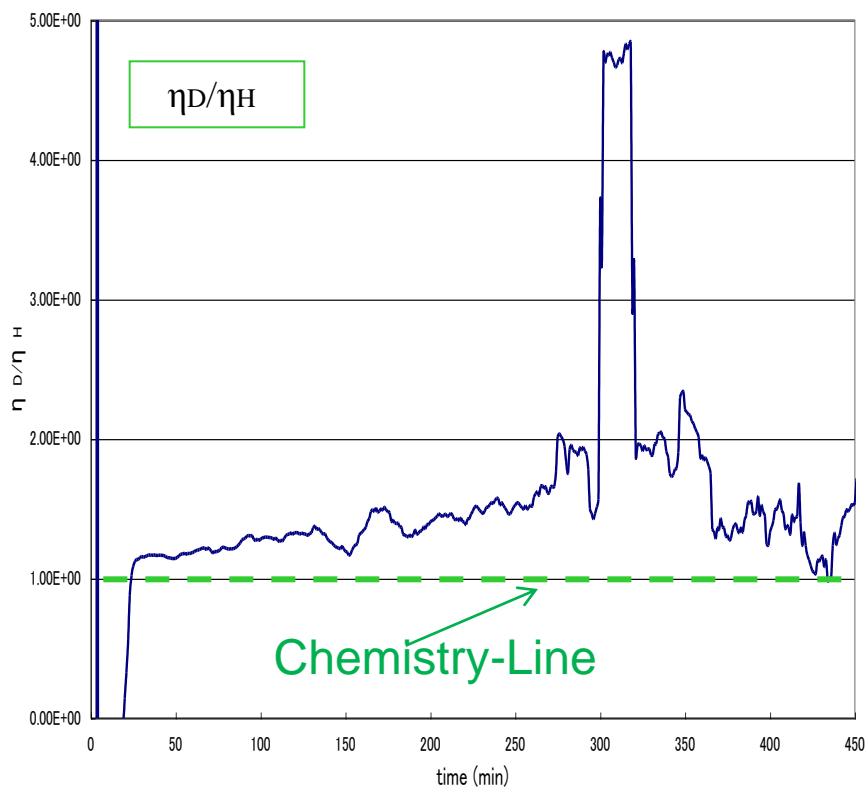
Raw Data for H-PNZ2B3#3 vs. D-PNZ2B4#3; 5.0sccm (H), 6.1sccm (D)
: After forced oxidization (8.7% MO)



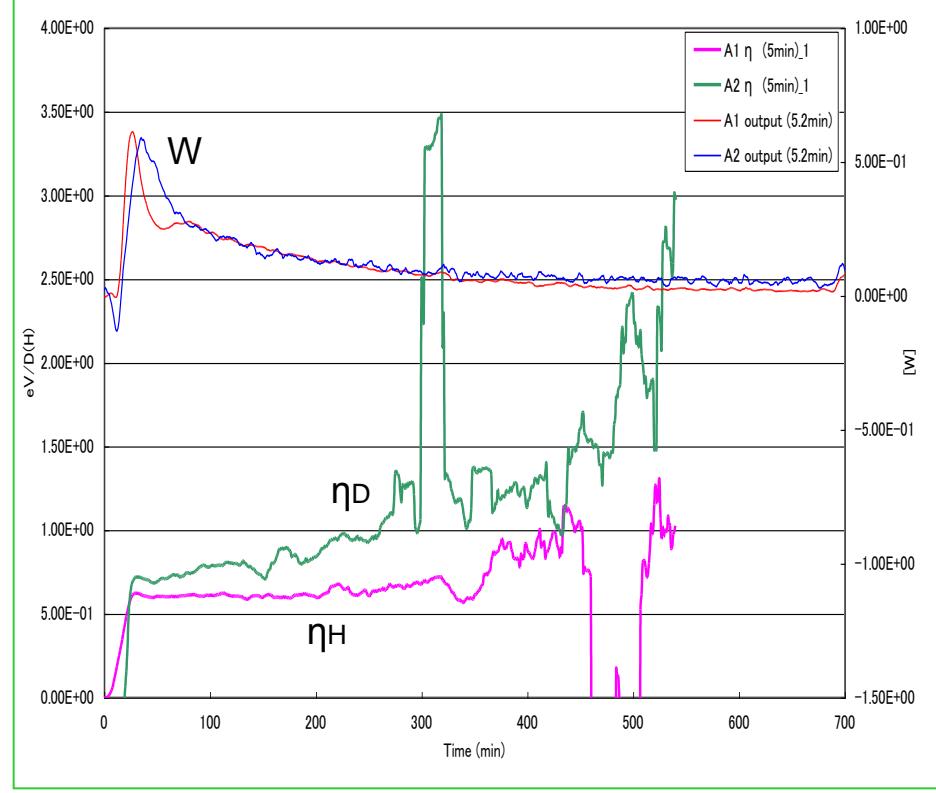
PNZ2B sample gave anomalously large heat and isotopic effect after the **Forced Oxidization (8.7%MO)** of used sample

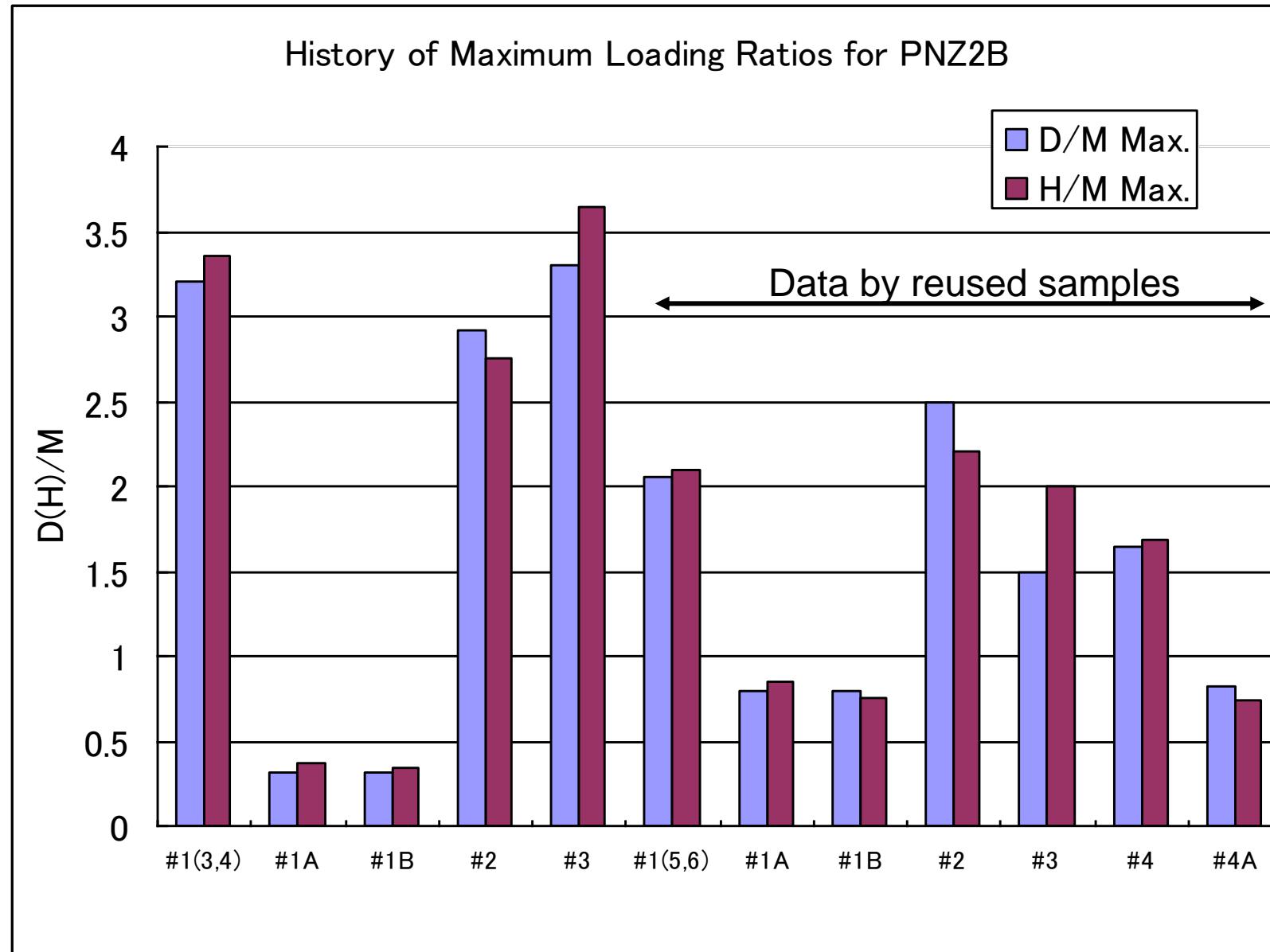
: Heat-Power (W), Energy per D(H)-sorption (η) and η_D/η_H

Nuclear Effect for $\eta_D/\eta_H \gg 1.0$! (?)

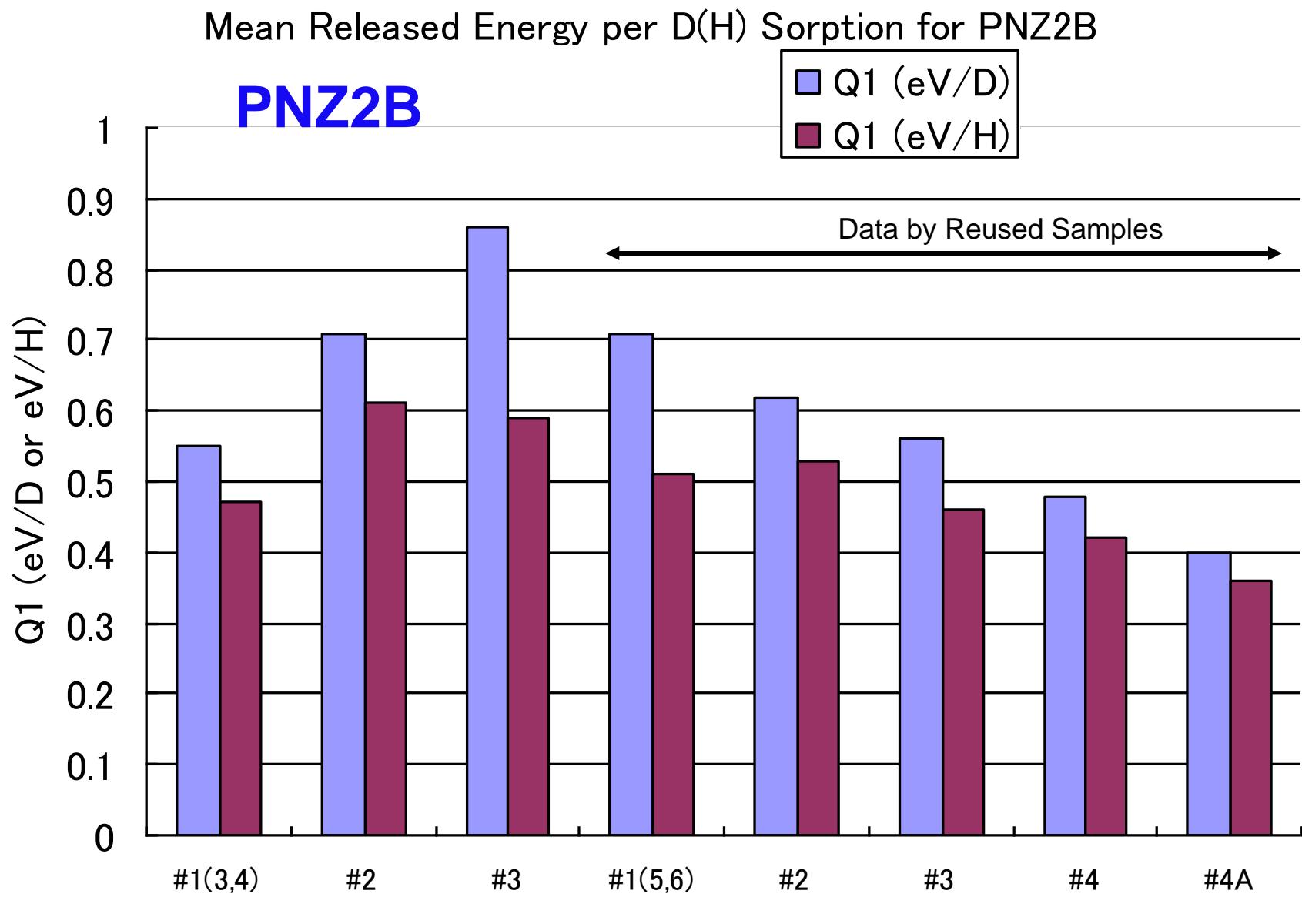


Ca. 2nm diameter Pd-Ni Particle





Released Energy for D is always larger than that for H. **Difference is Nuclear?**



Integrated Data for **PNZ2B3(4)**: [M] = [Ni_{0.875}Pd_{0.125}]

PNZ2B3(4) Run #	kJ/g-M for D	kJ/g-M for H	eV/M for D	eV/M for H	QD (eV)	QH (eV)
#1	2.67	2.35	1.81	1.59	0.55	0.47
#1d	-0.14	-0.13				
#2	2.83	2.32	1.91	1.57	0.71	0.61
#2d	-0.25	-0.21				
#3	3.35	2.77	2.41	2.04	0.86	0.59

Gain > 10

Isotopic Ratio
 $= 0.86/0.59$
 $= 1.46$

Tested Metal/Ceramics Powders and Results

	Pd	Ni	Zr	O	Supplier	Anomalies observed?
100nm ϕ -Pd PP	995%, 100nm ϕ	---	---	---	Nilaco Corp.	[1],[2] No, bulk metal data, but PdO
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mixed oxide NZ	---	0.358	0.642	(1.64)	Santoku Corp.	[2] No heat and loading
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2nm ϕ -PdNi PNZ2B	<u>0.04</u>	0.29	0.67	(1.67)	Dr. B. Ahern	Yes, very large heat and D(H)/M, reproducible

[1] Phys. Lett. A, 373 (2009) 3109-3112.

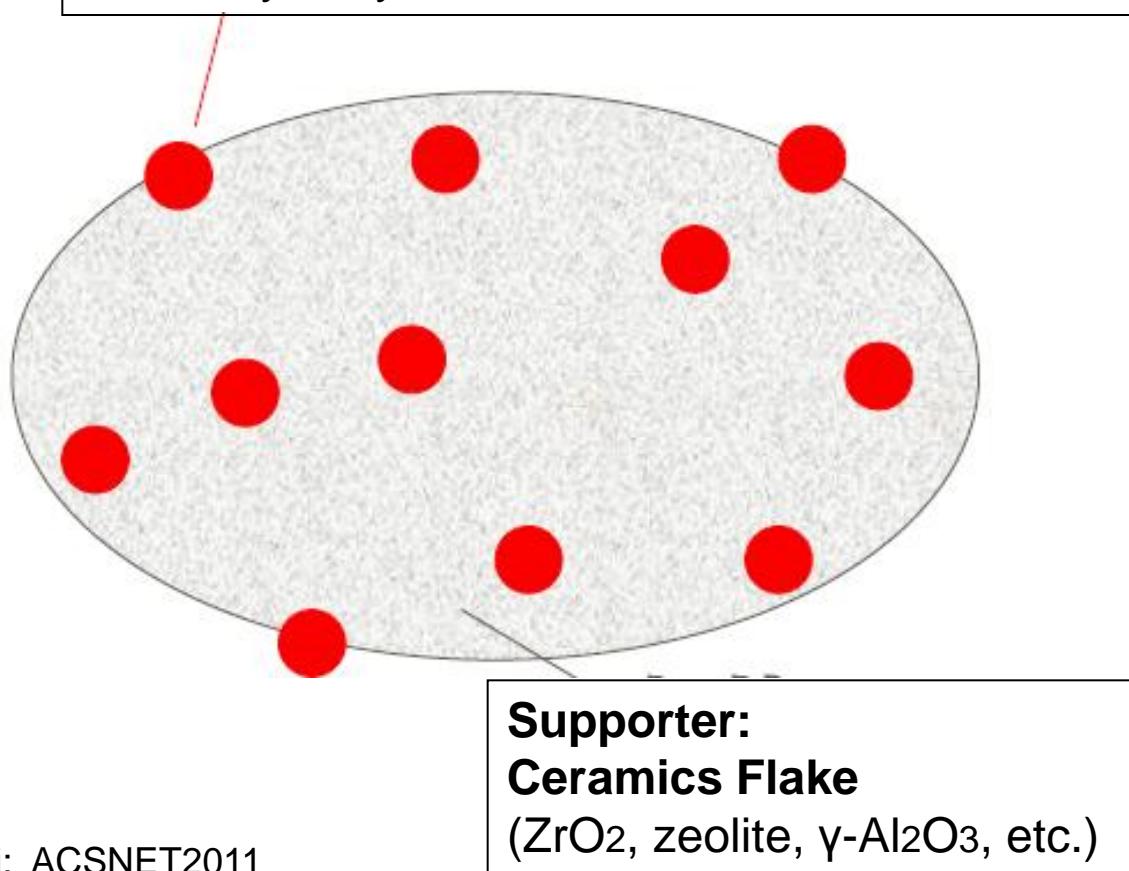
Drastic change happens! **Why?**

[2] **Low Energy Nuclear Reactions**, (AIP Conf. Proc. 1273, ed. Jan Marwan, 2010).

[3] **LENR Source Book 3**, (ed. Jan Marwan, ACS) to be published.

MDE Mesoscopic Catalyst

Nano-Particle Catalyst: as Core/"Incomplete"-Shell Structure
Mono-Metal (with oxide-surface layer)
Or Binary Alloy



Binary Alloy Metal Nano-Particle Catalyst ;Model for PdxNiy

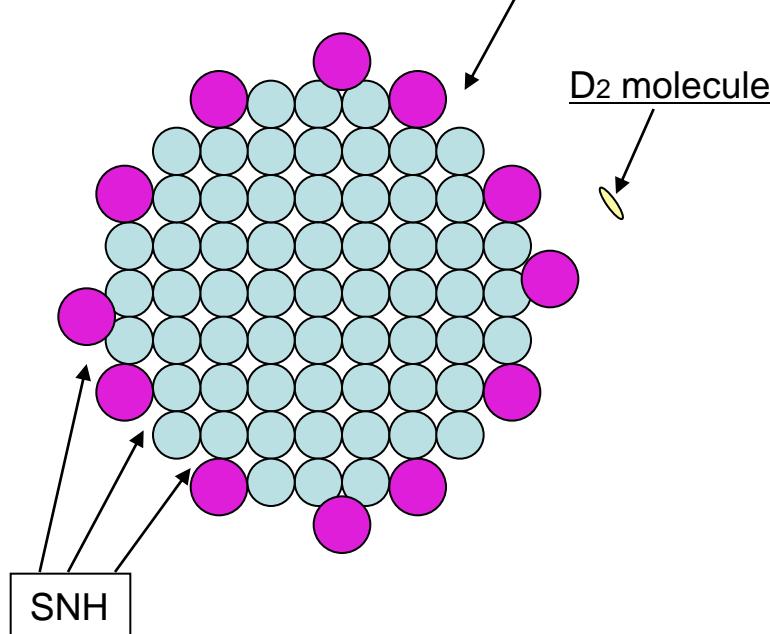


Ni-atom; $r_0 = 0.138 \text{ nm}$



Pd-atom; $r_0 = 0.152 \text{ nm}$

2nm diameter Pd_1Ni_7 particle



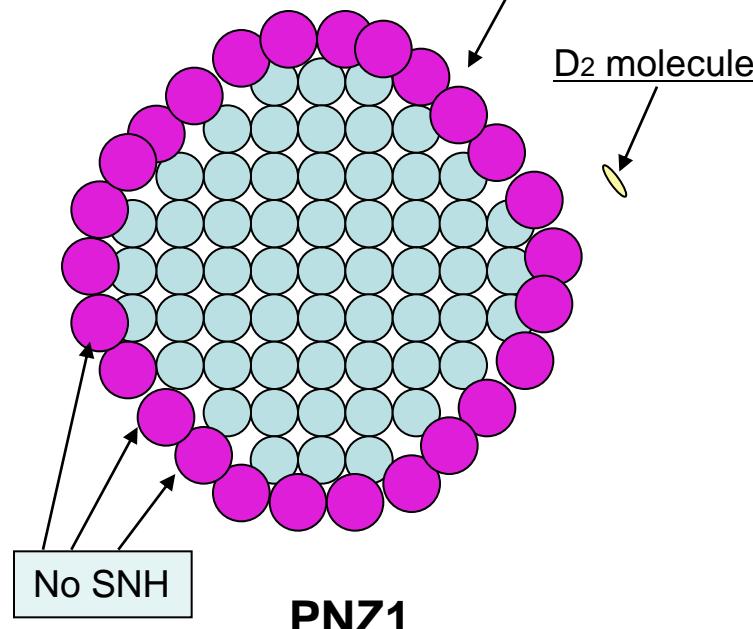
- Surface Pd adsorbs easier H(D).
- Pd ad-atom makes deeper adsorption potential for Ni-core lattice, due to fractal-dip's e- dangling bonds (**SNH**) on surface.
- Enhanced H(D) absorption into Ni-lattice sites (O-sites and T-sites)
- $[\text{H(D)}]/[\text{Pd}+\text{Ni}] > 3.0$
; 1.0 for O-sites, 2.0 for T-sites plus alpha for surface D(H)-clusters
- 4D/TSC formation at surface sub-nano-dips (holes) (**SNH**); at defects and fractal dips
- Pd ad-atom works “similarly” to Oxygen of PdO-coated Pd-nano-particle.

Binary Alloy Metal Nano-Particle Catalyst ;Model for Pd_xNi_y

a) Complete-Pd-shell/Ni-core

- (light blue circle) Ni-atom; $r_0 = 0.138 \text{ nm}$
- (magenta circle) Pd-atom; $r_0 = 0.152 \text{ nm}$

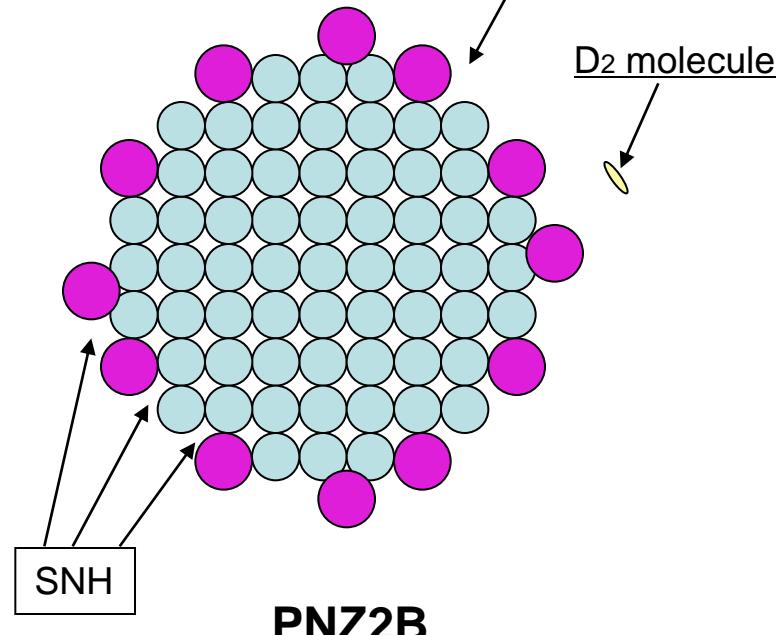
2nm diameter Pd₂Ni₆ particle



b) Incomplete-Pd-shell/Ni-core

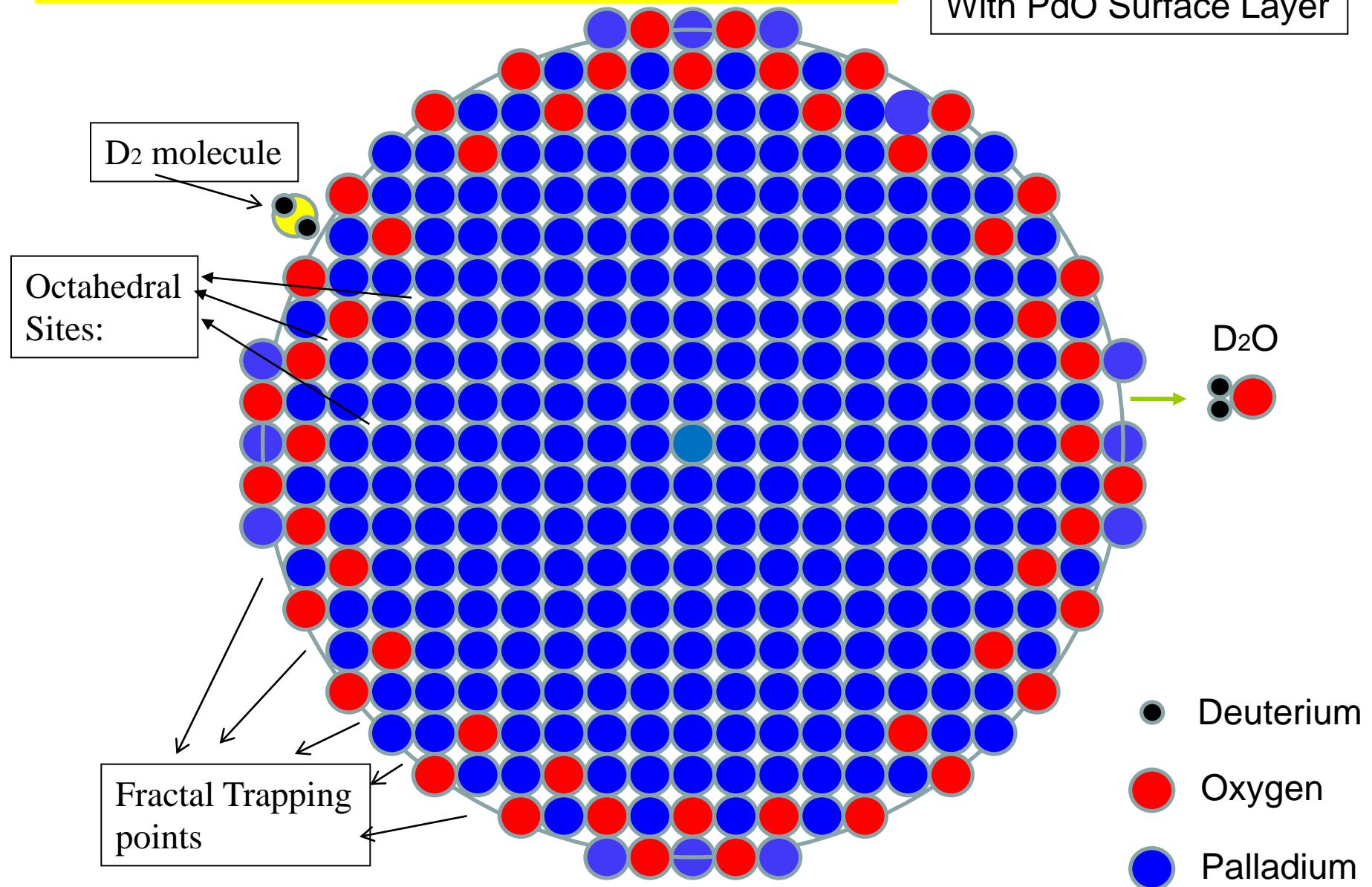
- (light blue circle) Ni-atom; $r_0 = 0.138 \text{ nm}$
- (magenta circle) Pd-atom; $r_0 = 0.152 \text{ nm}$

