Research Status of Nano-Metal Hydrogen Energy

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Research Status of Nano-Metal Hydrogen Energy

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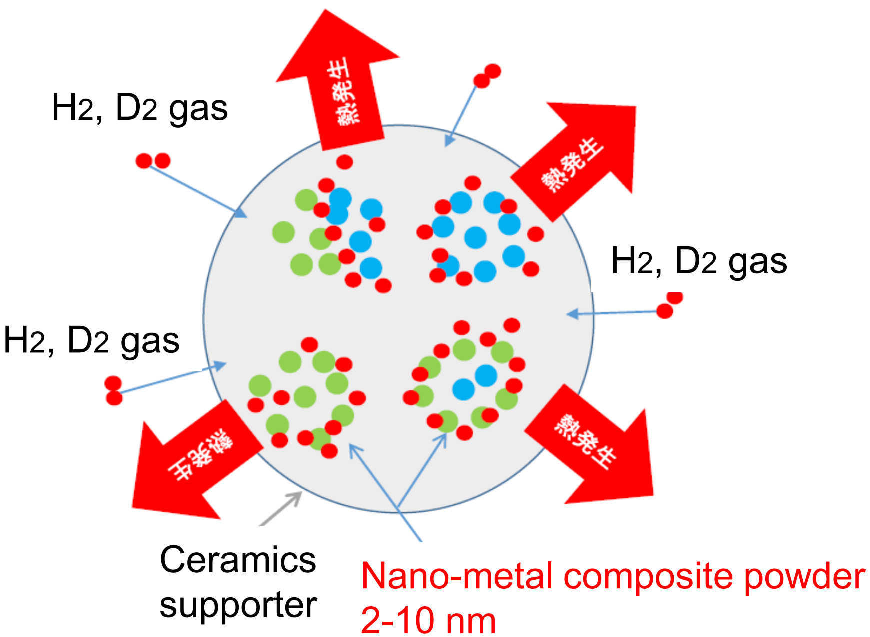
MHE-Group, Japan

To be presented at ICCF21, 3-8 June 2018, Colorado SU, USA

1. MHE Aspect

Anomalously large heat can be generated by the interaction of nano-composite metals and H(D)-gas