2nm diameter Pd₁Ni₇ particle



PdO coating on surface of Pd nano-particle: 2) Local De-oxidation

Model for PZ With PdO Surface Layer



Phenomenological Model for PdO-coated Pd-nano particle and Pd-Ni binary shell-core nano-particle as “Mesoscopic Catalyst”

- PdO surface coating for few atomic layers (**Pd ad-atoms on Ni core**)
- Reduction of PdO by incoming D(H)-gas
- De-sorption of D(H)2O into vacuum
- “**Sub-Nano Hole**”, SNH with active chemical dangling bonds
- Rapid adsorption of D(H) in SNHs
- 4D/TSC, cluster formation at SNHs
- Rapid lattice absorption (PdD(H) formation) through surface nano-holes, reaching to **over-loaded $x>1$** state
- Formation of **Collective Mesoscopic Potential Well**
- Non-linear coupled oscillation of “long”- and “short”-pendulum state (PdD or NiD₃ local lattice)
- 4D/TSC cluster formation under non-linear oscillation

PdO coating on surface of Pd nano-particle:
4) Another D₂ comes onto trapped D₂

Model for PZ
With PdO Surface Layer

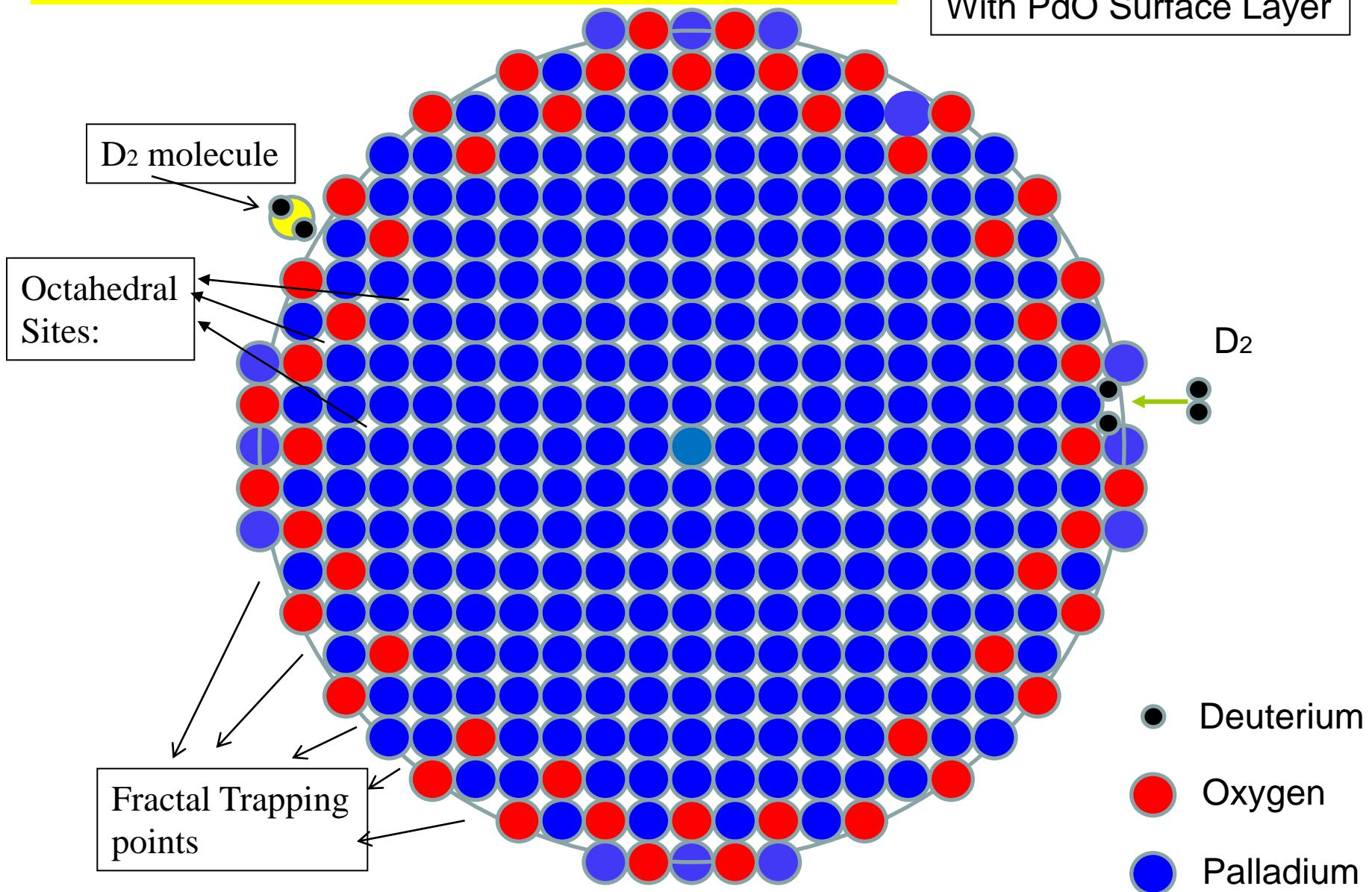
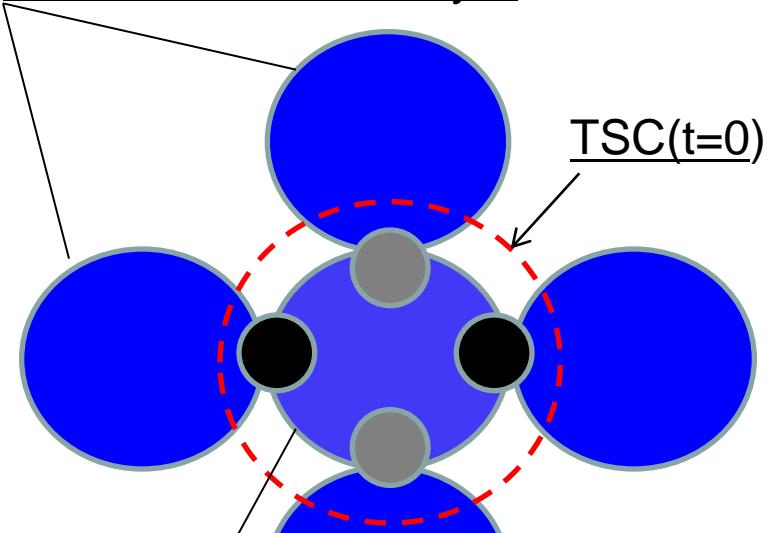


Image on Formation of TSC($t=0$) at Sub-Nano-Hole

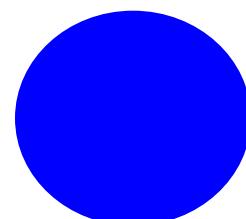
Pd or Ni at surface layer



TSC($t=0$)

● D trapped first

● D trapped second



Pd or Ni

4D/TSC fusion events in the beginning of D(H)-gas loading to PdO-coated Pd-particle

- Formation of 4D/TSC($t=0$) makes 100% simultaneous 4D fusion ($23.8\text{MeV}/\text{He-4}$) in 1.4 fs (*A. Takahashi, LENR-SB Vol.1&2*)
- One 4D/TSC($t=0$) generation per second in SNHs, per 10 million Pd nano-particles, generates about 1 watt heat-power level for 1g-Pd-contained PZ sample under D-gas charging
- It is comparable to observed heat-power level in the beginning of D-loading for PZ sample (see below)

If heat evolution is a step function, we observe like-this.
Heat evolution by H-gas follows to it.

Indicial Response for Calorimetry
 $: (1 - \exp(-t/T_1))$, $T_1 = 5$ min

Observed Heat Response for rapid heat release

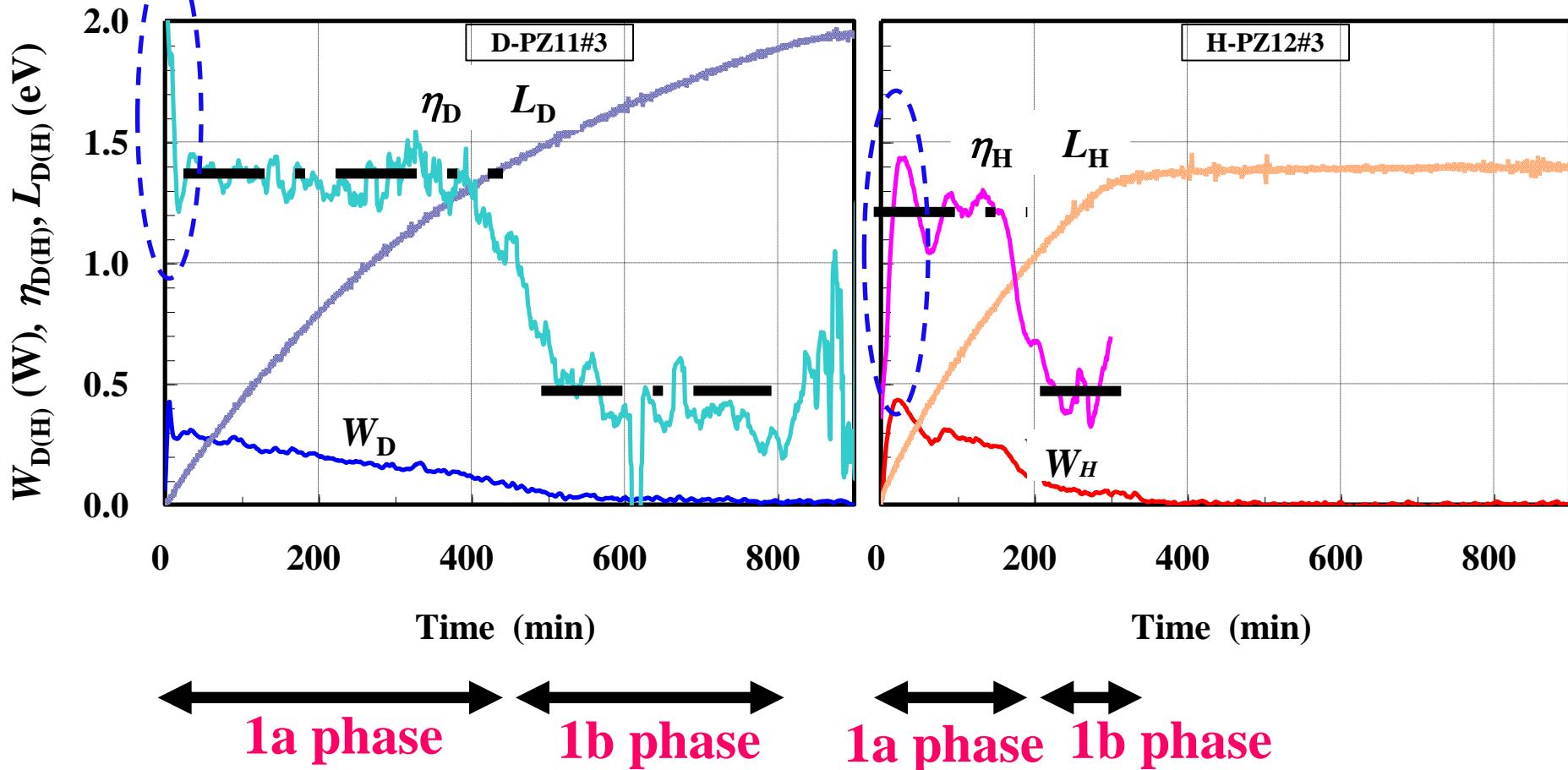
Rapid Heat Response : $\exp(-t/T_2)$, $T_2 = 3$ min
 By supposed Nuclear Reaction by D-gas on surface

Relative Scale

Time (min)

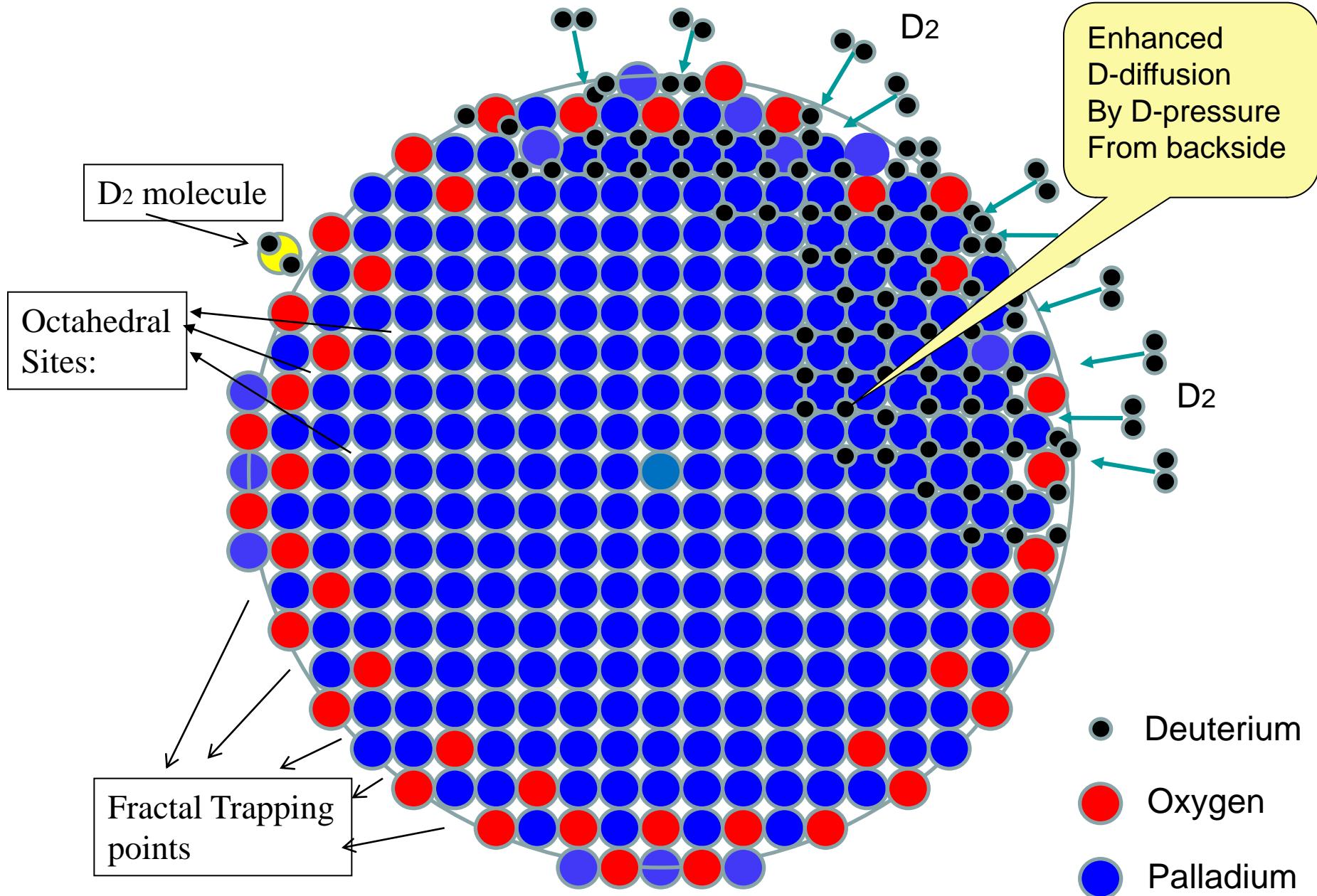
At the beginning, large heat-power appears for D-charging only!

Two components appear in Phase-I, by PdO effect?



Typical variation of the specific sorption energy, η_D (η_H), compared with the power, W_D (W_H), and pressure, P_D (P_H), in the #3 run for the PZ11(12) sample.

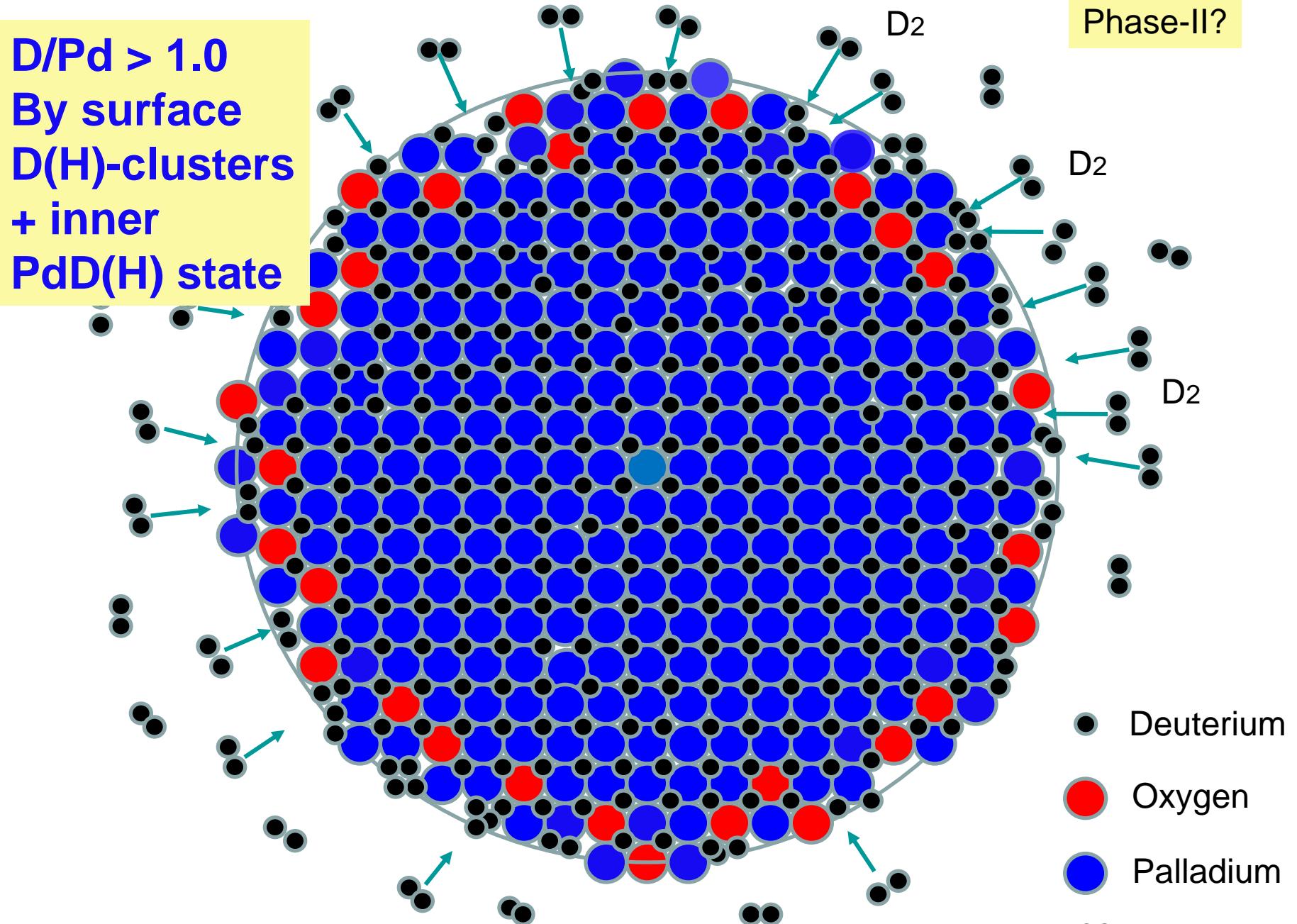
PdO coating on surface of Pd nano-particle and D-absorption: 11)



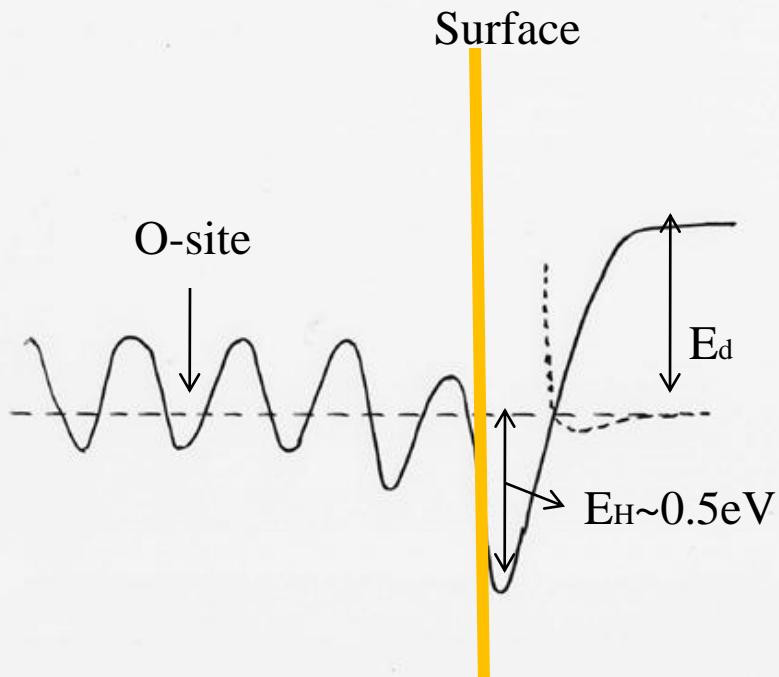
PdO coating on surface of Pd nano-particle and D-absorption: 14)

D/Pd > 1.0
By surface
D(H)-clusters
+ inner
PdD(H) state

Phase-II?

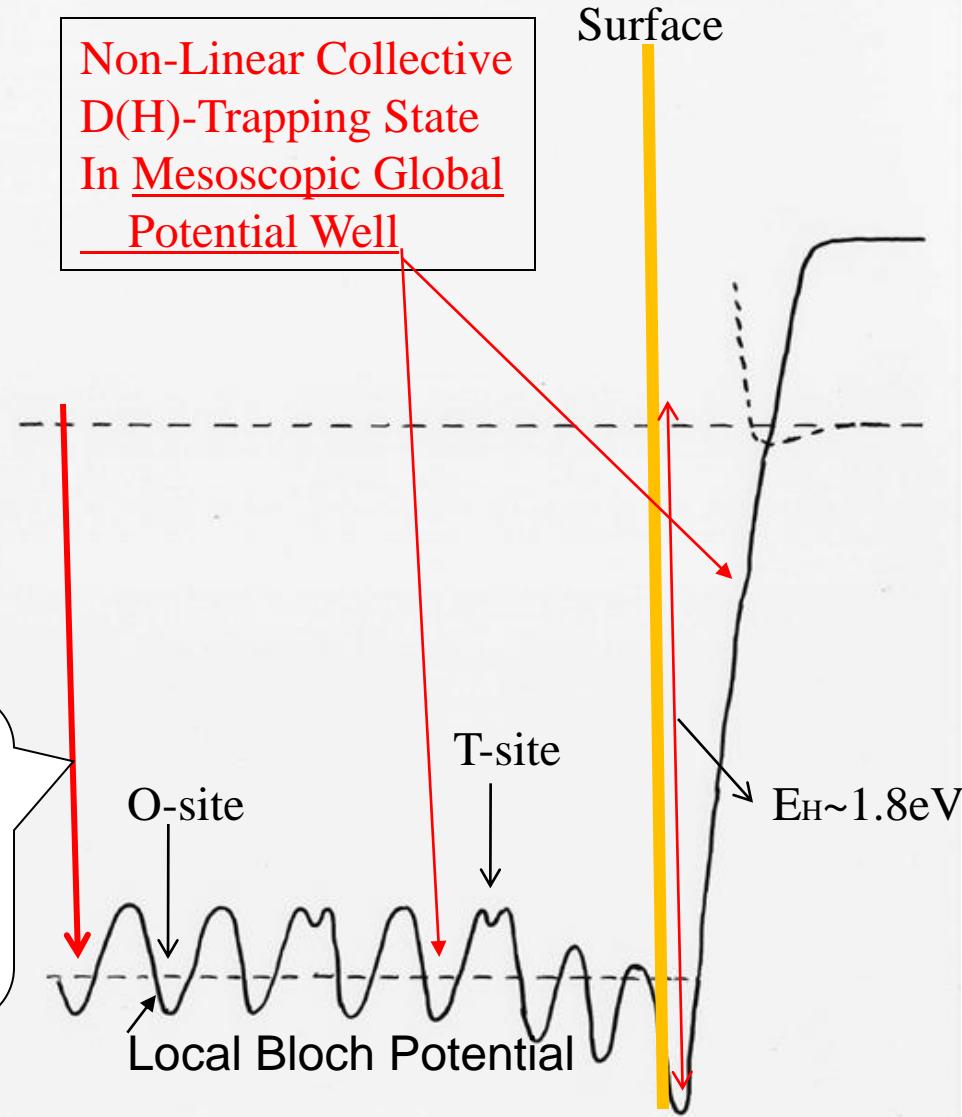


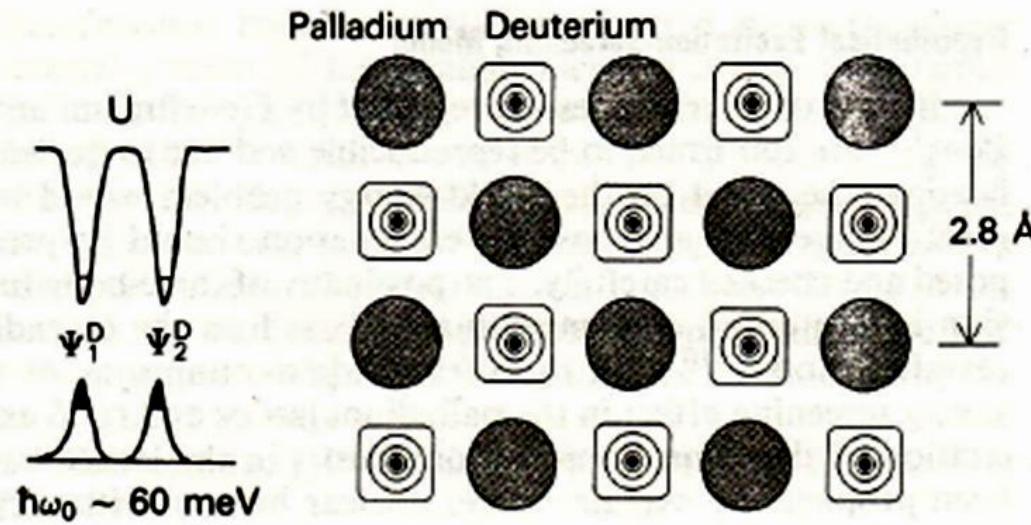
A) Bulk Pd Lattice



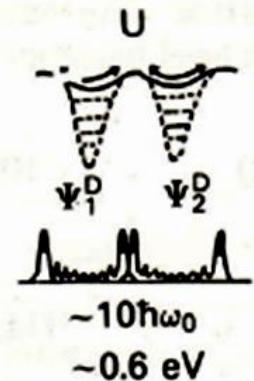
Reason for Anomalously Large Chemical Heat:
Mesoscopic Catalyst!
Deeper (ca. 1.5eV) for nano-PdD
Shallower (ca. 0.5eV) for nano- PdNiD₃

B) Mesoscopic Pd Lattice



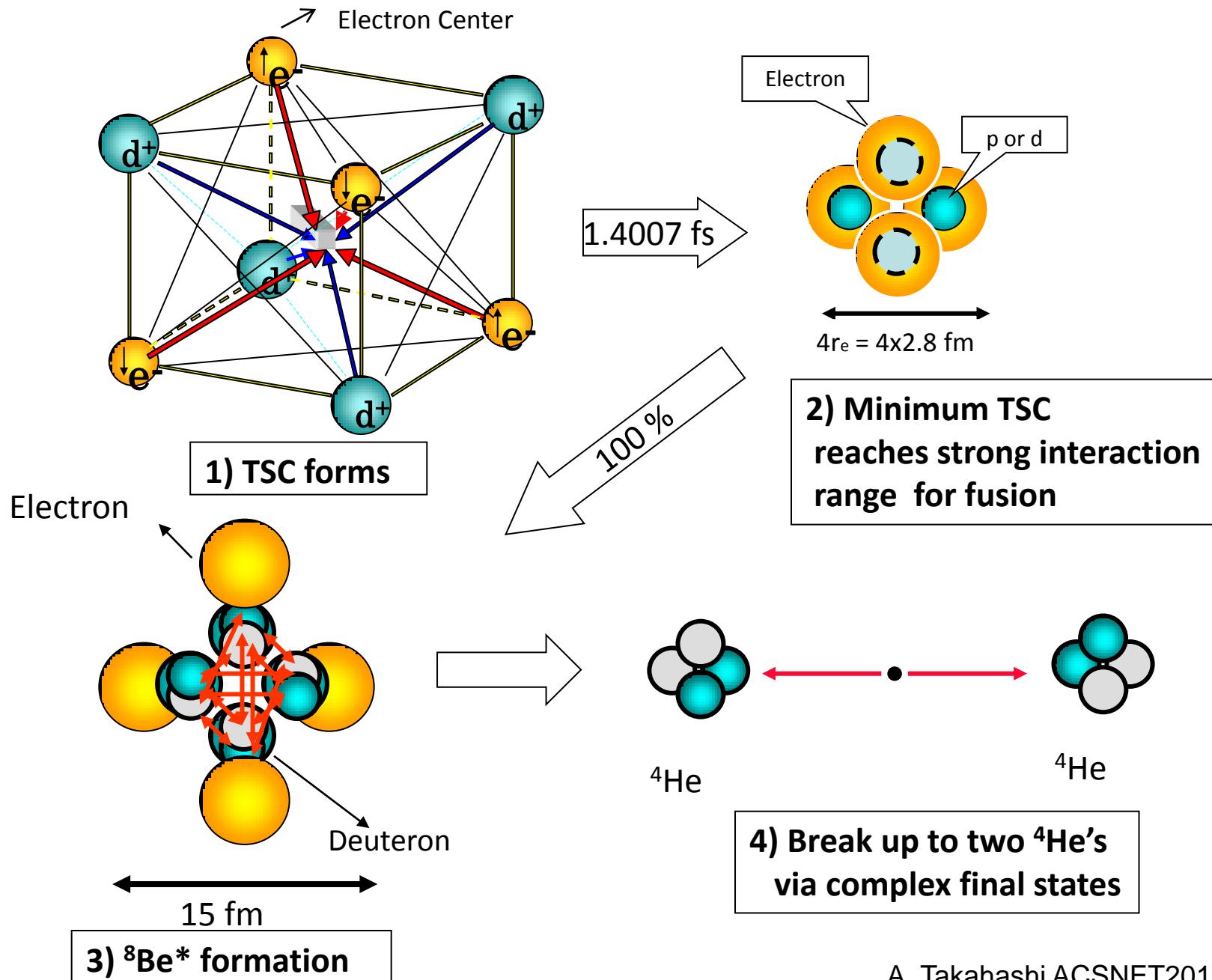


Transient formation of 4D/TSCs around T-sites in Mesoscopic PdD and NiD₃ Particles with GPT



D-Cluster Formation
Probability will be Enhanced at around T-sites.

Result of Dynamic Condensation of 4D/TSC by Langevin Equation

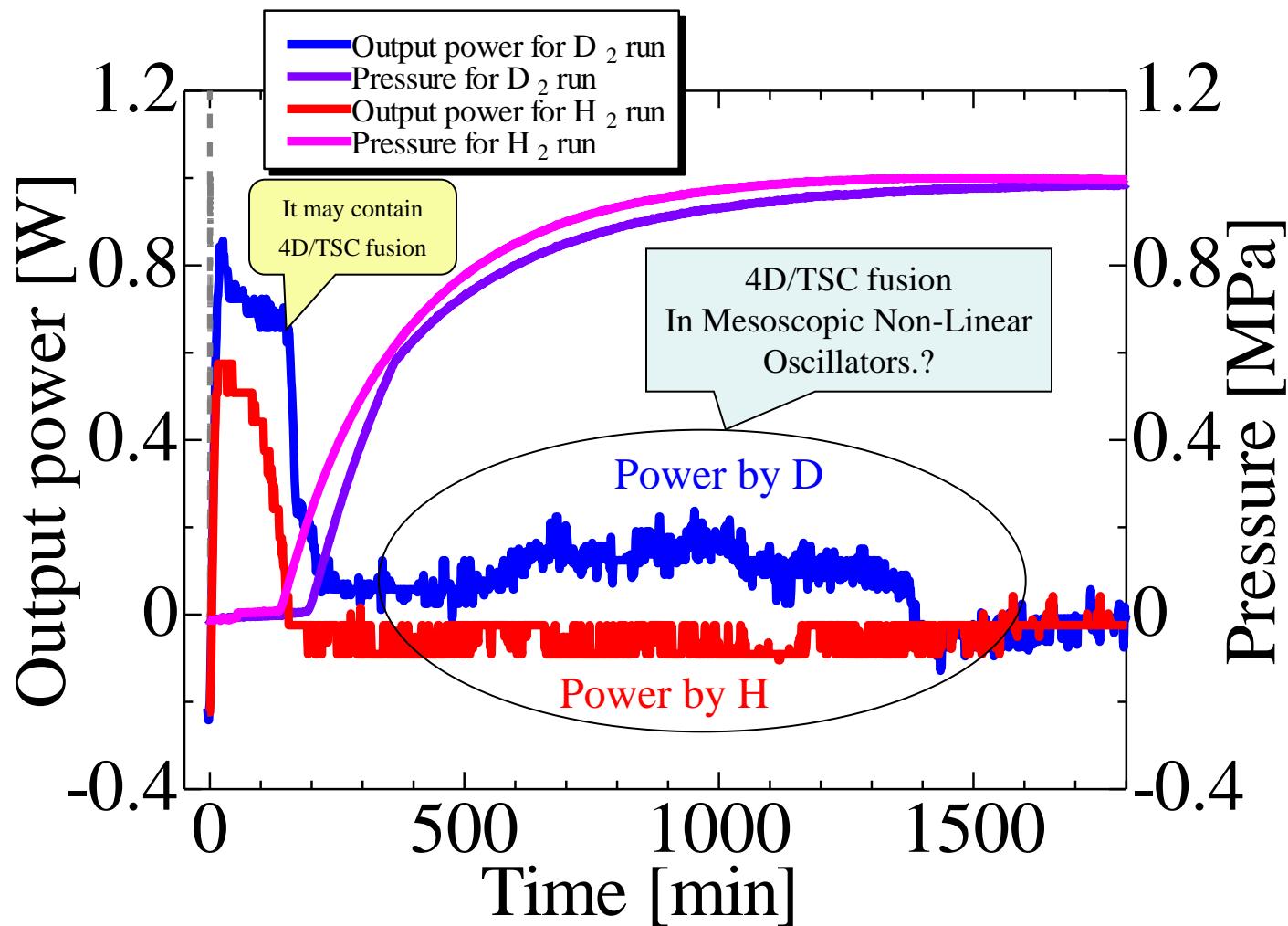


D-PZ1#1 vs. H-PZ2#1

For 1st phase: 7.0 kJ by D and 3.6kJ by H; 3.4KJ net excess heat

For 2nd phase: 6.8kJ by D

Total Excess Heat = 10.2kJ → 3.4kJ/g-Pd (**About 75% Nuclear**)



Conclusions-1

- Phenomenon of anomalous heat release and high D(H) absorption ratio by nano-metal particles (Pd, Ni-Pd binary) under D(H)-gas loading was confirmed by repeatable (reproducible) experimental results.
- D(H)/M loading ratio exceeds 1.0 for Pd-nano-particle dispersed in ZrO₂ supporter flake, and exceeds 3.0 for Ni₇Pd₁ binary (core-shell structure) nano-particle in ZrO₂ flake.
- Newly defined quantity, **η-value** which is energy per D(H) sorption is very useful for studying dynamic behavior (mechanism) of anomalous heat and loading.
- Integrated heat values (in eV per D(H) or per M) in Phase-I were far greater than known absorption energy-values for bulk metal.
- Anomalous heat in Phase-I consists of two components;
 - 1) mesoscopic chemical heat and 2) some nuclear heat.
- Anomalous heat in Phase-II has appeared only for D-gas charging, but not 100% repeatable. We need to investigate good conditions. (better for PNZ)
- Nickel-Pd binary particle can be good candidate for reducing necessary amount of palladium for the MDE application. (Various combination of binary nano-particles for Mesoscopic Catalyst)

Conclusions-2

- PdO coating of Pd-nano-particle (and/or Pd ad-atoms on Ni nano-core) may arrange **fractal nano-dips/holes (SNH)** on surface when D(H)-gas is charged.
- Fractal nano-dips make **deep adsorption potential (well-type) and rapid penetration of D-atoms** (ions) into Pd (or Ni)-local lattice (Bloch potential) of nano-particle.
- **Large absorption (chemical) heat** by “mesoscopic potential” even by H-sorption. (**Mesoscopic Catalyst**)
- Formation of **D-clusters**, such as 4D/TSC on surface may be enhanced to induce **4D-fusion**.
- D-motion in “mesoscopic potential” may be **quasi-free** to enhance transient D-cluster (4D/TSC) formation probability in PdD (or NiD₃) nano-particle.
- **Only when with PdO coating for PZ and when PNZ2B used, we saw clearly “Nuclear-Like Heat Component” in Phase-I.**

Additional Data follow below for more detail.

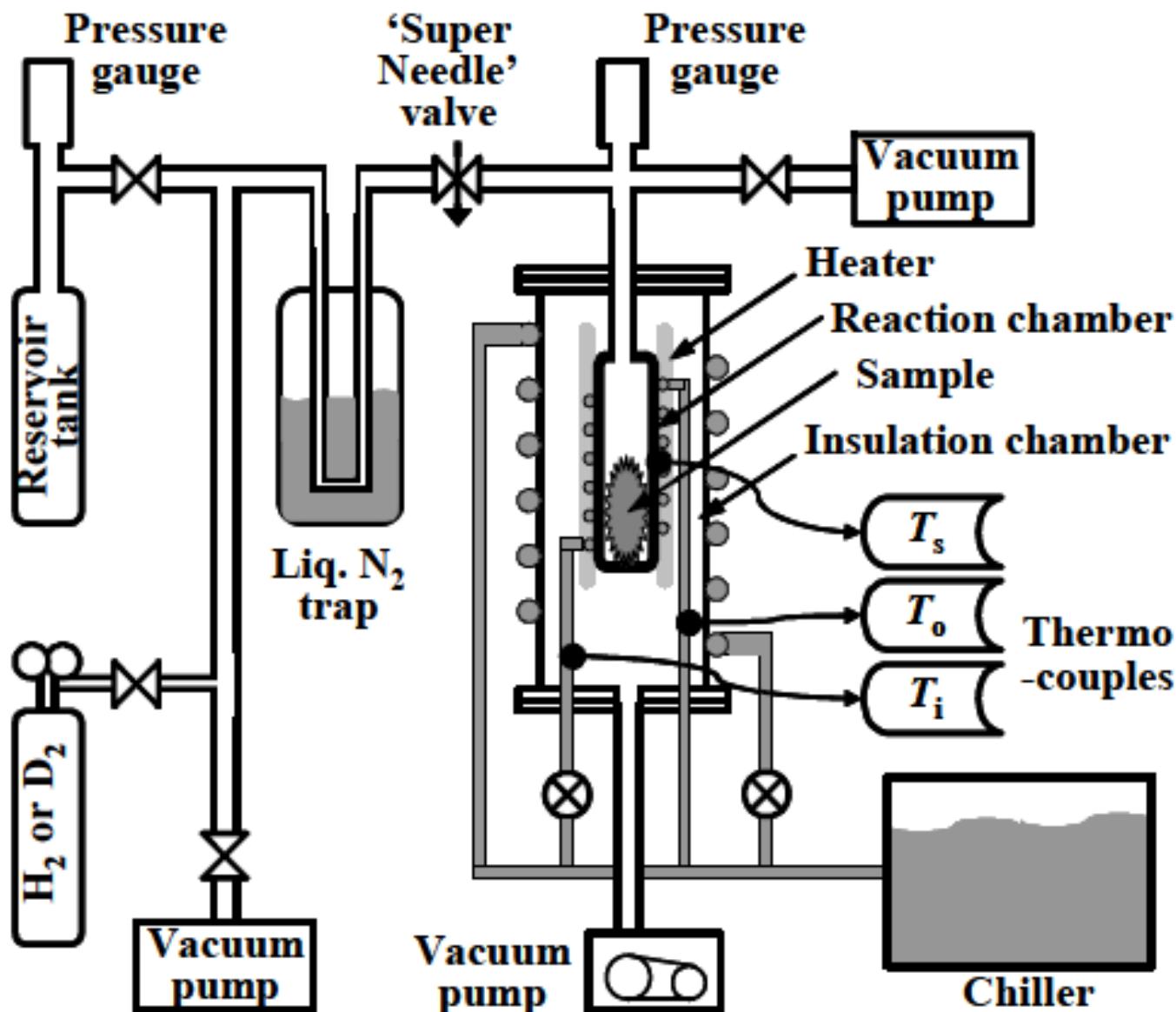


Figure 1. Schematic of one of the twin absorption systems.

Net Energy Gain by Sorption and Desorption

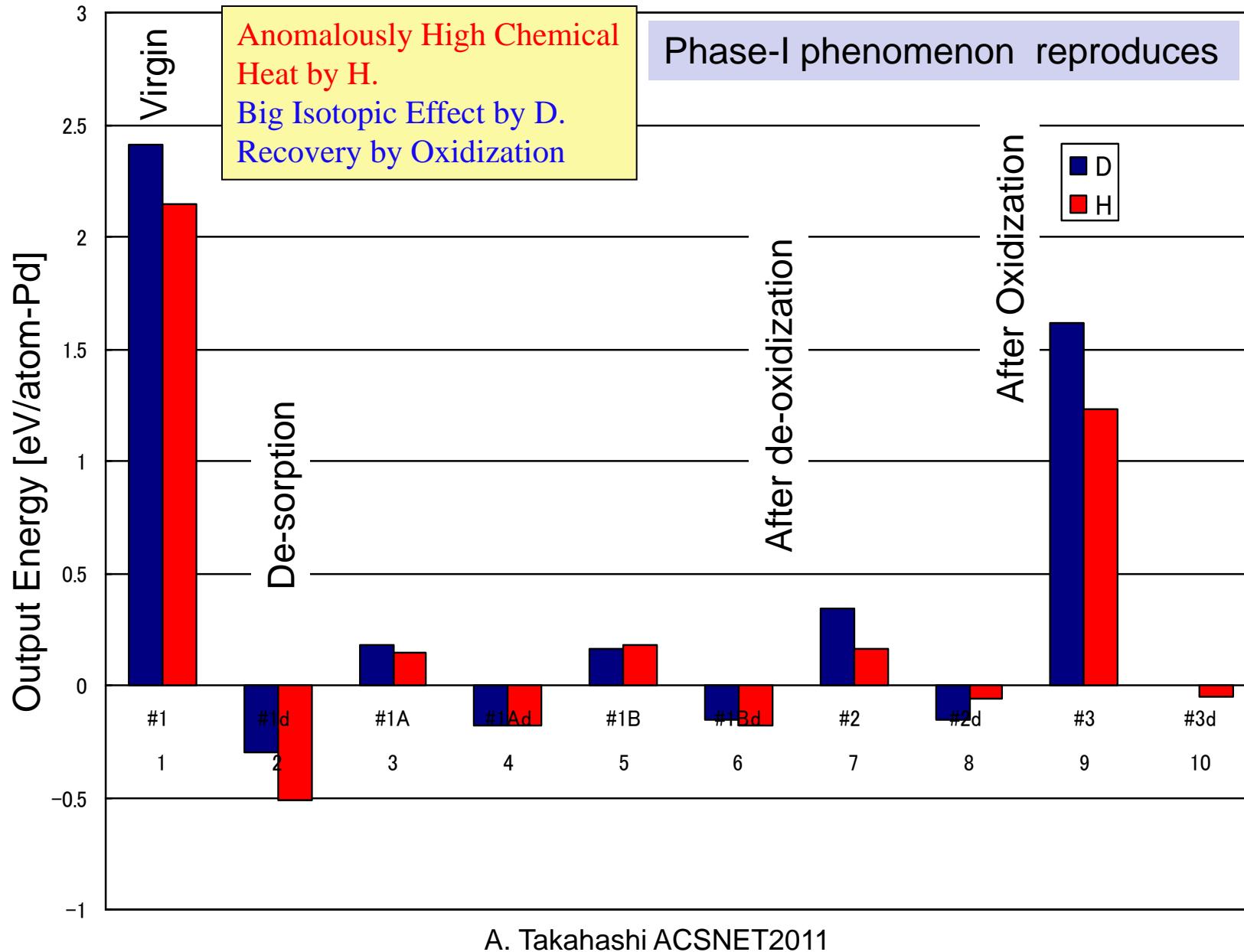
- **Gain = (Sorption Energy)/(Desorption Energy)**
- (Sorption Energy) = (Output Energy from Sample by D(H)-sorption)
- (Desorption Energy) = (Input Energy to Sample by D(H)-desorption)

1st Phase Results for D-PZ11 and H-PZ12

skip

Run	% PdO	Specific Energy		Loading R.	Q_D
		[kJ/g-Pd]	[eV/atom-Pd]	D(H)/Pd	[eV/D(H)]
D-PZ11#1	?	1.55 ± 0.11	1.72 ± 0.12	1.79	<0.96 ± 0.12
H-PZ12#1	?	1.18 ± 0.07	1.31 ± 0.08	1.85	<0.71 ± 0.08
D-PZ11#2	0	0.12 ± 0.02	0.14 ± 0.03	0.55	0.25 ± 0.03
H-PZ12#2	0	0.12 ± 0.02	0.13 ± 0.02	0.44	0.30 ± 0.02
D-PZ11#3	8.5	1.61 ± 0.01	1.94 ± 0.01	1.37	1.30 ± 0.01
H-PZ12#3	5.4	0.97 ± 0.01	1.16 ± 0.01	1.05	1.02 ± 0.01
D-PZ11#4-1	0	0.14 ± 0.02	0.16 ± 0.02	0.57	0.27 ± 0.02
H-PZ12#4-1	0	0.12 ± 0.02	0.13 ± 0.02	0.46	0.28 ± 0.02
D-PZ11#4-2	0	0.14 ± 0.02	0.16 ± 0.02	0.57	0.27 ± 0.02
H-PZ12#4-2	0	0.11 ± 0.02	0.12 ± 0.02	0.46	0.27 ± 0.02

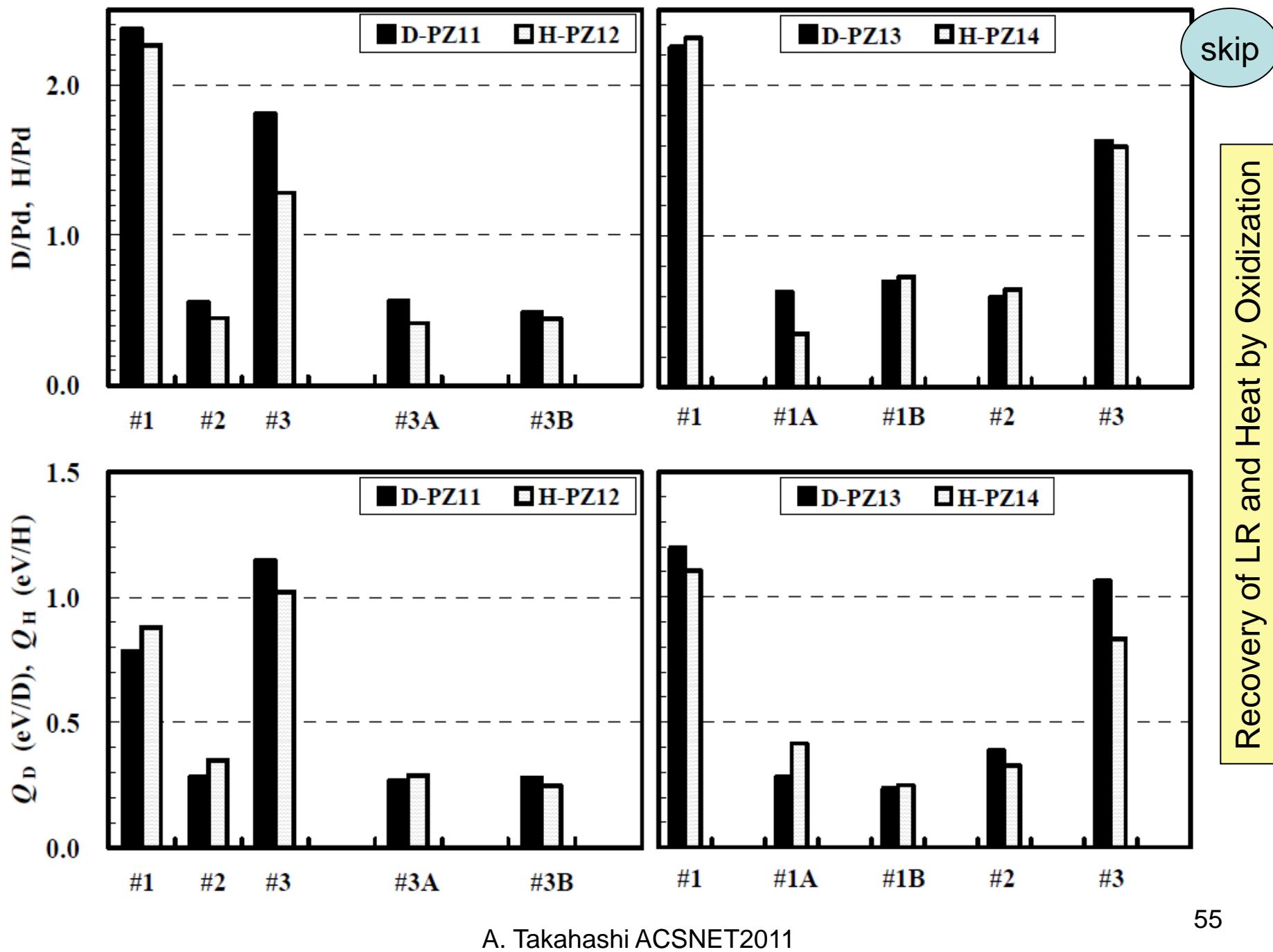
Specific Energy for Phase-I: PZ-13,14



1st Phase Results for D-PZ13 and H-PZ14

skip

Run	% PdO	Specific Energy		Loading R.	Q_D
		[kJ/g-Pd]	[eV/atom-Pd]	D(H)/Pd	[eV/D(H)]
D-PZ13#1	?	2.18 \pm 0.11	2.41 \pm 0.12	1.84	<1.31 \pm 0.12
H-PZ14#1	?	1.94 \pm 0.07	2.15 \pm 0.08	1.91	<1.12 \pm 0.08
D-PZ13#1d	0	-0.27 \pm 0.02	-0.30 \pm 0.03		(0.16): Cal.
H-PZ14#1d	0	-0.46 \pm 0.02	-0.51 \pm 0.02		(0.27): Cal.
D-PZ13#1B	0	0.15 \pm 0.01	0.16 \pm 0.01	0.70	0.23 \pm 0.01
H-PZ14#1B	0	0.16 \pm 0.01	0.18 \pm 0.01	0.73	0.25 \pm 0.01
D-PZ13#1Bd	0	-0.14 \pm 0.02	-0.16 \pm 0.02		(0.23): Cal.
H-PZ14#1Bd	0	-0.16 \pm 0.02	-0.18 \pm 0.02		(0.25): Cal.
D-PZ13#3	7.3	1.46 \pm 0.02	1.61 \pm 0.02	1.18	1.25 \pm 0.02
H-PZ14#3	6.1	1.12 \pm 0.02	1.23 \pm 0.02	0.98	1.15 \pm 0.02



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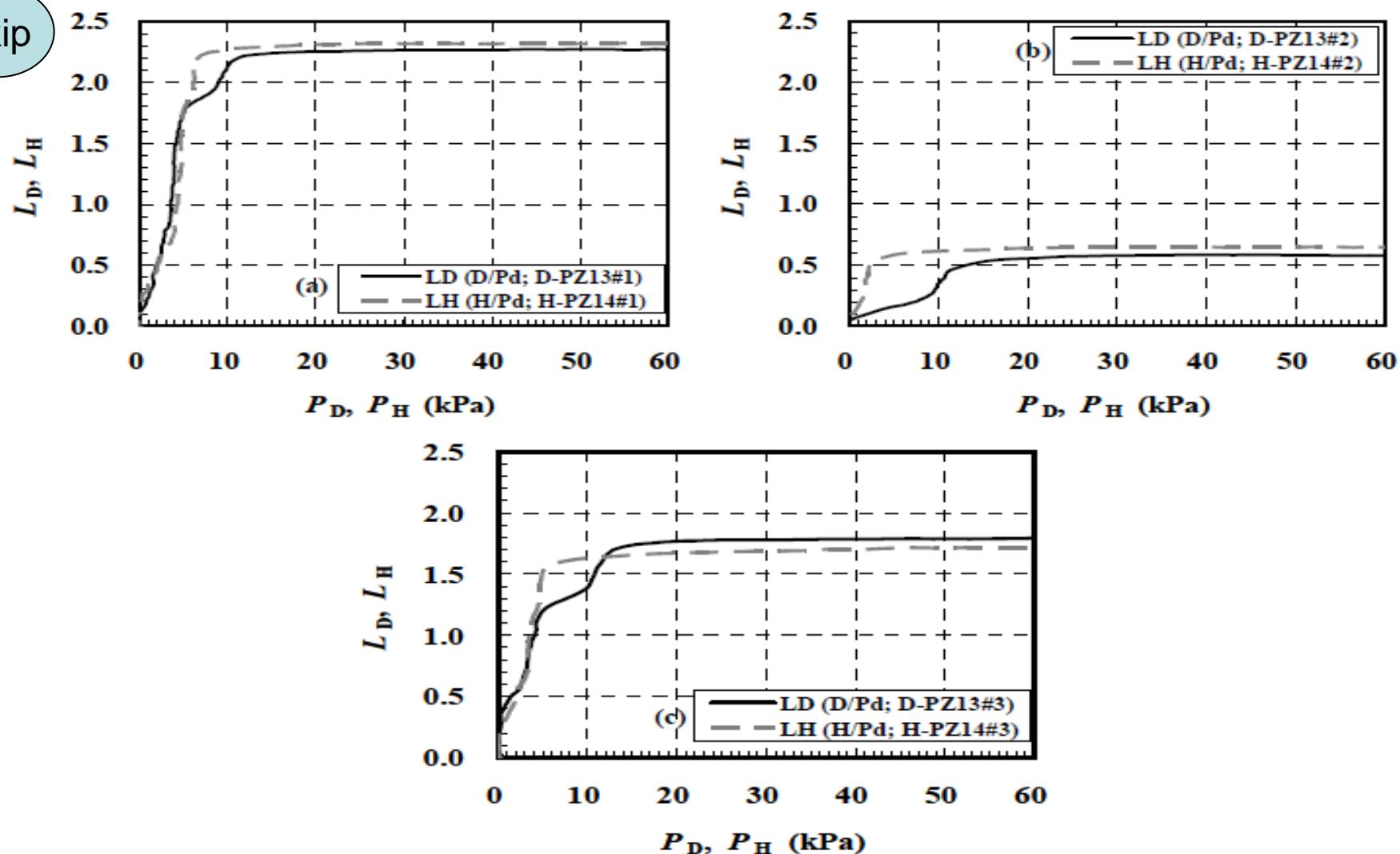


Figure 4. Time-resolved loading ratio, L_D and L_H , expressed as a function of pressure in PZ13(14)#1-3 runs. The first phase appears to be divided into 1a-phase and 1b-phase.

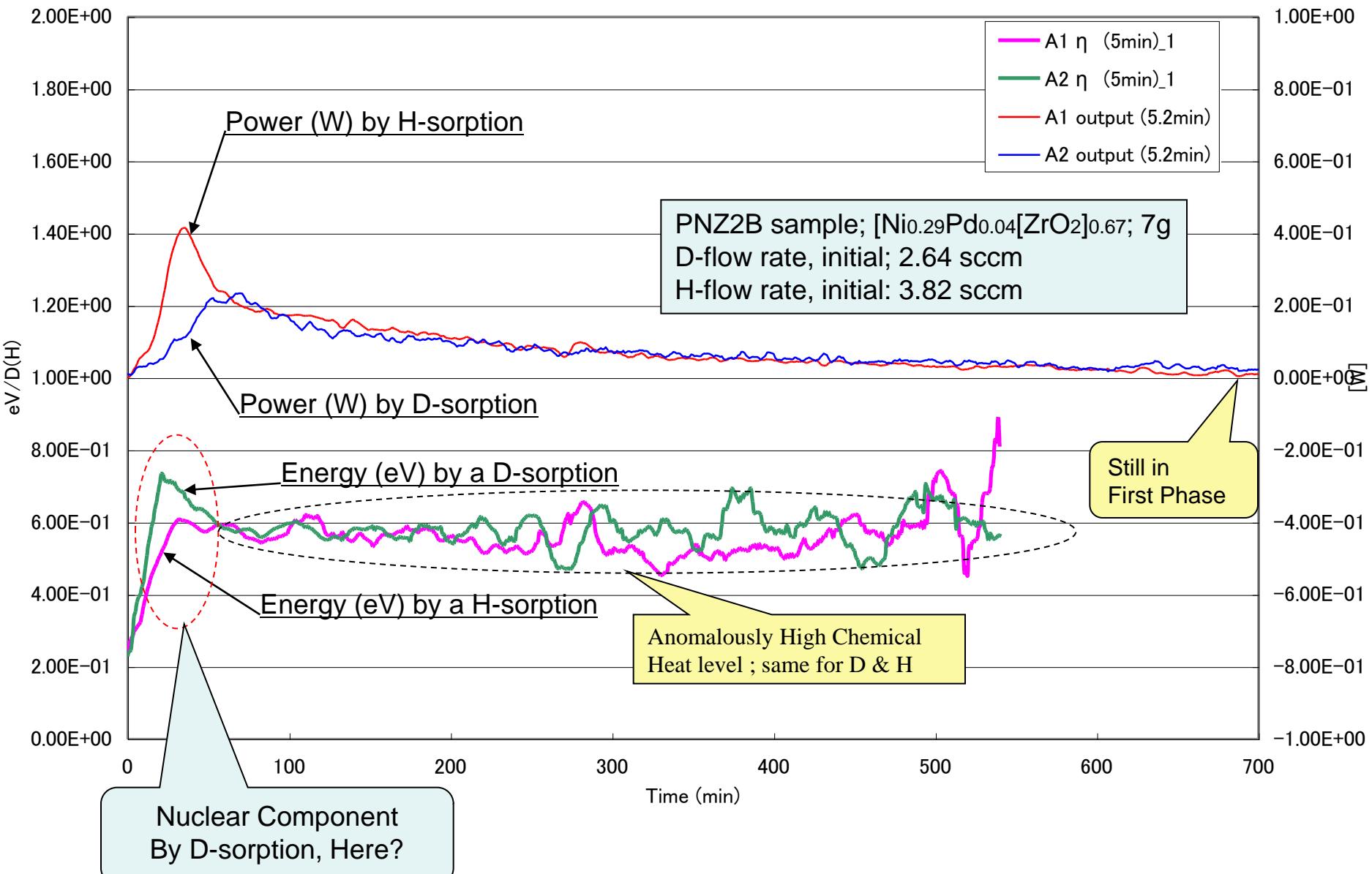
Specific Heat Data for 1st Phase; PNZ2B Sample by Brian Ahern

skip

PNZ2B run#	SH D (kJ)	SH H (kJ)	SH/g– NiPd D	SH/g– NiPd H	D/[NiPd]	H/[NiPd]	eV/D	eV/H	eV/Pd D	eV/Pd H
#1	3.78	3.54	2.78	2.6	3.21	3.36	0.58	0.52	14.9	13.9
#1d	-0.14	-0.14	-0.1	-0.1						
#1A	0.506	0.464	0.37	0.34	0.31	0.37	0.8	0.61	1.7	1.6
#1Ad	-0.13	-0.2	-0.096	-0.147						
#1B	0.234	0.305	0.17	0.22	0.32	0.34	0.36	0.43	0.8	1
#1Bd	-0.14	-0.16	-0.1	-0.12						
#2 (De-Ox)	2.35	2.02	1.72	1.48	1.89	2.02	0.57	0.52	8.6	8.4

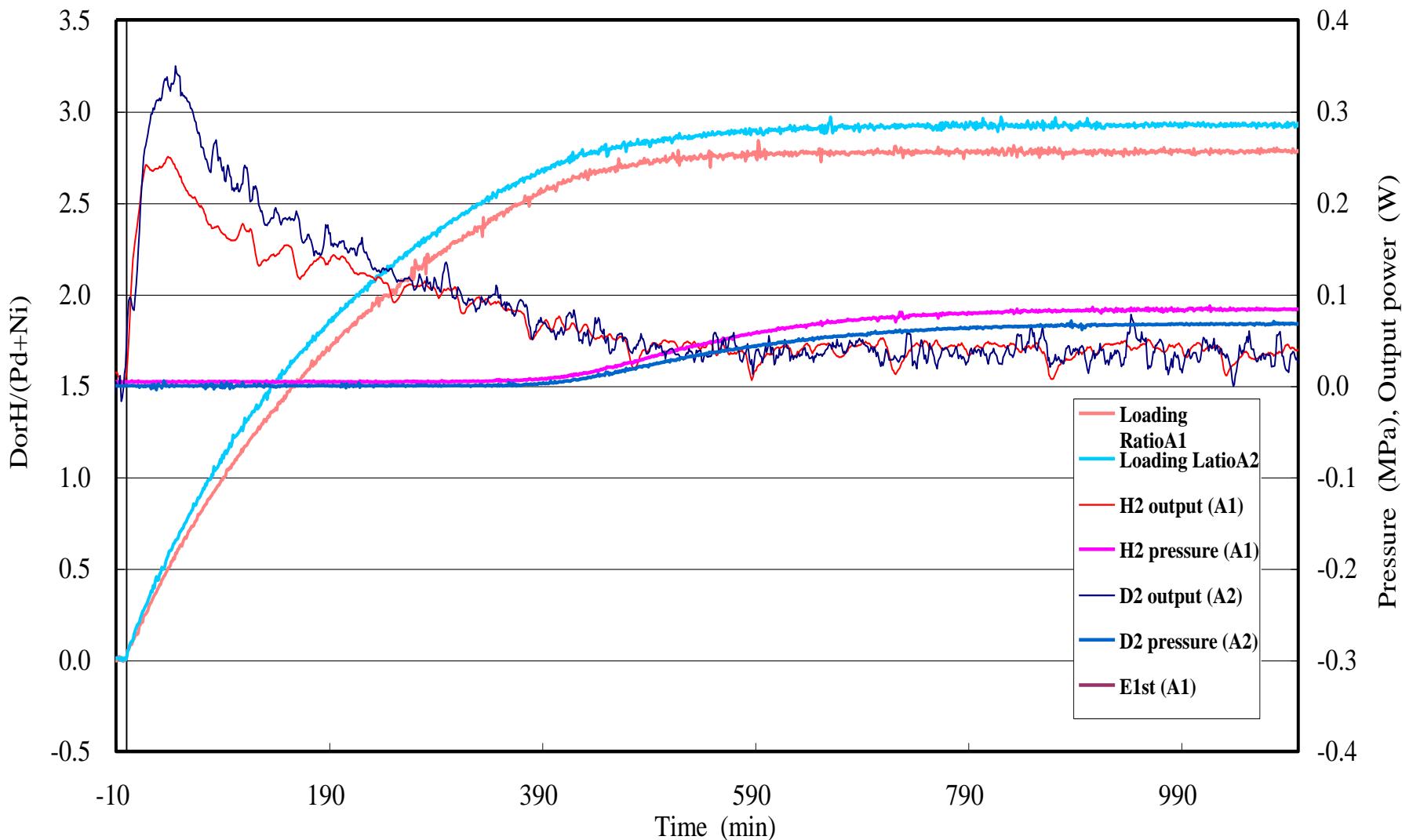
We need to adjust gas-flow rates as same as possible between D and H.

PNZ2B1,2#1; η -values; [Ni7Pd1]1.6g



Raw Data for H-PNZ2B3#2 vs. D-PNZ2B4#2;

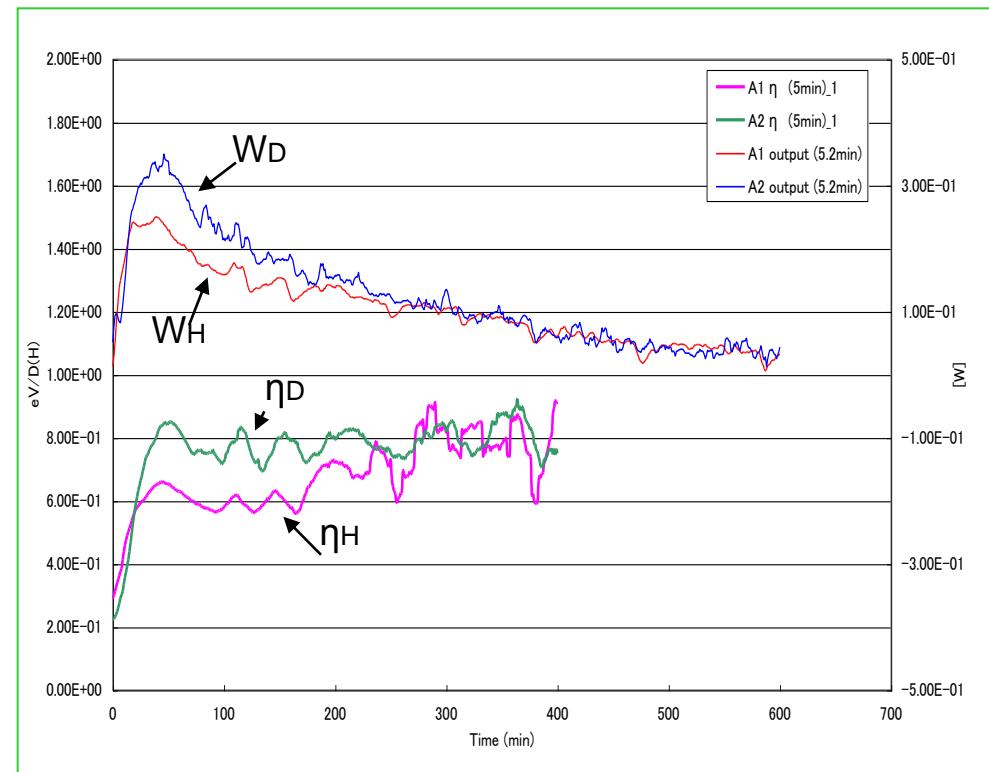
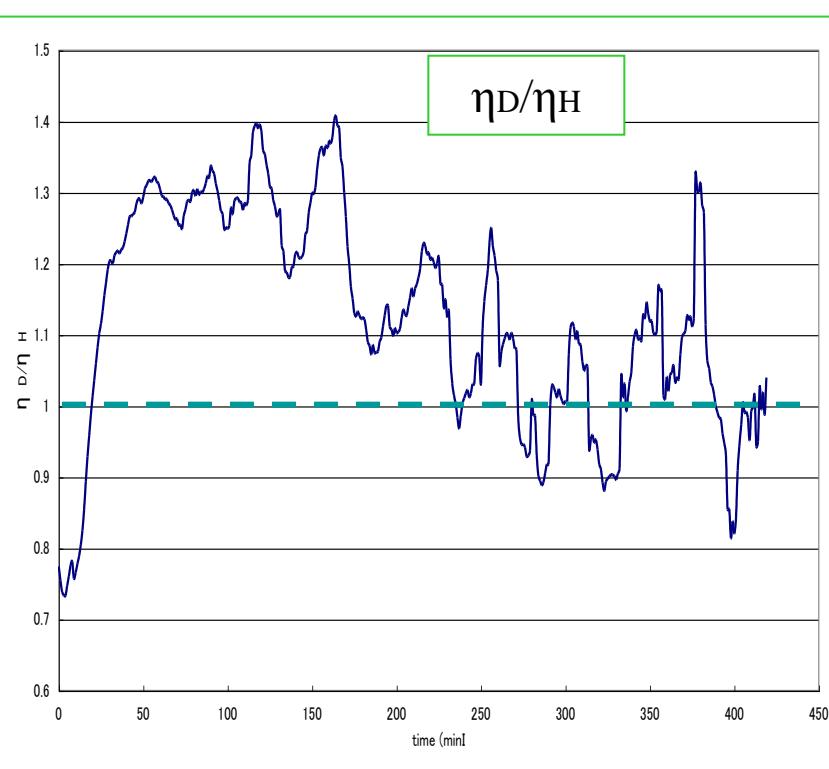
3.1sccm (H), 3.6sccm(D); **After forced de-oxidization of used sample**



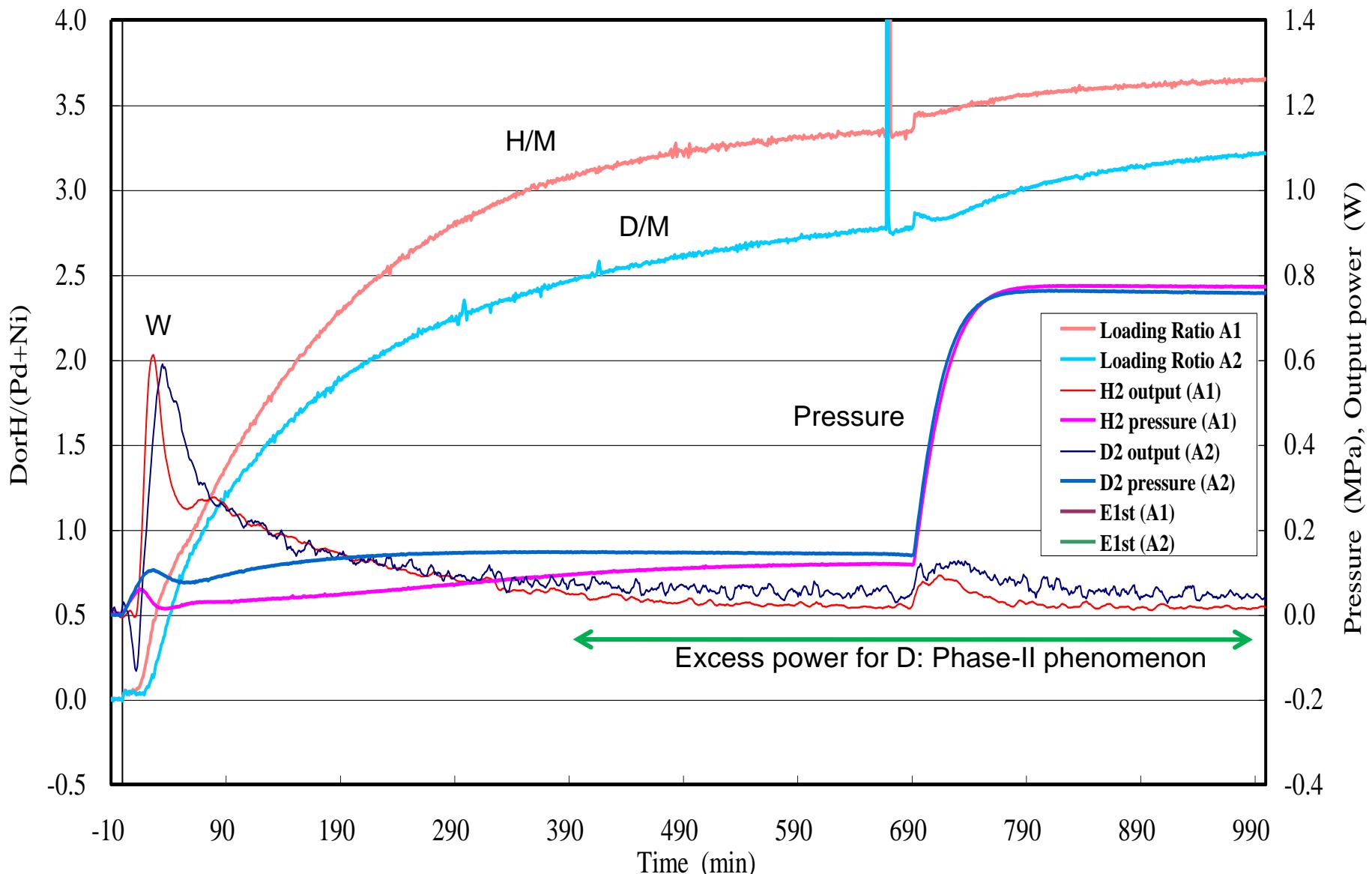
PNZ2B sample gave anomalously large heat and isotopic effect even after the forced reduction of Oxygen

: Heat-Power (W), Energy per D(H)-sorption (η) and η_D/η_H

D-PNZ2B#2 vs. H-PNZ2B#2



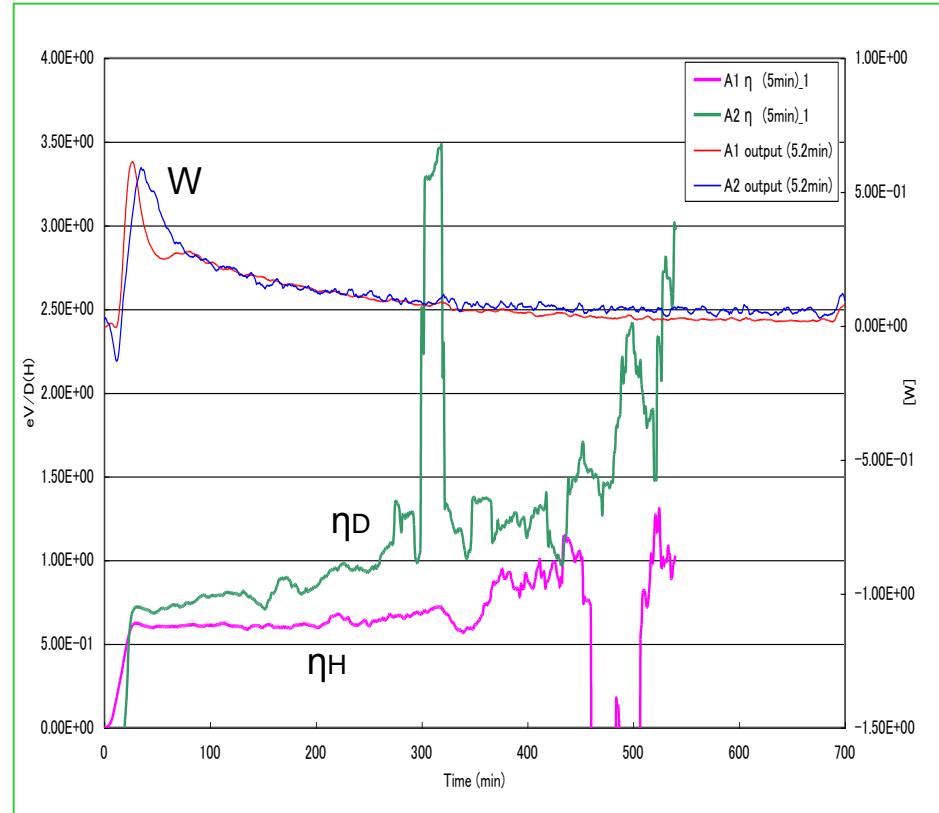
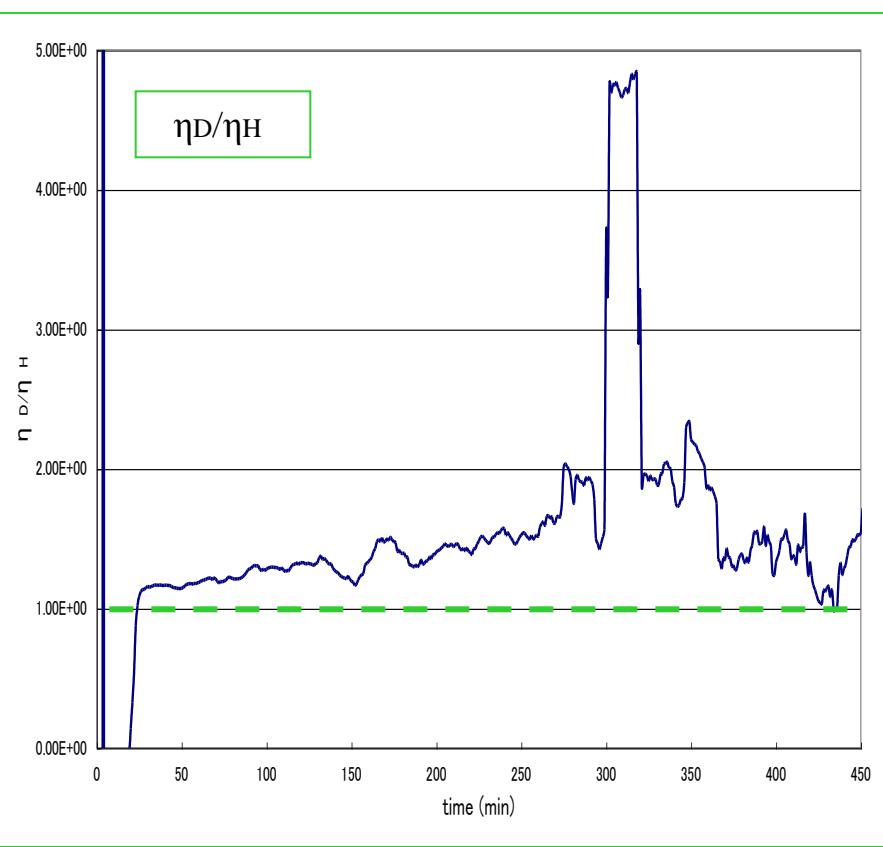
Raw Data for H-PNZ2B3#3 vs. D-PNZ2B4#3; 5.0sccm (H), 6.1sccm (D)
: After forced oxidization (8.7% MO)



PNZ2B sample gave anomalously large heat and isotopic effect after the Forced Oxidization of usedf sample

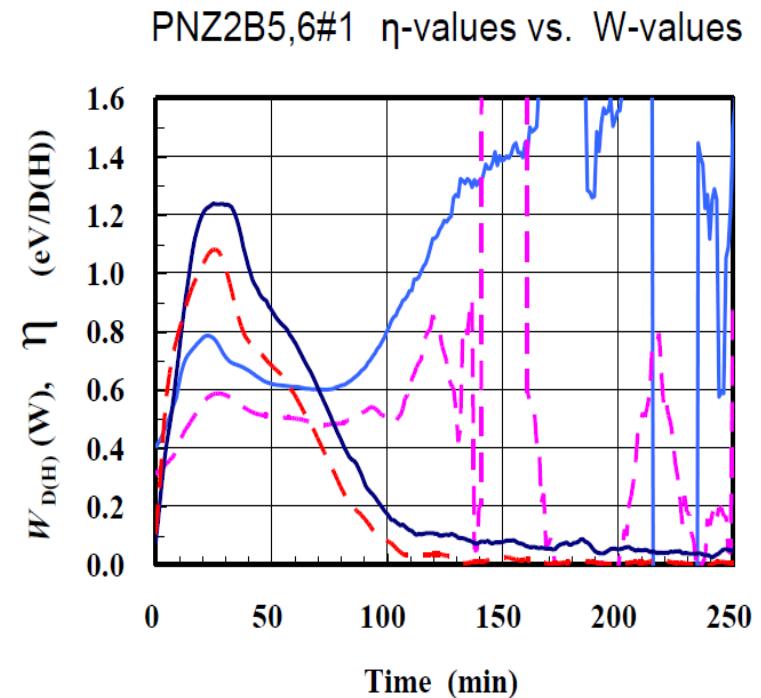
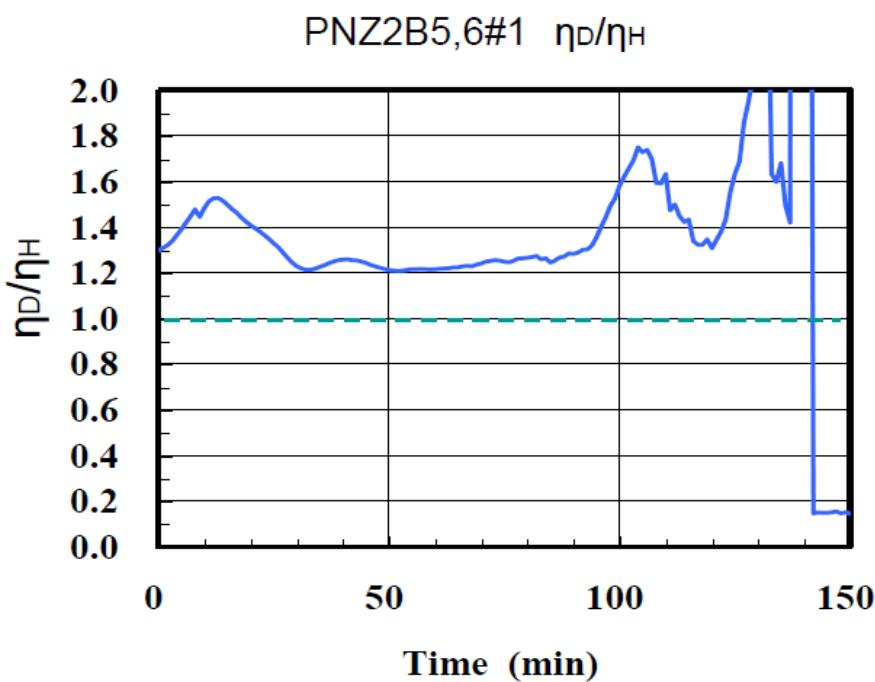
: Heat-Power (W), Energy per D(H)-sorption (η) and η_D/η_H

Nuclear Effect for $\eta_D/\eta_H \gg 1.0$!(?)

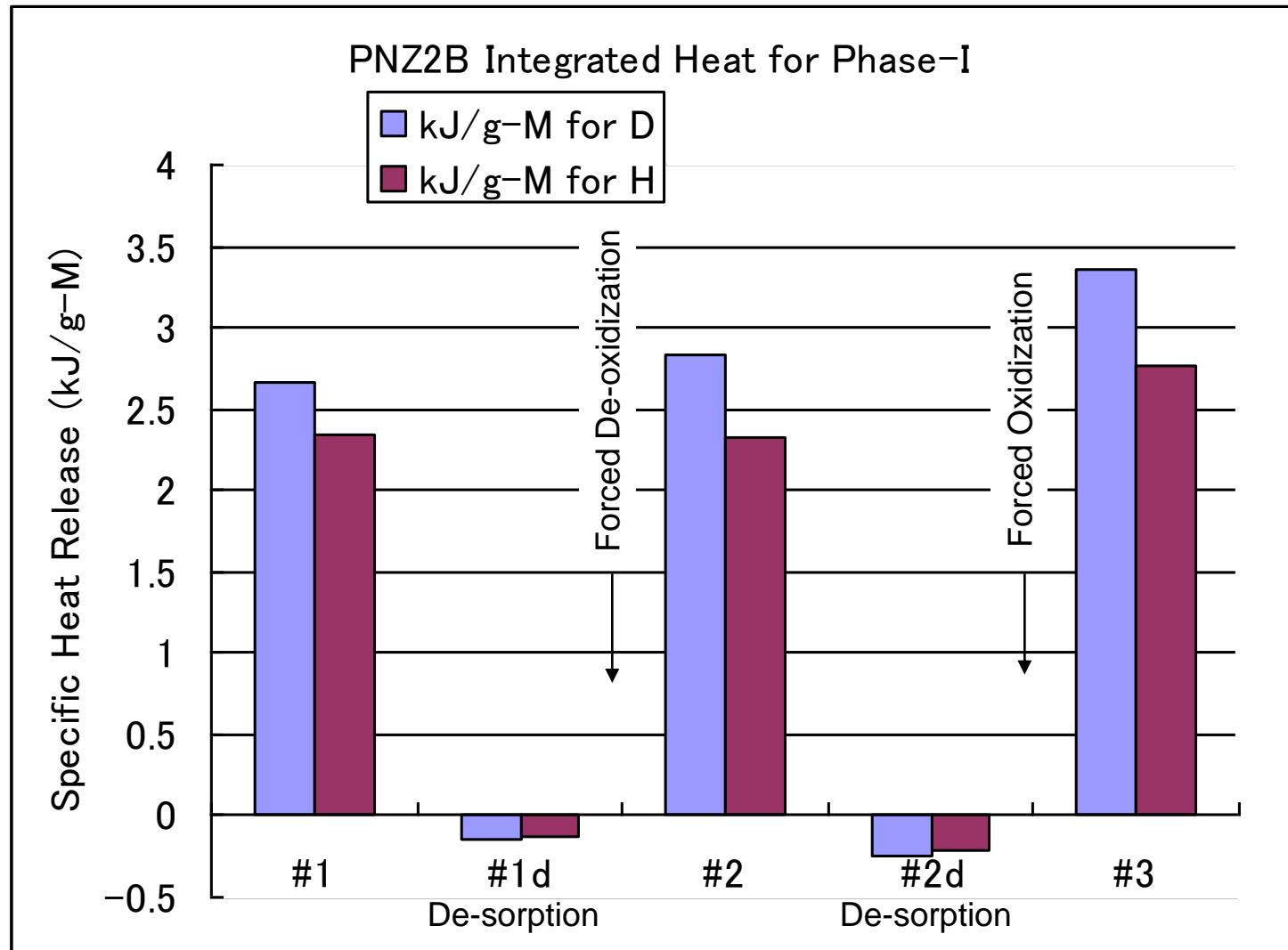


PNZ2B sample gave anomalously large heat and isotopic effect for #1 runs of reused samples (5,6)

: Heat-Power (W), Energy per D(H)-sorption (η) and η_D/η_H

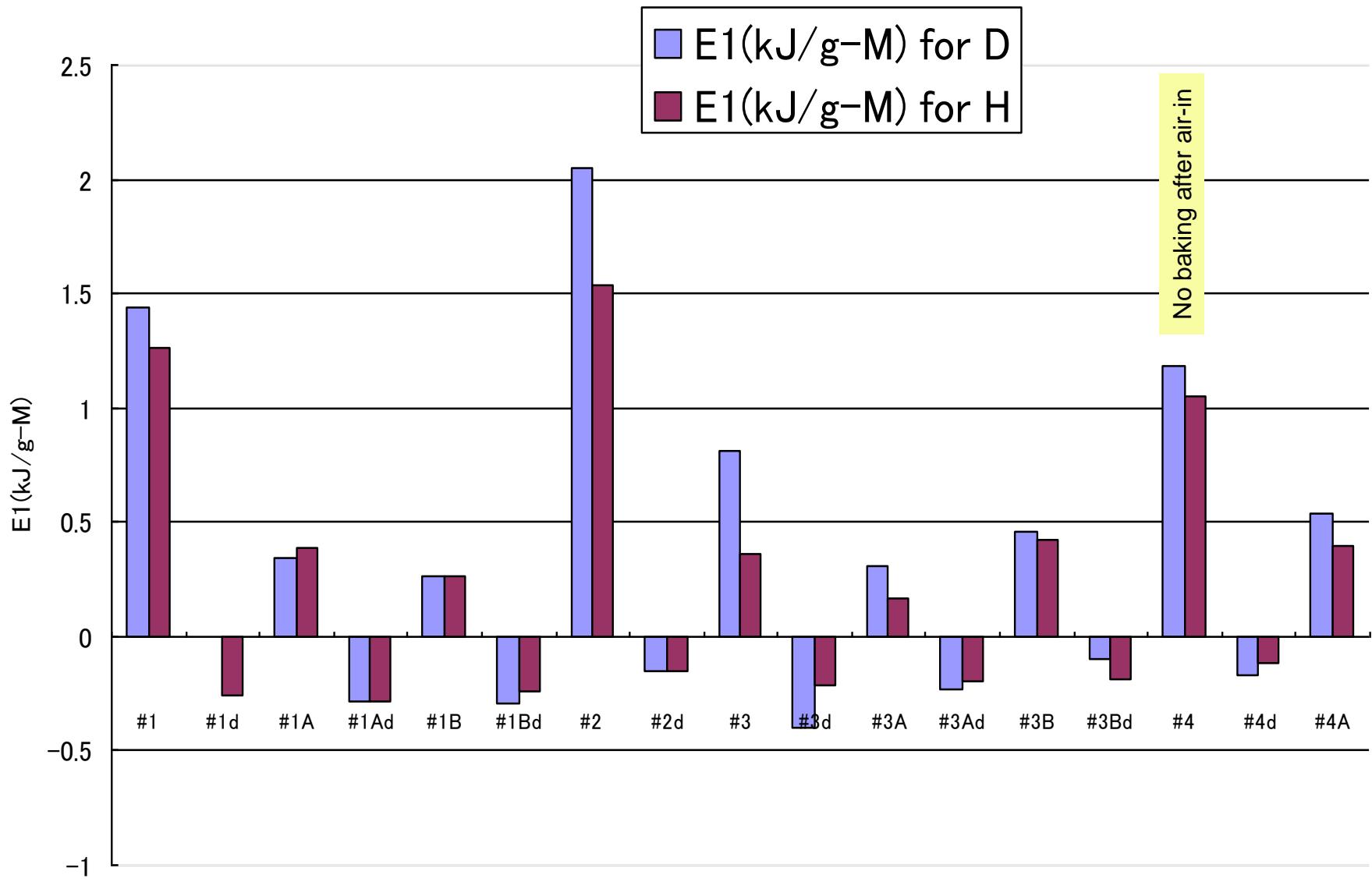


Anomalously Large Heat Release by PNZ2B3(4) sample



Total Heat in Phase-I changes by run condition:
De-oxidization (#2) works well for used sample

Phase-I Heat E1 for PNZ2B5,6; Reused Samples

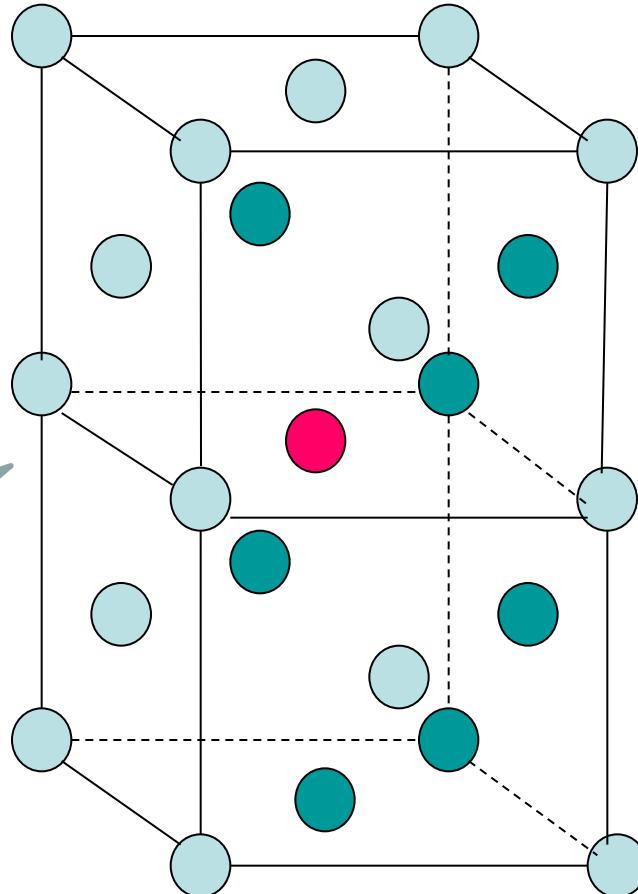


Ni₇Pd₁ ?

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(pink circle) Pd
(light blue circle) Ni

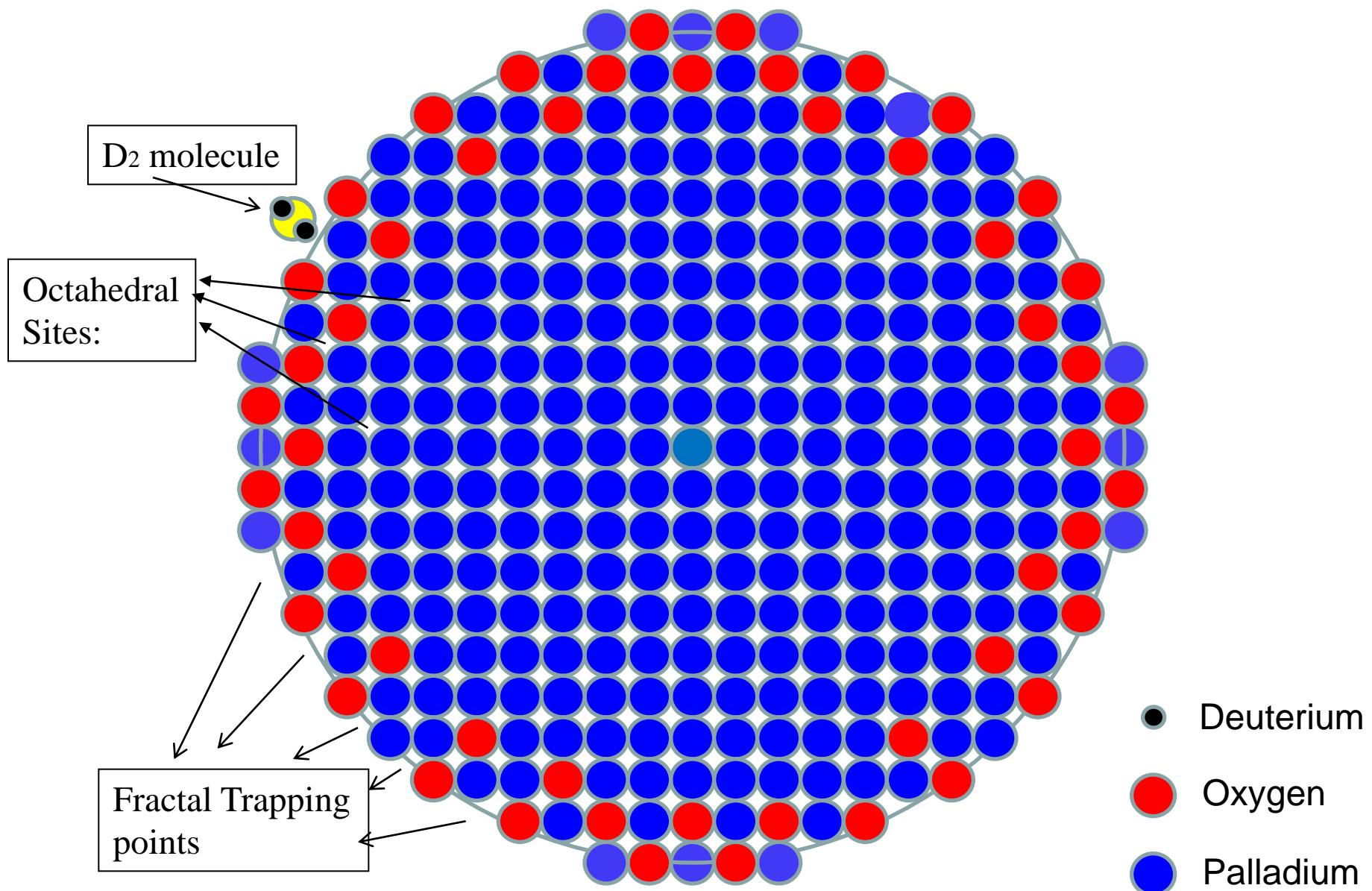
Ni-Pd nano-particle does not have such regular lattice structure, but has random and complex surface with defects!



B2 Sample by Brian Ahern: Ni_{0.29}Pd_{0.04}Zr_{0.67}

PdO 30% coating on surface of Pd nano-particle

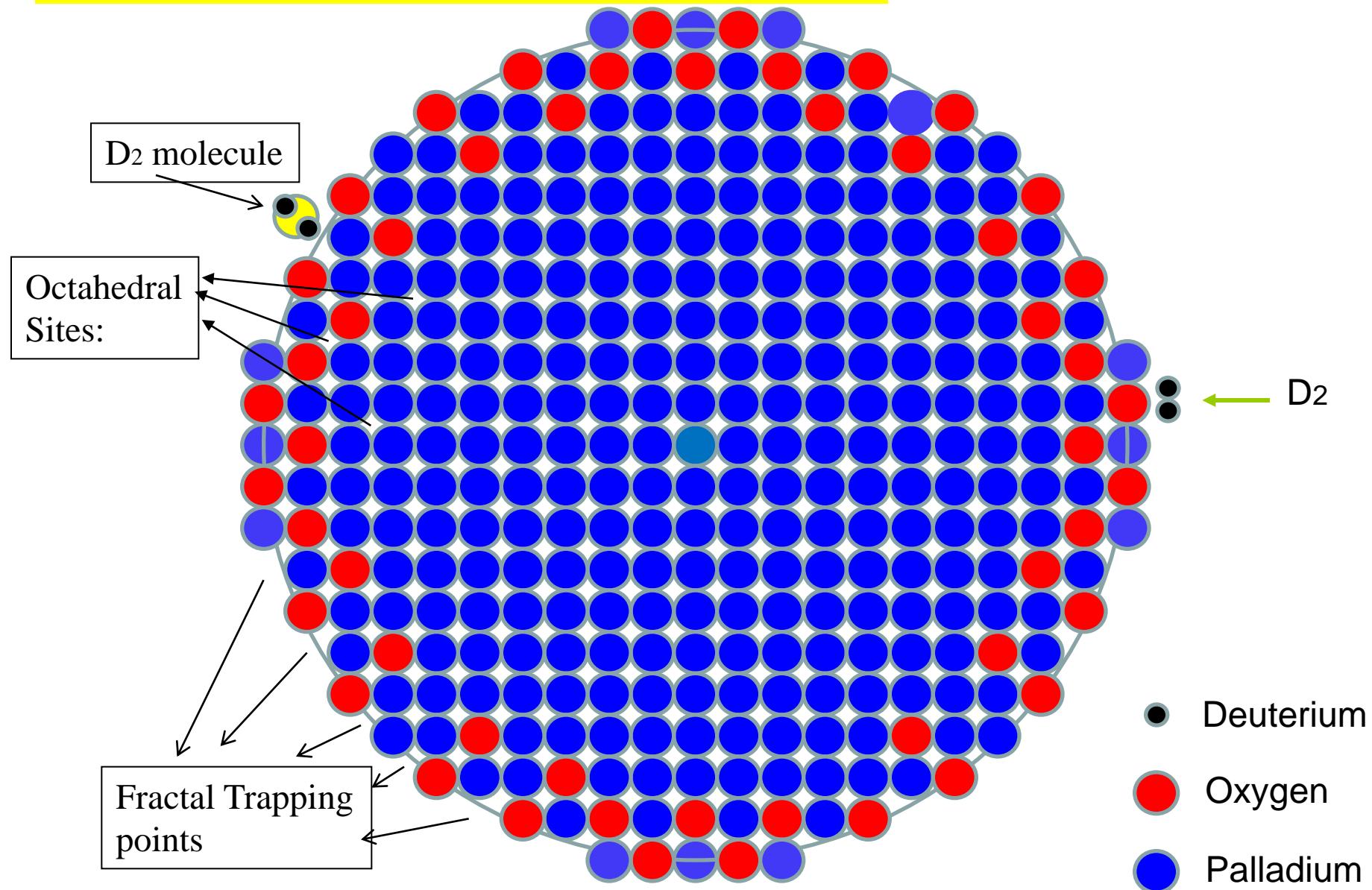
$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1 - 0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



PdO coating on surface of Pd nano-particle

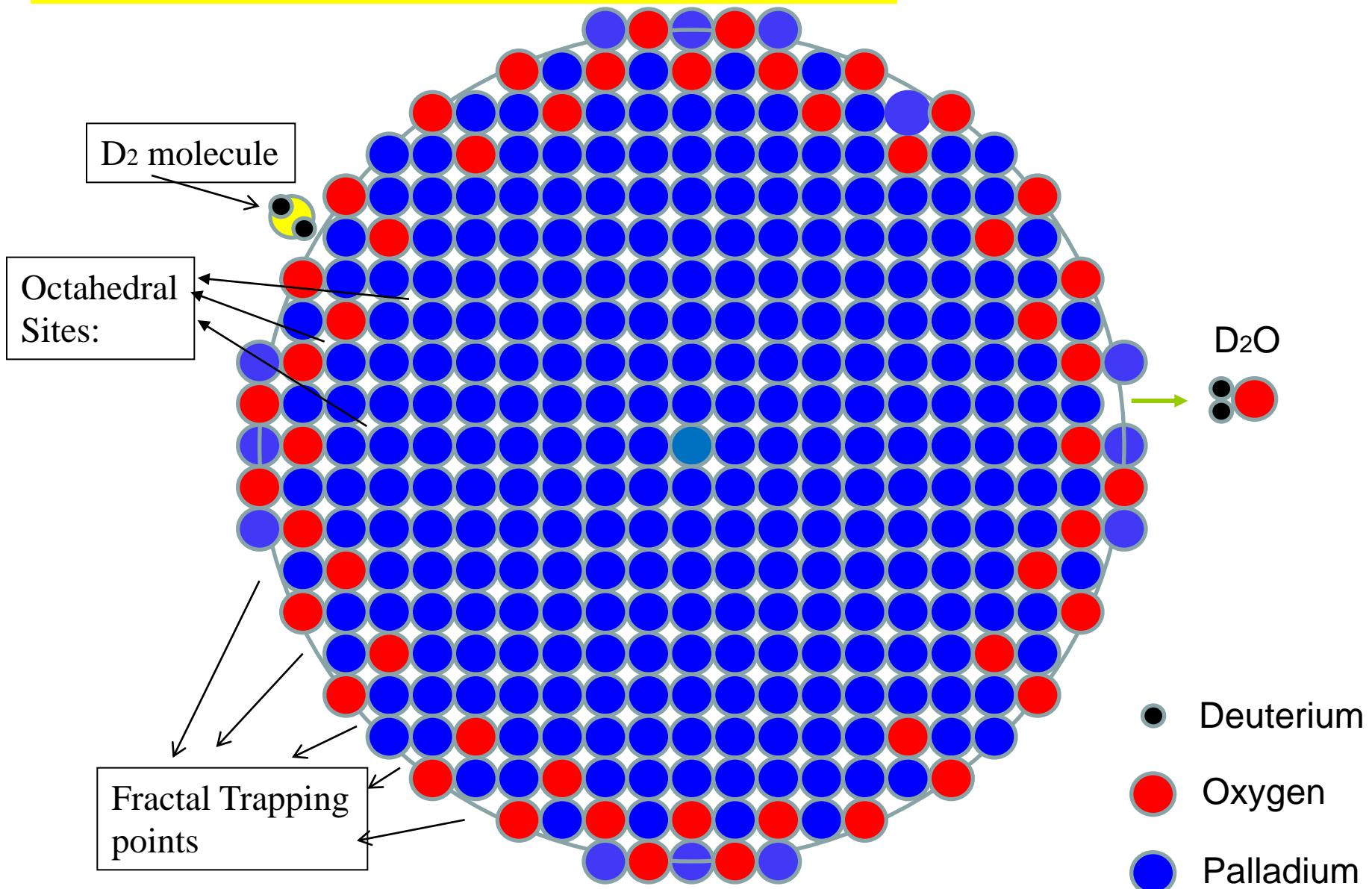
1) Start D₂ charge

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1 - 0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



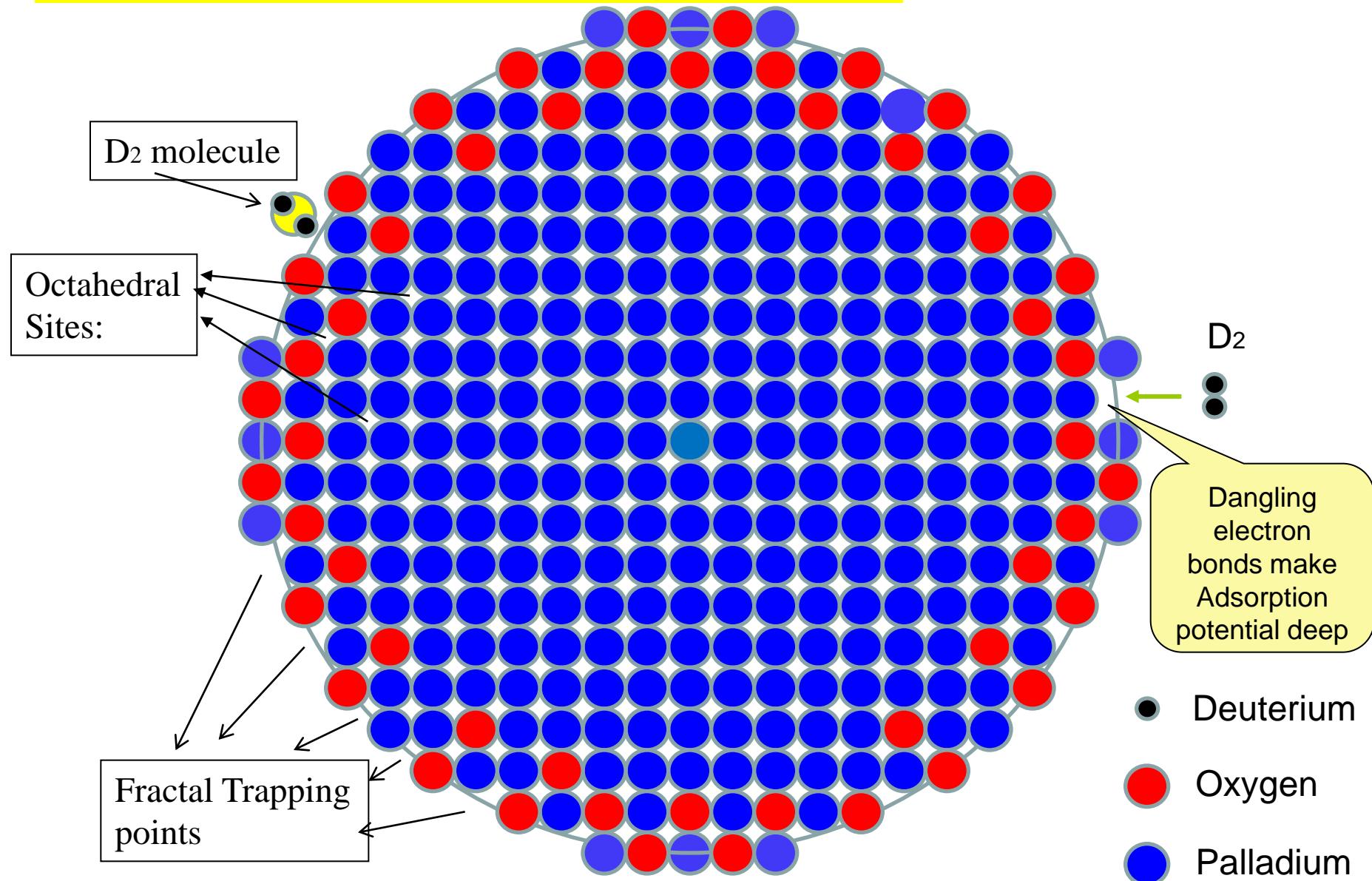
PdO coating on surface of Pd nano-particle: 2) Local De-oxidation

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



PdO coating on surface of Pd nano-particle: 3) D₂ comes in a sub-nano-hole (nano-dip)

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



PdO coating on surface of Pd nano-particle:
4) Another D₂ comes onto trapped D₂

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$

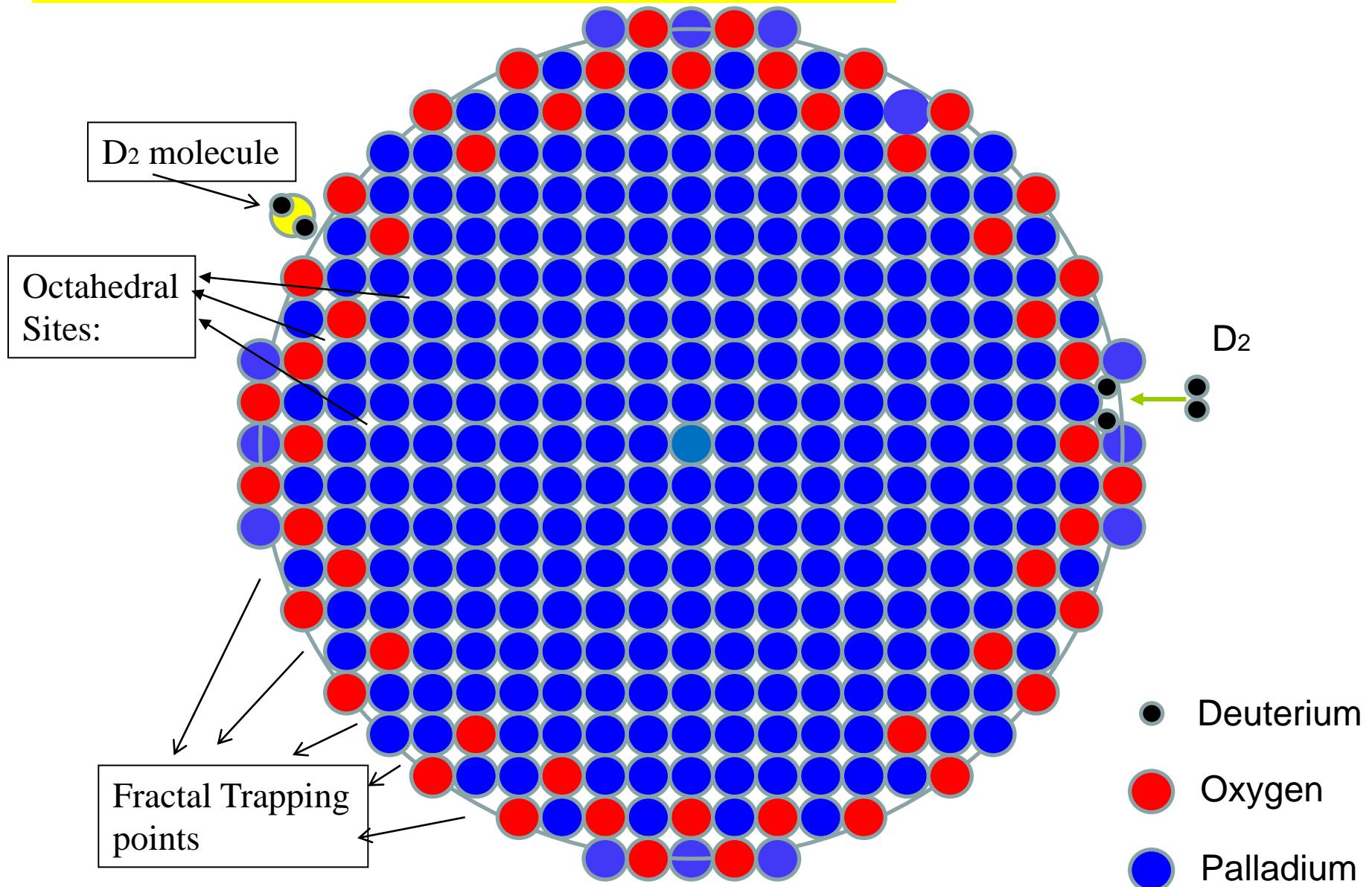
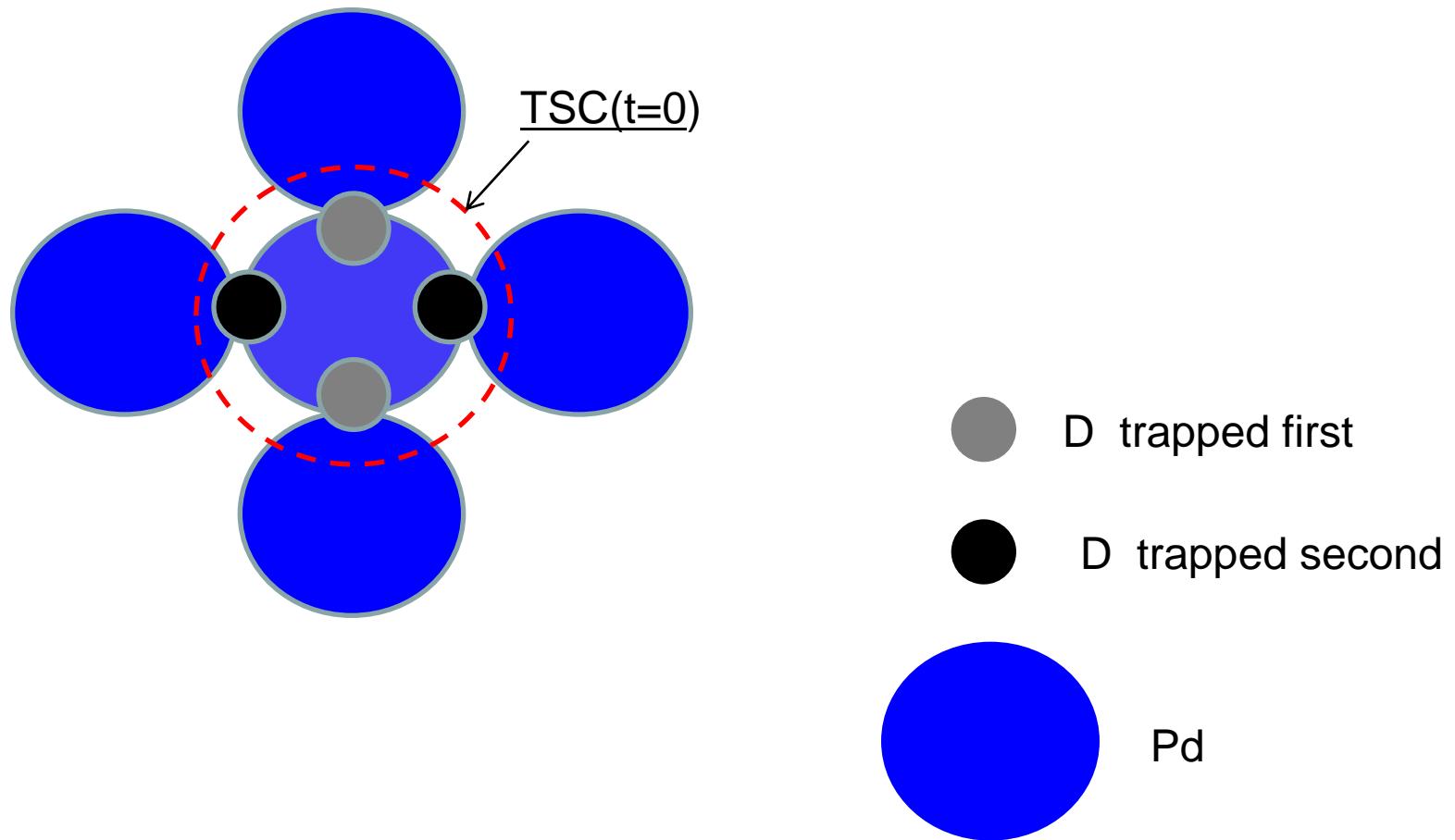
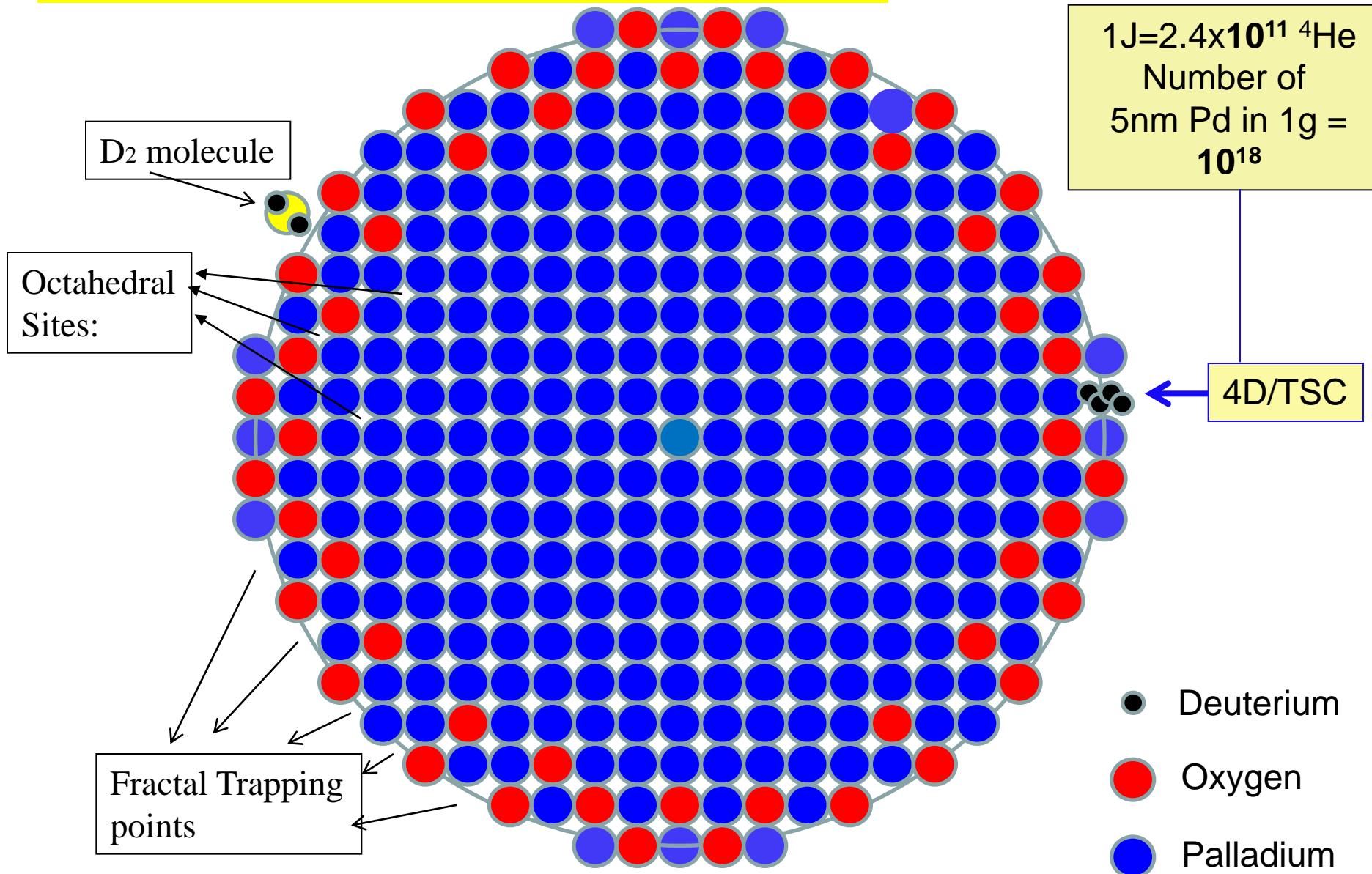


Image on Formation of TSC($t=0$) at Sub-Nano-Hole



PdO coating on surface of Pd nano-particle: 5) 4D/TSC forms at a sub-nano-hole

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



4D/TSC fusion events in the beginning of D(H)-gas loading to PdO-coated Pd-particle

- Formation of 4D/TSC($t=0$) makes 100% simultaneous 4D fusion (23.8MeV/He-4) in 1.4 fs (*A. Takahashi, LENR-SB Vol.1&2*)
- One 4D/TSC($t=0$) generation per second in SNHs, per 10 million Pd nano-particles, generates about 1 watt heat-power level for 1g-Pd-contained PZ sample under D-gas charging
- It is comparable to observed heat-power level in the beginning of D-loading for PZ sample (see below)

If heat evolution is a step function, we observe like-this.
Heat evolution by H-gas follows to it.

Indicial Response for Calorimetry
 $: (1 - \exp(-t/T_1))$, $T_1 = 5$ min

Observed Heat Response for rapid heat release

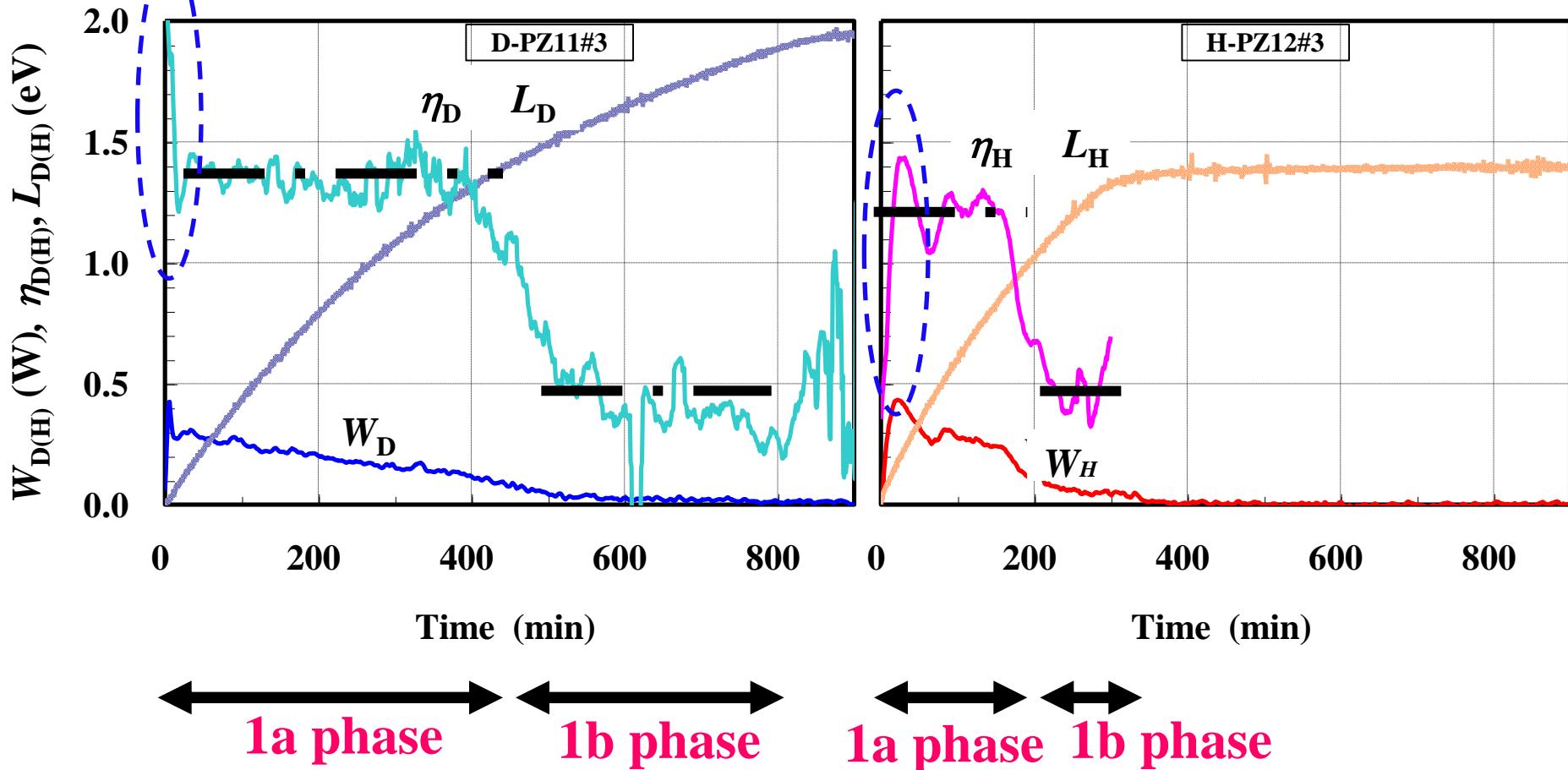
Rapid Heat Response : $\exp(-t/T_2)$, $T_2 = 3$ min
 By supposed Nuclear Reaction by D-gas on surface

Relative Scale

Time (min)

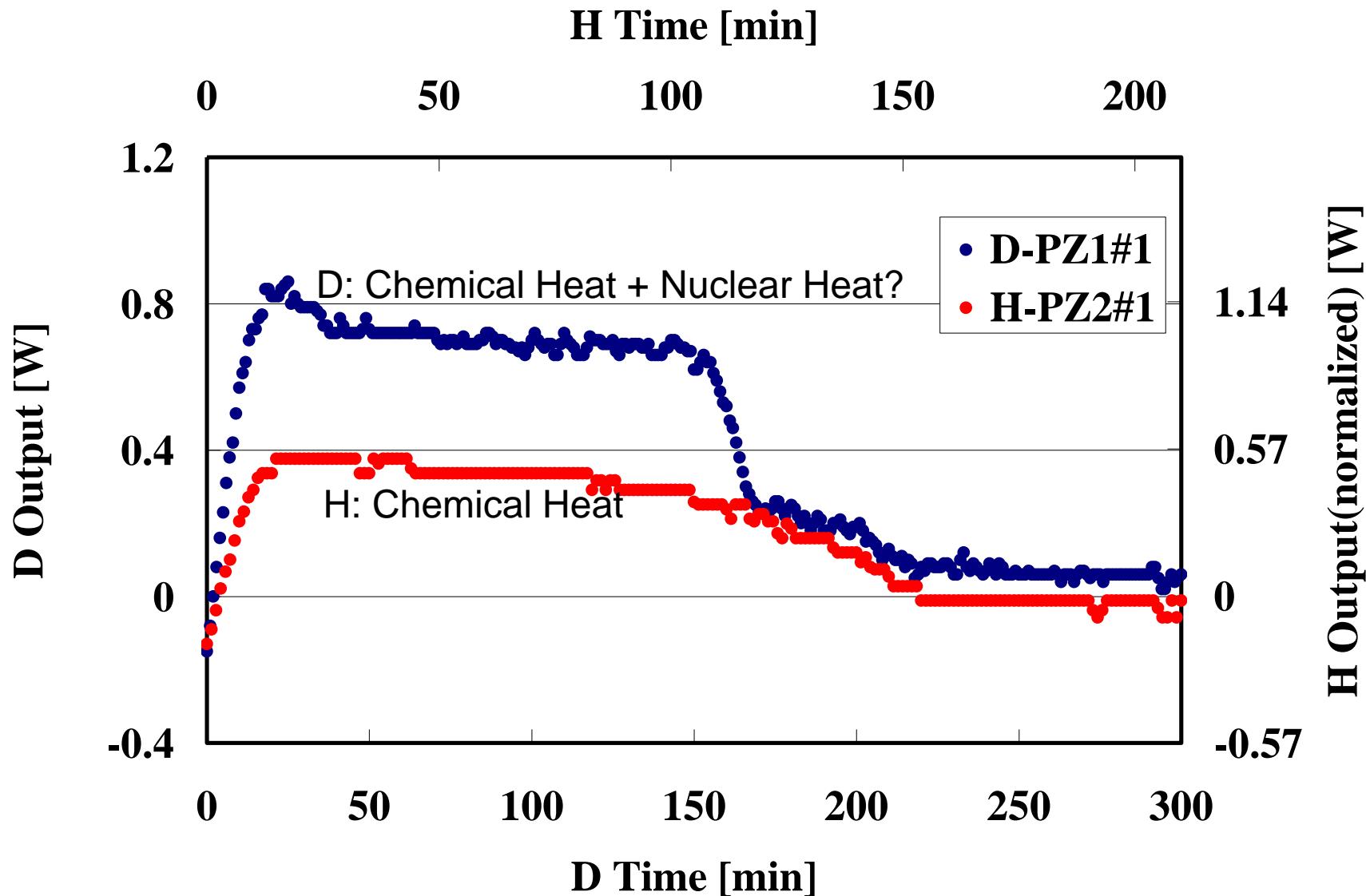
At the beginning, large heat-power appears for D-charging only!

Two components appear in Phase-I, by PdO effect?



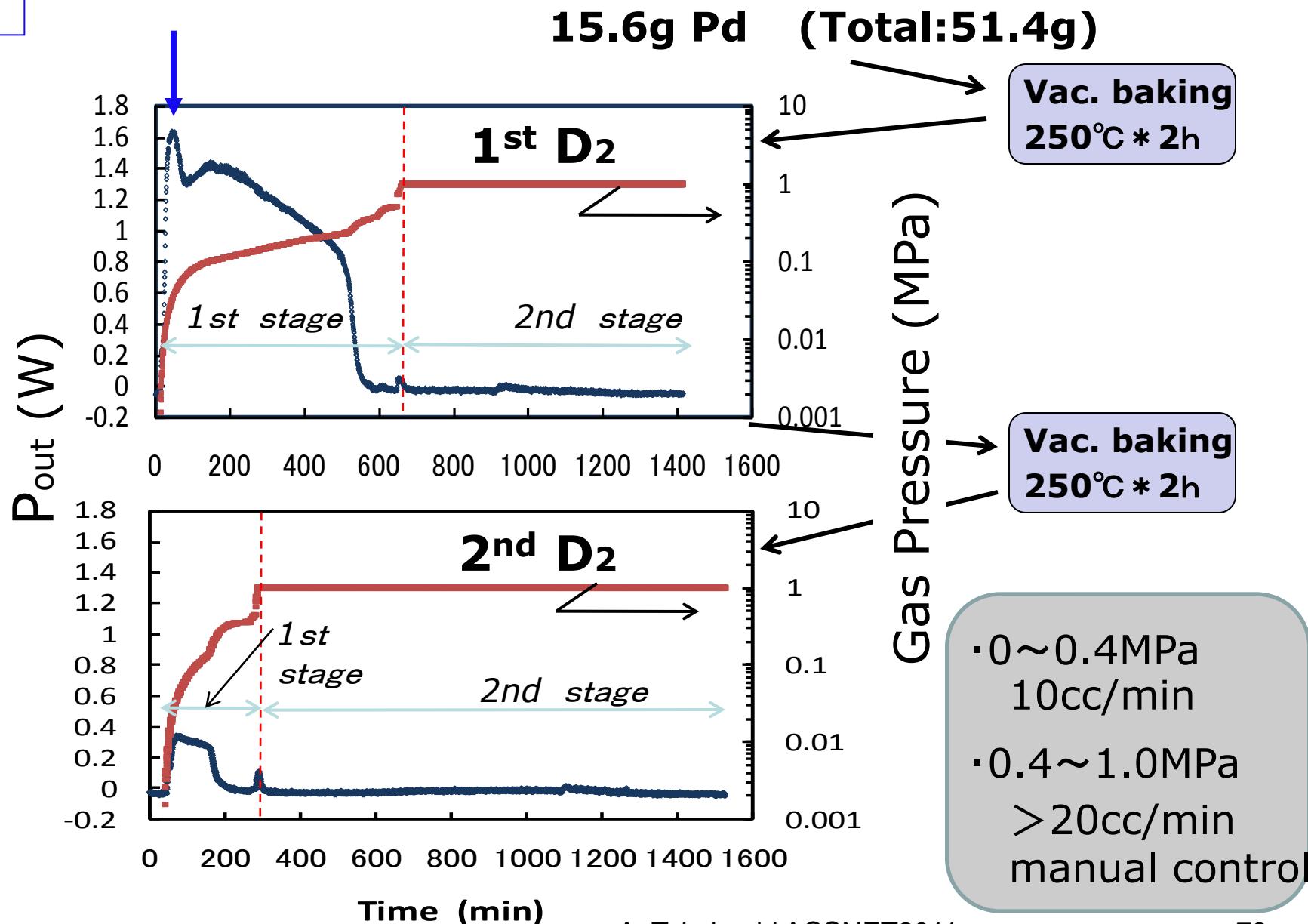
Typical variation of the specific sorption energy, η_D (η_H), compared with the power, W_D (W_H), and pressure, P_D (P_H), in the #3 run for the PZ11(12) sample.

Normalized Heat Evolution Curves in Phase-I; Case-I



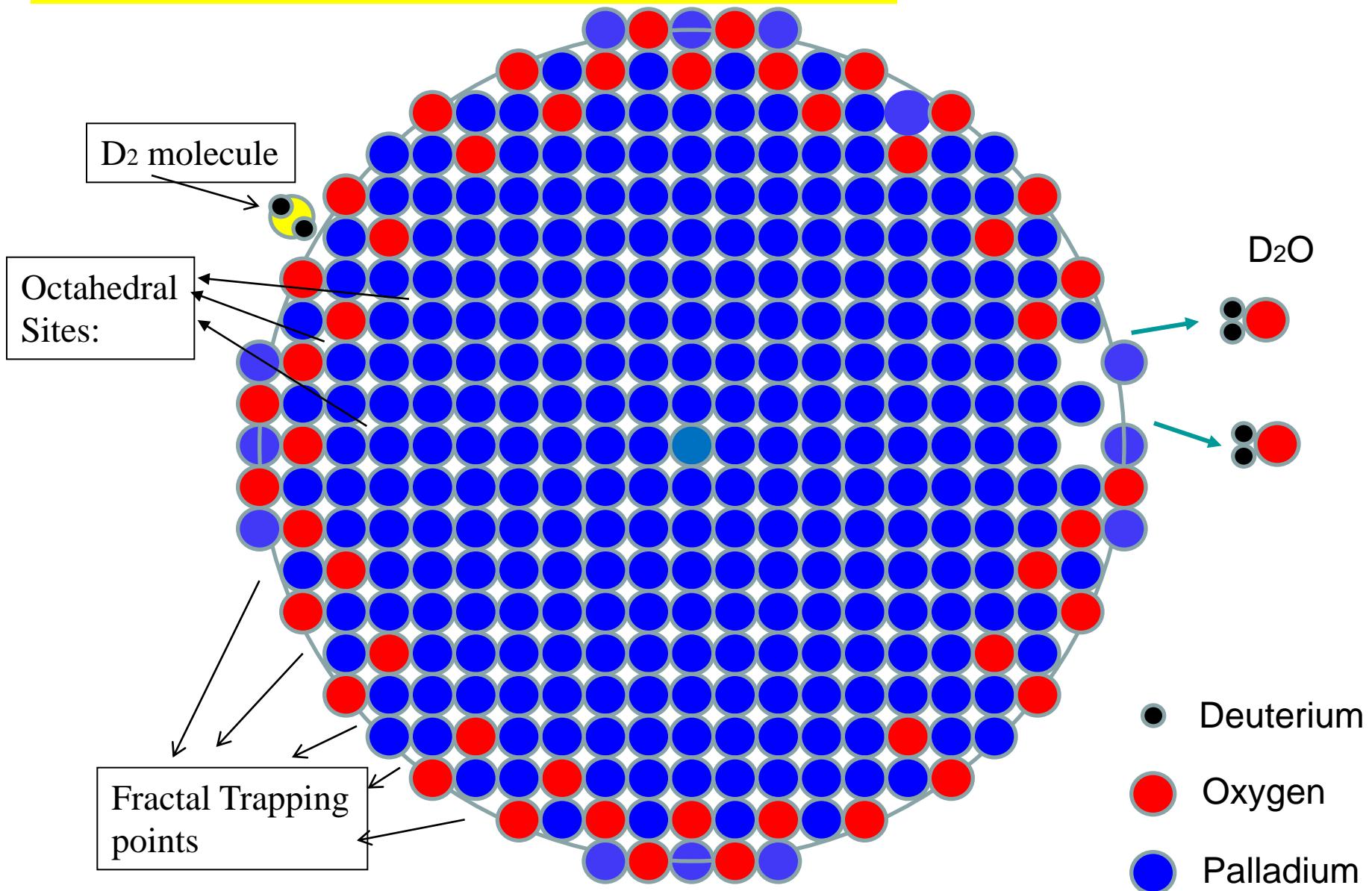
Heat Evolution : 30wt%Pd-ZrO₂

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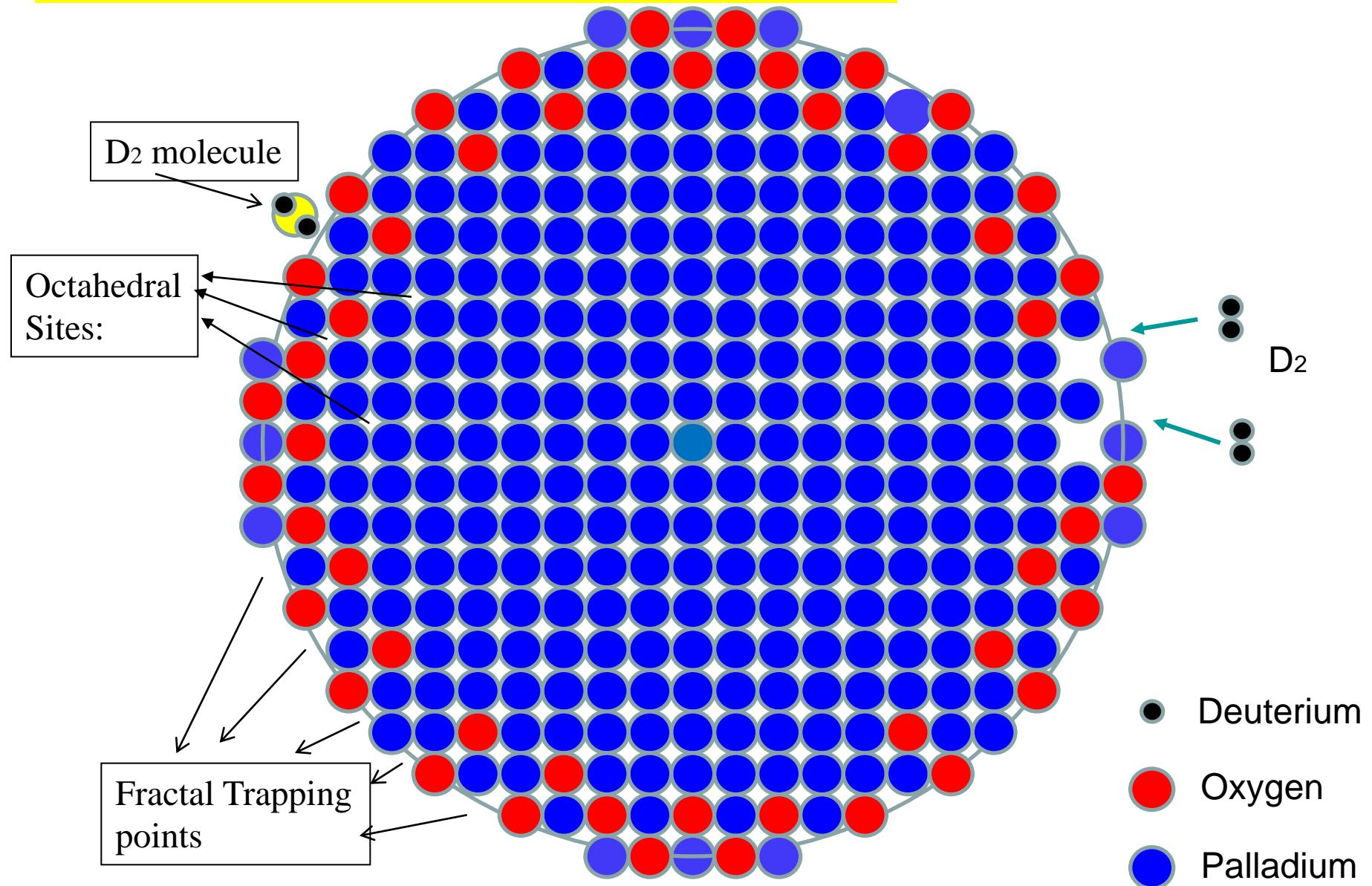
PdO coating on surface of Pd nano-particle: 6) De-oxidation proceeds

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



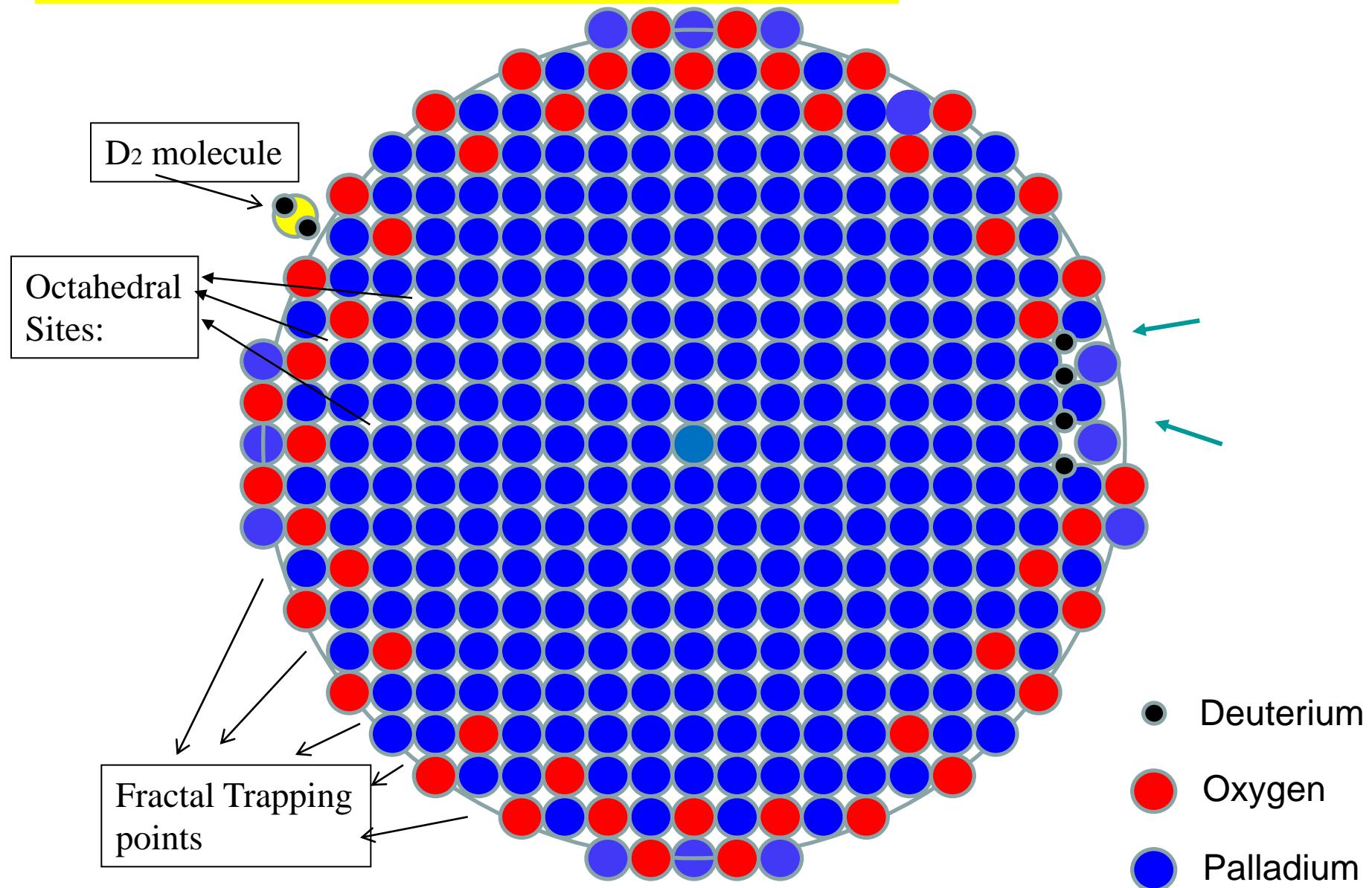
PdO coating on surface of Pd nano-particle: 7) D₂ comes in nano-holes

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



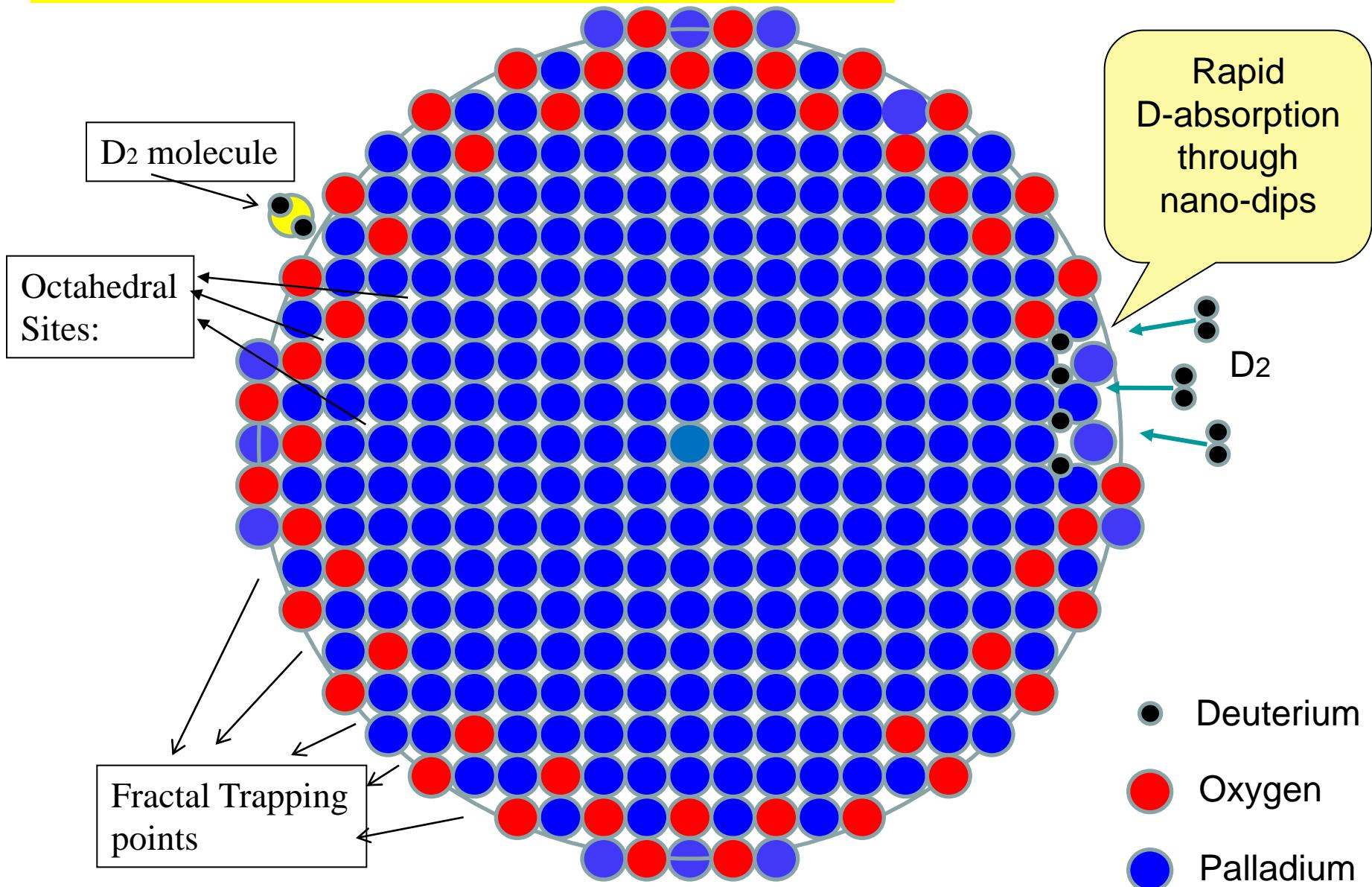
PdO coating on surface of Pd nano-particle: 8) Dissociated D-particles get in lattice

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



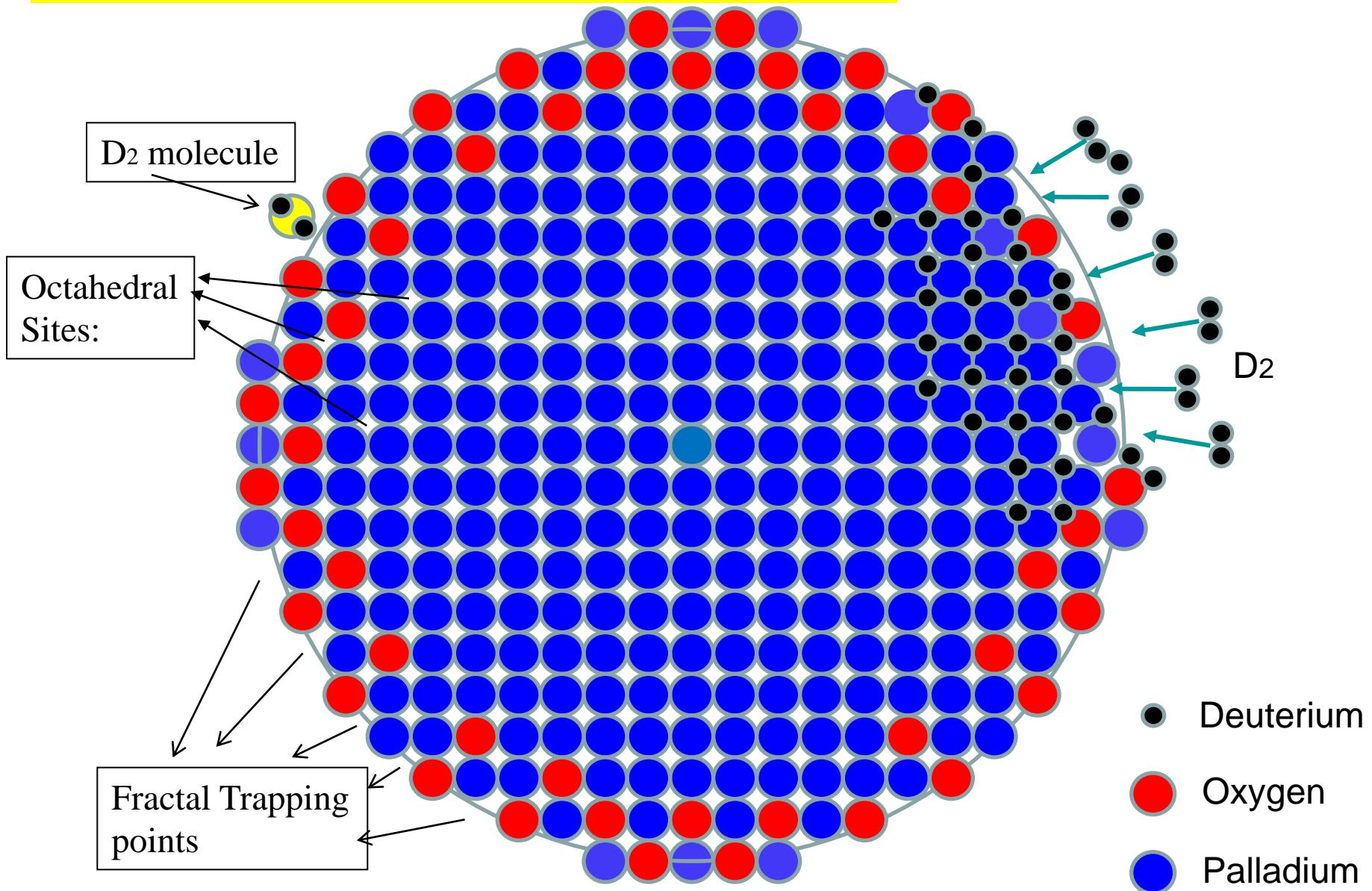
PdO coating on surface of Pd nano-particle: 9) D₂ molecules come in further

$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$

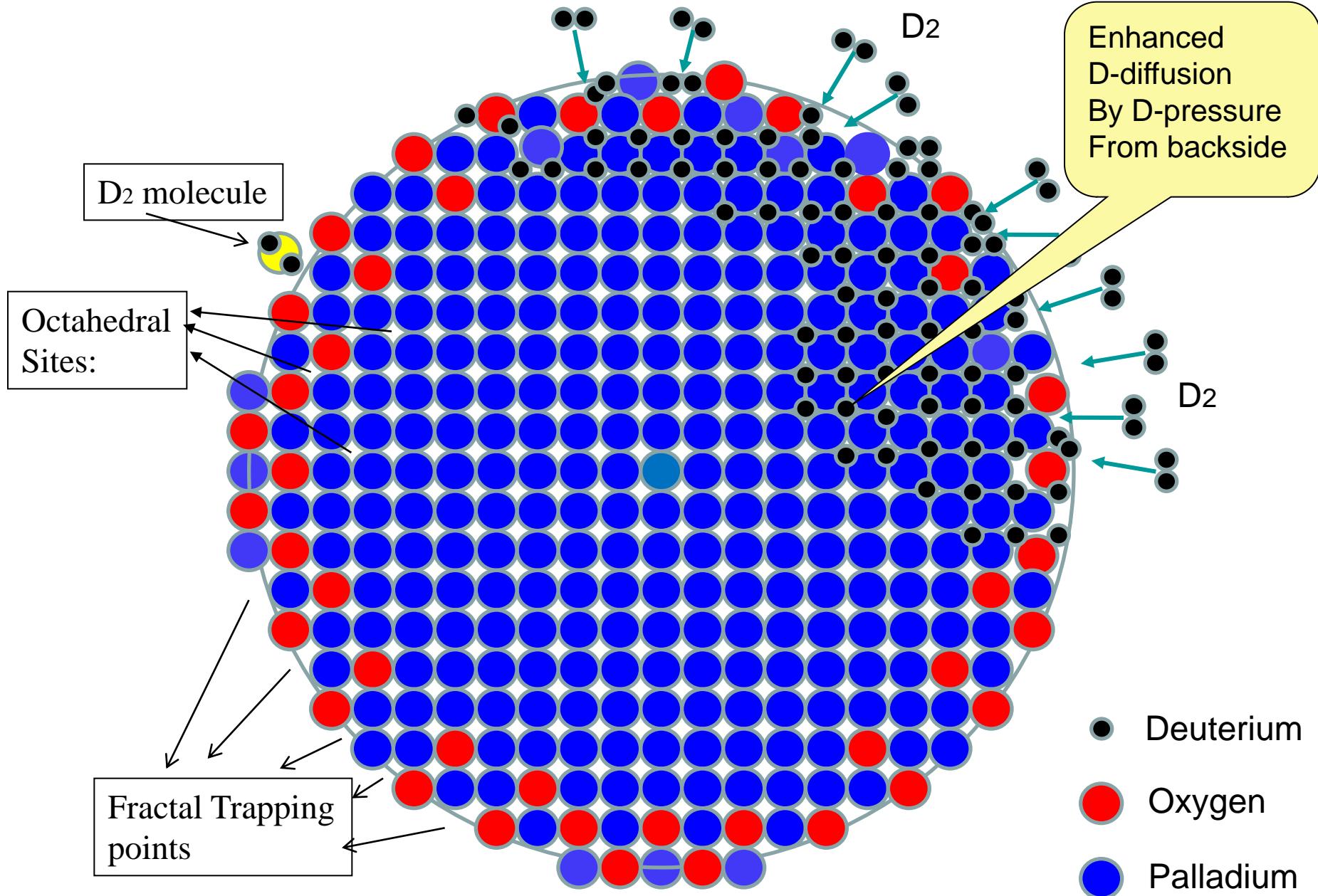


PdO coating on surface of Pd nano-particle: 10) QM penetration of D-particles deeper

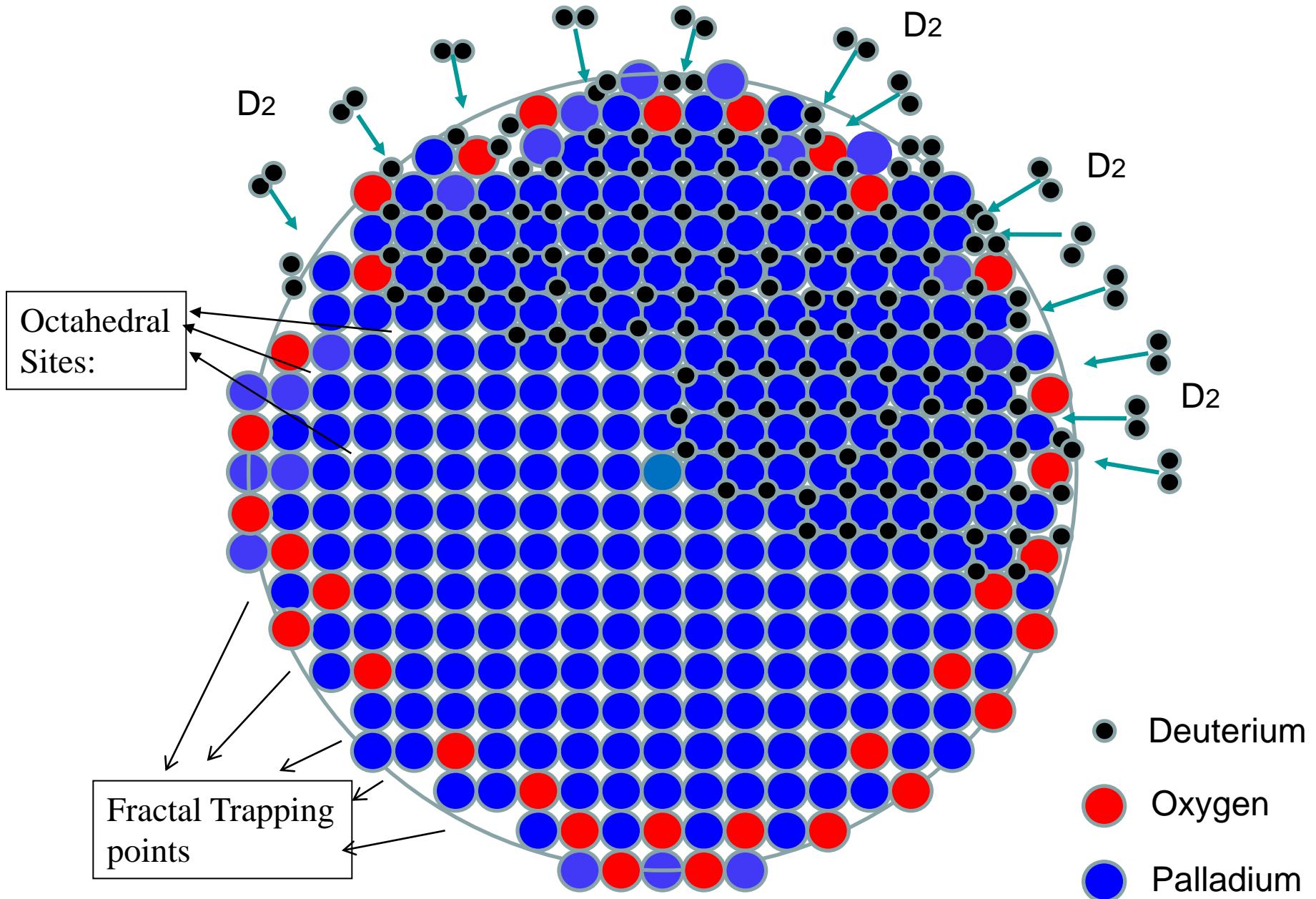
$$\begin{aligned} [\text{PdO}]/[\text{Pd}] &= [1-0.9^3]/0.9^3 \\ &= 0.27/0.729 = 0.37 \end{aligned}$$



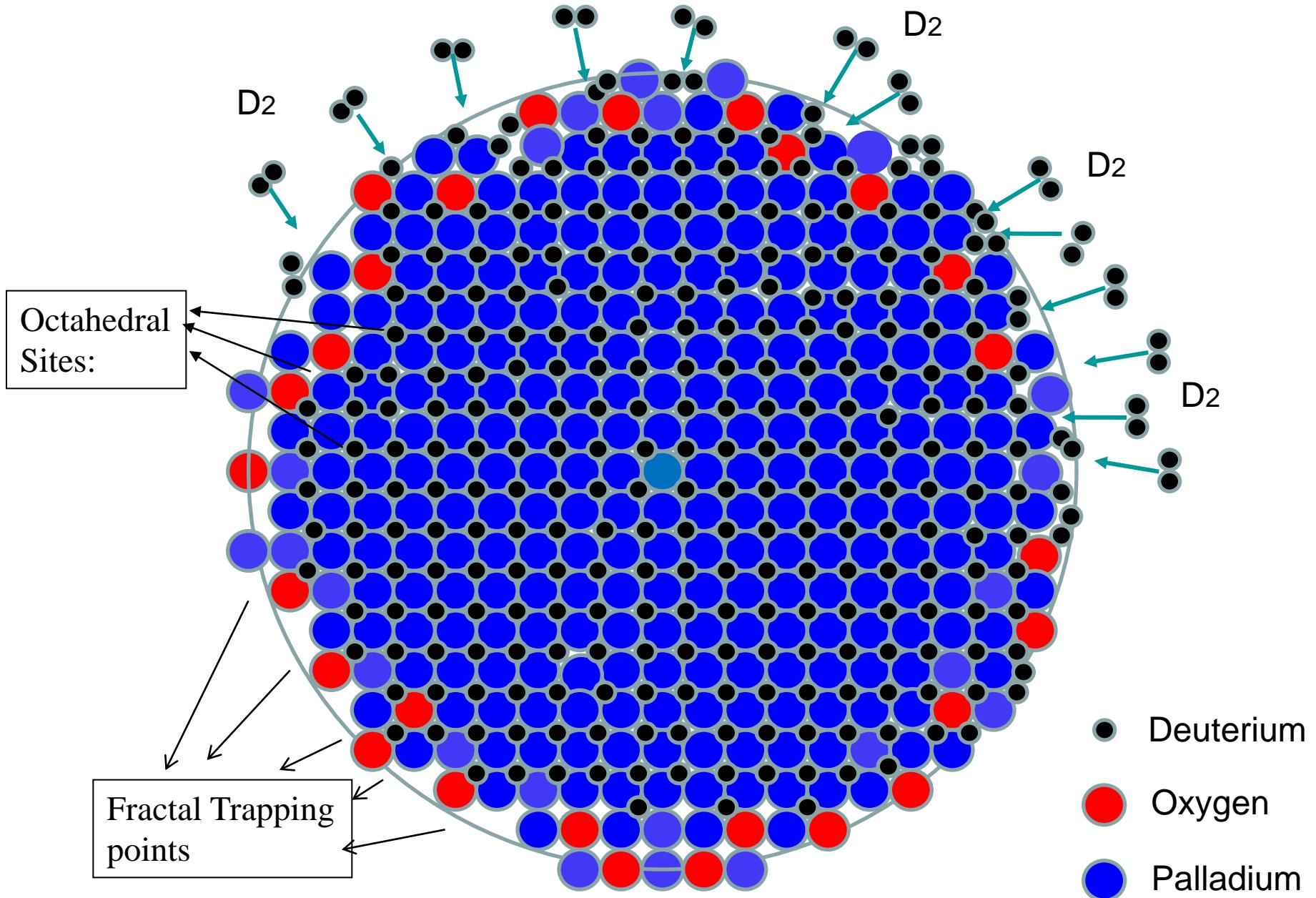
PdO coating on surface of Pd nano-particle and D-absorption: 11)



PdO coating on surface of Pd nano-particle and D-absorption:12)



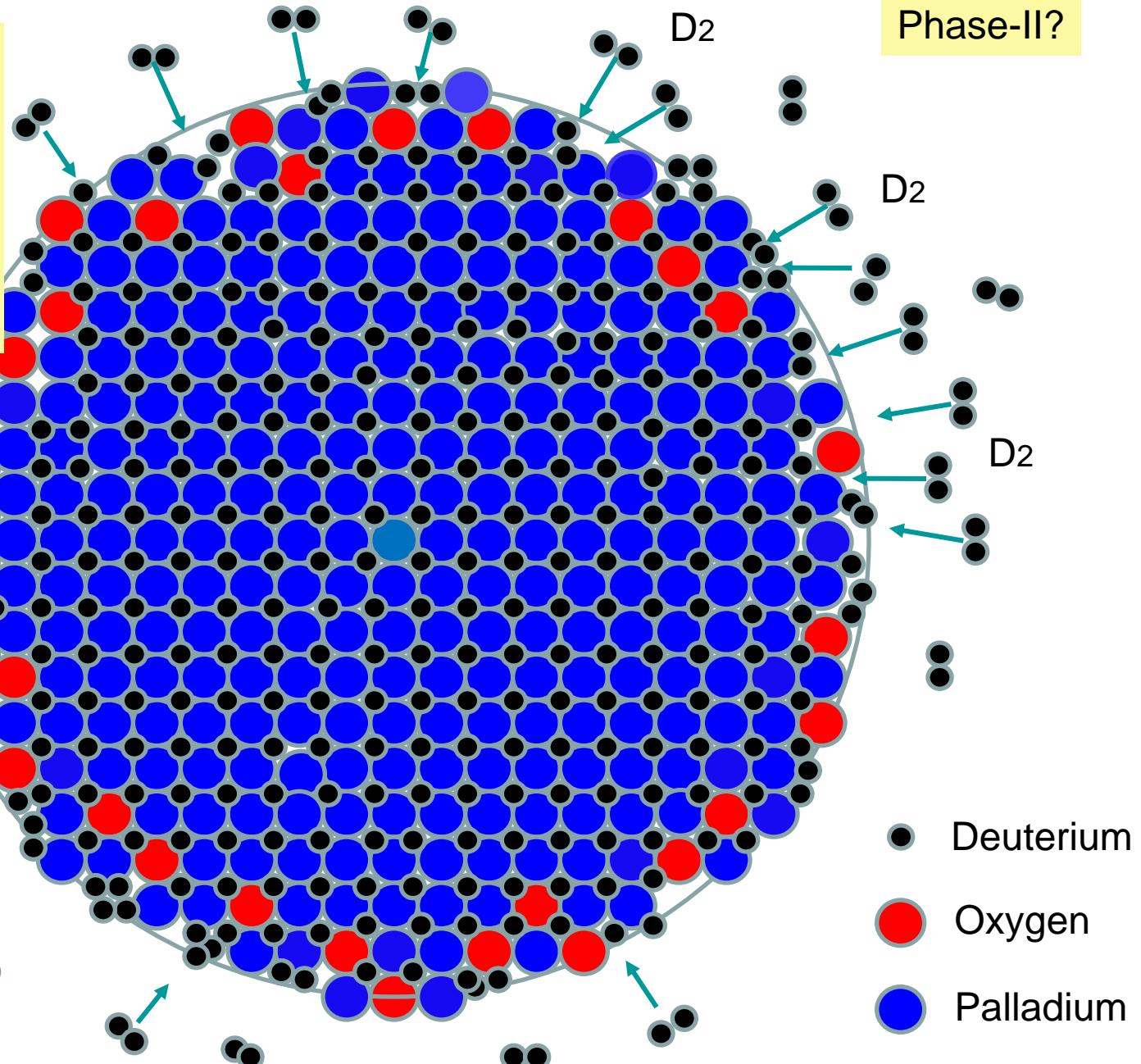
PdO coating on surface of Pd nano-particle and D-absorption: 13)



PdO coating on surface of Pd nano-particle and D-absorption: 14)

D/Pd > 1.0
By surface
D(H)-clusters
+ inner
PdD(H) state

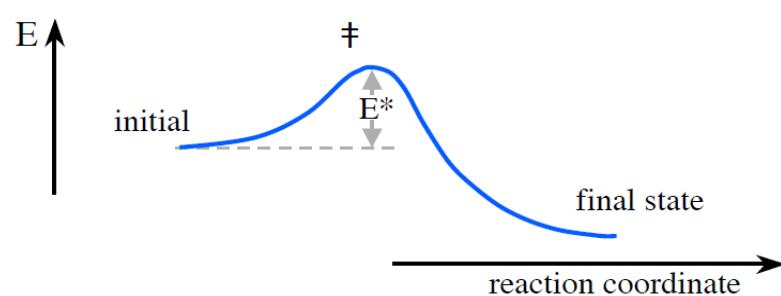
Phase-II?



Molecules at surfaces and mechanism of catalysis

Gerhard Ertl

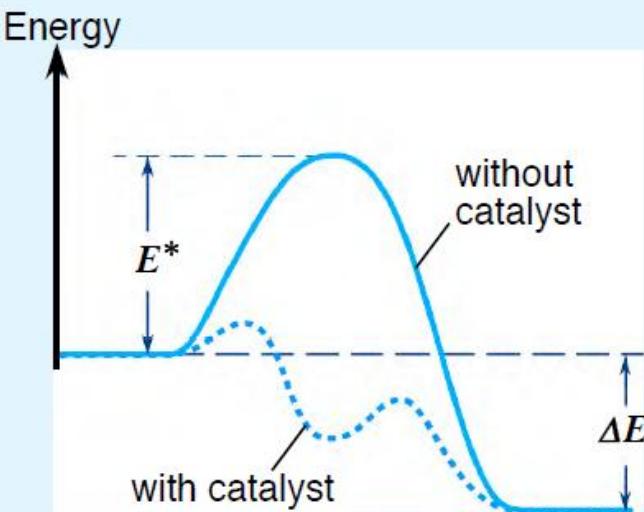
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Transition state theory

$$k_r = \frac{k_B T}{h} e^{\Delta S^\ddagger / R} \cdot e^{-E^*/RT}$$

Progress of a chemical reaction



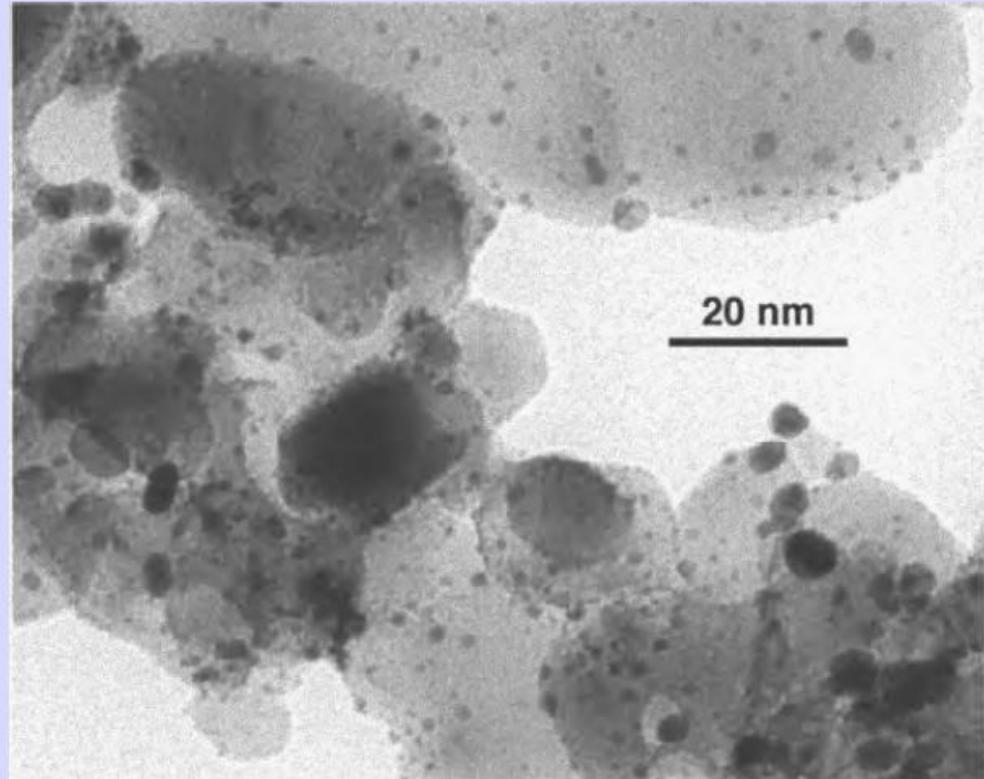
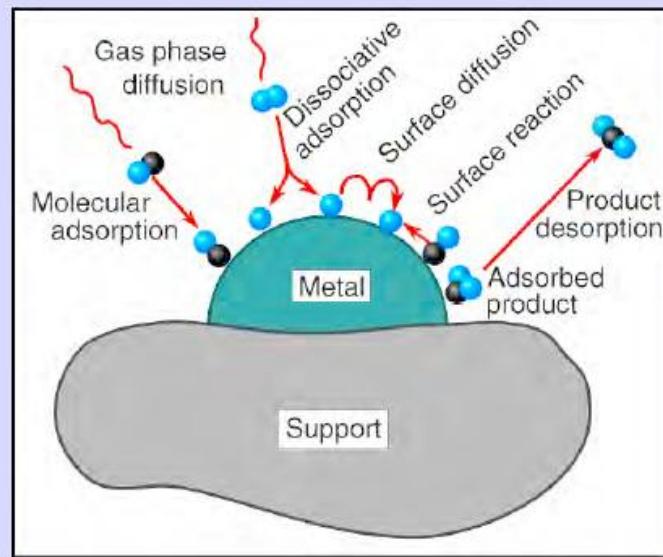
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Molecules at surfaces and mechanism of catalysis

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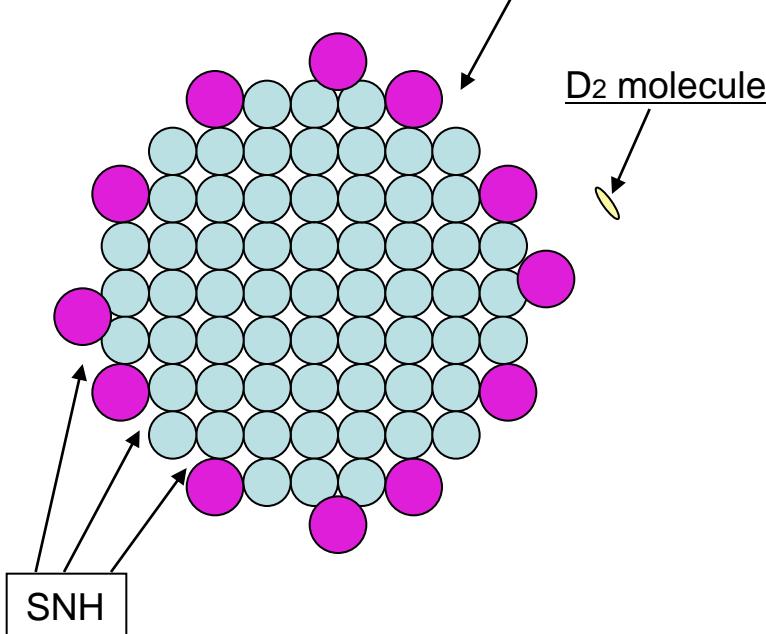


Binary Alloy Metal Nano-Particle Catalyst

;Model for PdxNiy: $x/y = 0.05$ to 0.1 optimum for
Mesoscopic Catalyst

- Ni-atom; $r_0 = 0.138 \text{ nm}$
- Pd-atom; $r_0 = 0.152 \text{ nm}$

2nm diameter Pd_1Ni_7 particle

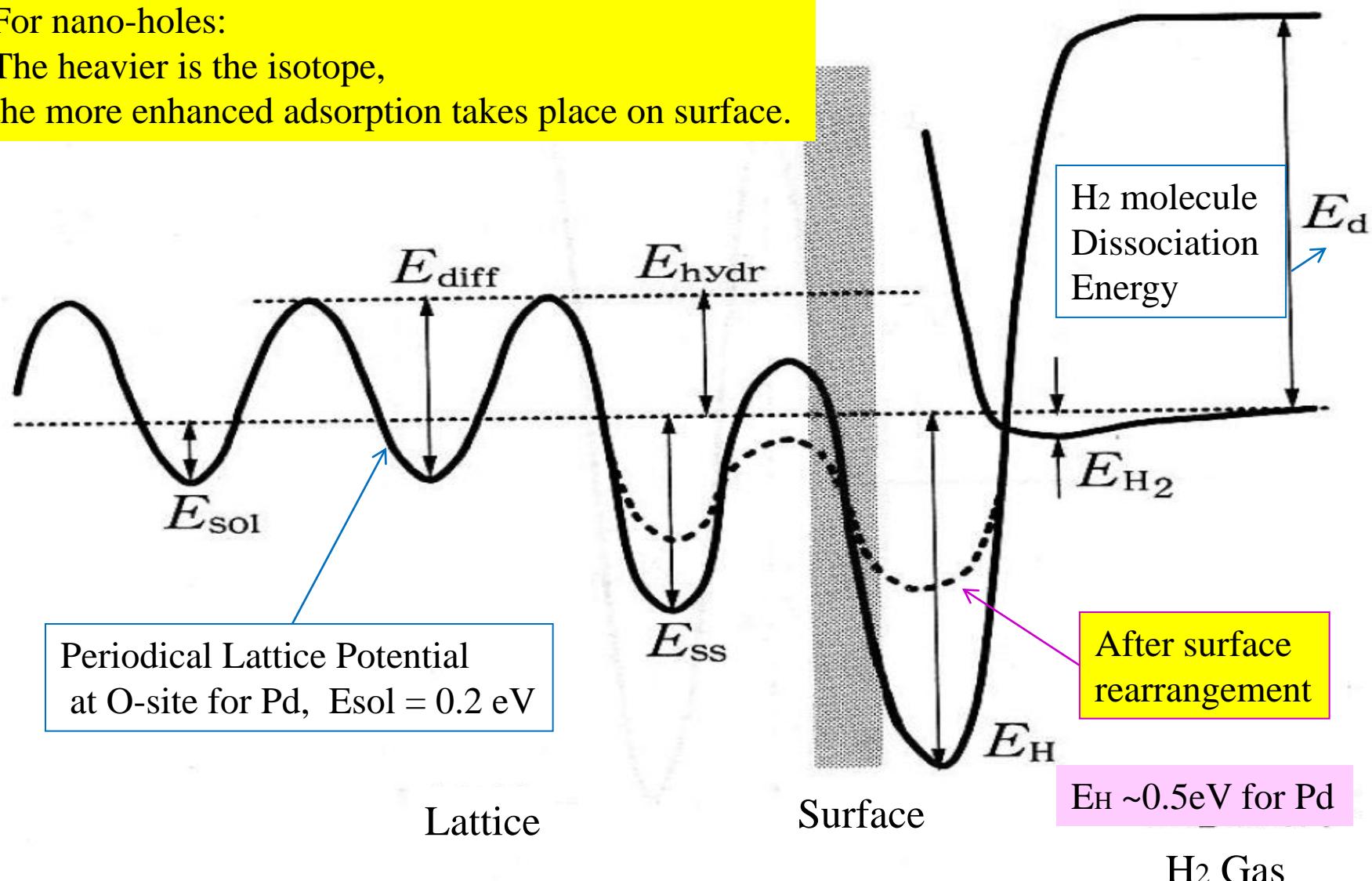


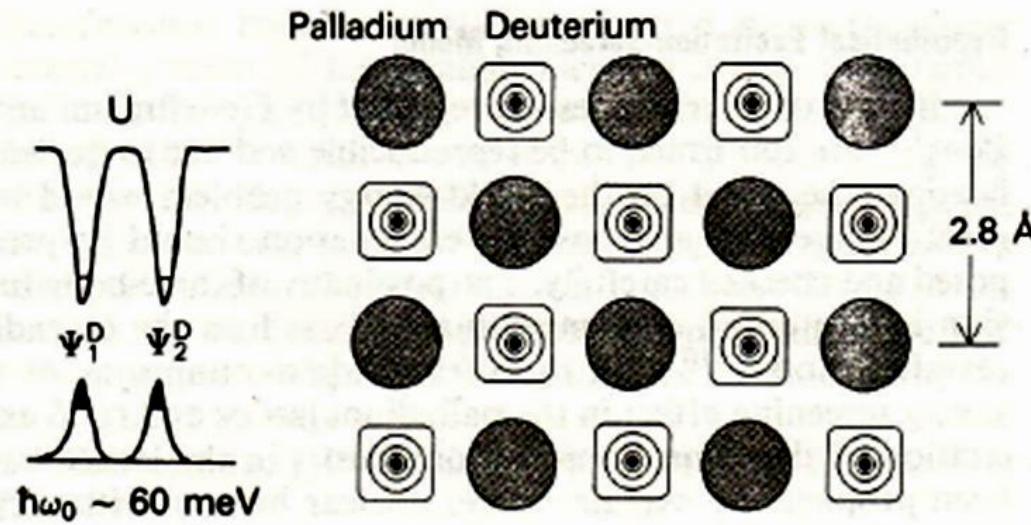
- Surface Pd adsorbs easier H(D).
- Pd ad-atom makes deeper adsorption potential for Ni-core lattice, due to fractal-dip's e- dangling bonds (**SNH**) on surface.
- Enhanced H(D) absorption into Ni-lattice sites (O-sites and T-sites)
- $[\text{H(D)}]/[\text{Pd}+\text{Ni}] > 3.0$
; 1.0 for O-sites, 2.0 for T-sites plus alpha for surface D(H)-clusters
- 4D/TSC formation at surface sub-nano-dips (holes) (**SNH**); at defects and fractal dips
- Pd ad-atom works “similarly” to Oxygen of PdO -coated Pd-nano-particle.

Potential form of hydrogen adsorption and absorption near surface

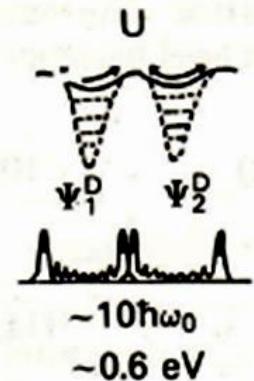
For nano-holes:

The heavier is the isotope,
the more enhanced adsorption takes place on surface.



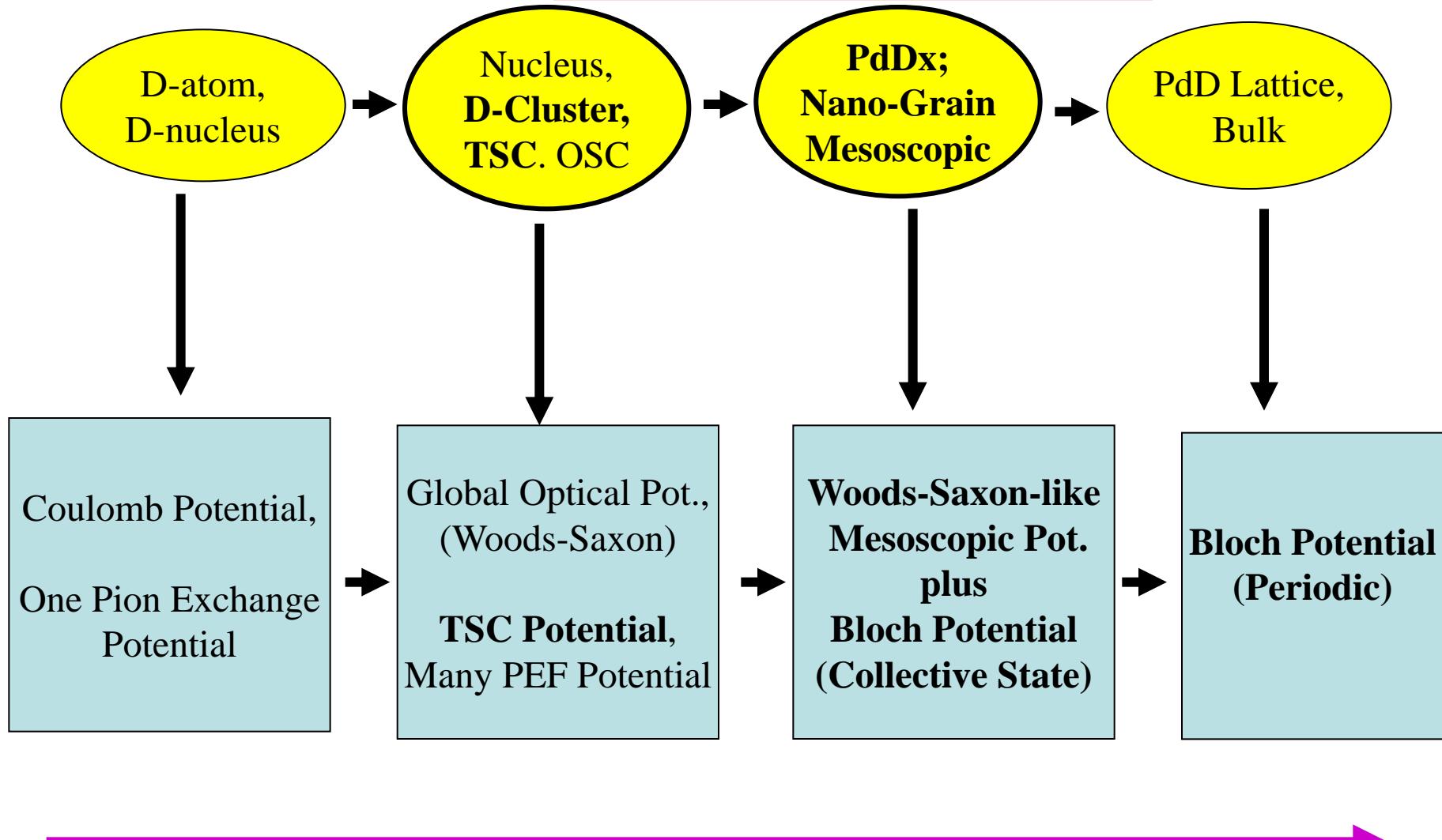


Transient formation of
4D/TSCs around T-sites in
Mesoscopic PdD and NiD₃
Particles with GPT



D-Cluster Formation
Probability will be
Enhanced at around
T-sites.

D-Cluster Fusion



(From Few Body System to Many Body System under Constraint (Self-Organization))