- Nano-metal composite powder

  Several nm to several 10s nm
  (Pd-Ni)/ZrO_2, (Cu-Ni)/ZrO_2, (Cu-Ni)/ZrO_2,

- Absorption of H- or D-gas

  Gas-pressure: 0.1 to 1.0 Mpa
  RC temperature: RT to 500˚ C C

Heat Measurement

- Excess heat >> chemical heat

  Power : more than several W
  Energy : more than a few MJ
  No radiations

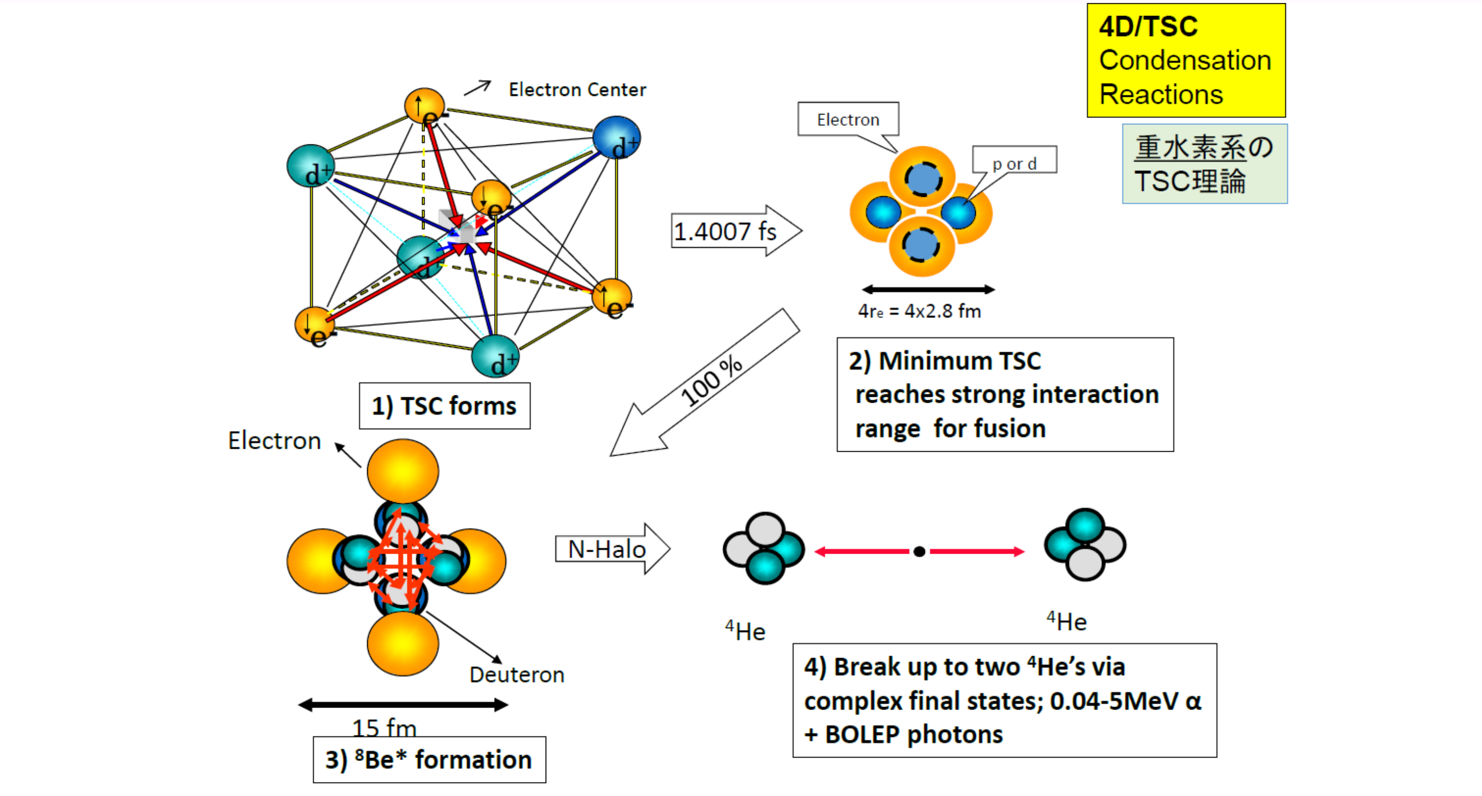
Candidate Reaction Mechanism

CCF/TSC-theory by Akito Takahashi; see Appendix

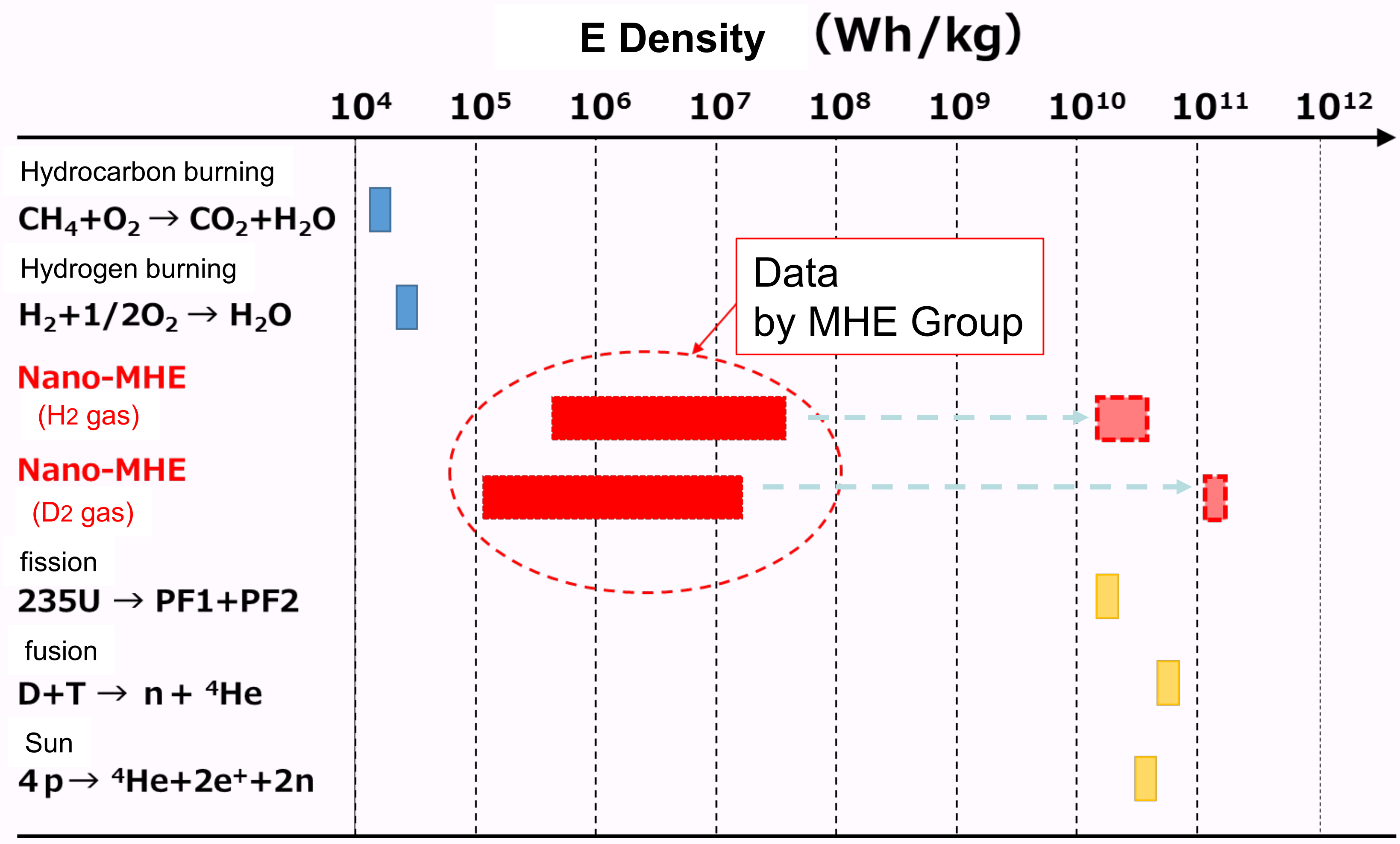
4D/TSC : $4D \rightarrow 2\ {}^4He + 47.6MeV$

4H/TSC : $4H \rightarrow {}^3He + p + (2\text{-}7)MeV$

$MeV = 1.602 \times 10^{-13} J = 4.45 \times 10^{-17}$ Wh



Comparison of Energy-Density for Various Sources



Comparison of Various Energy Resources

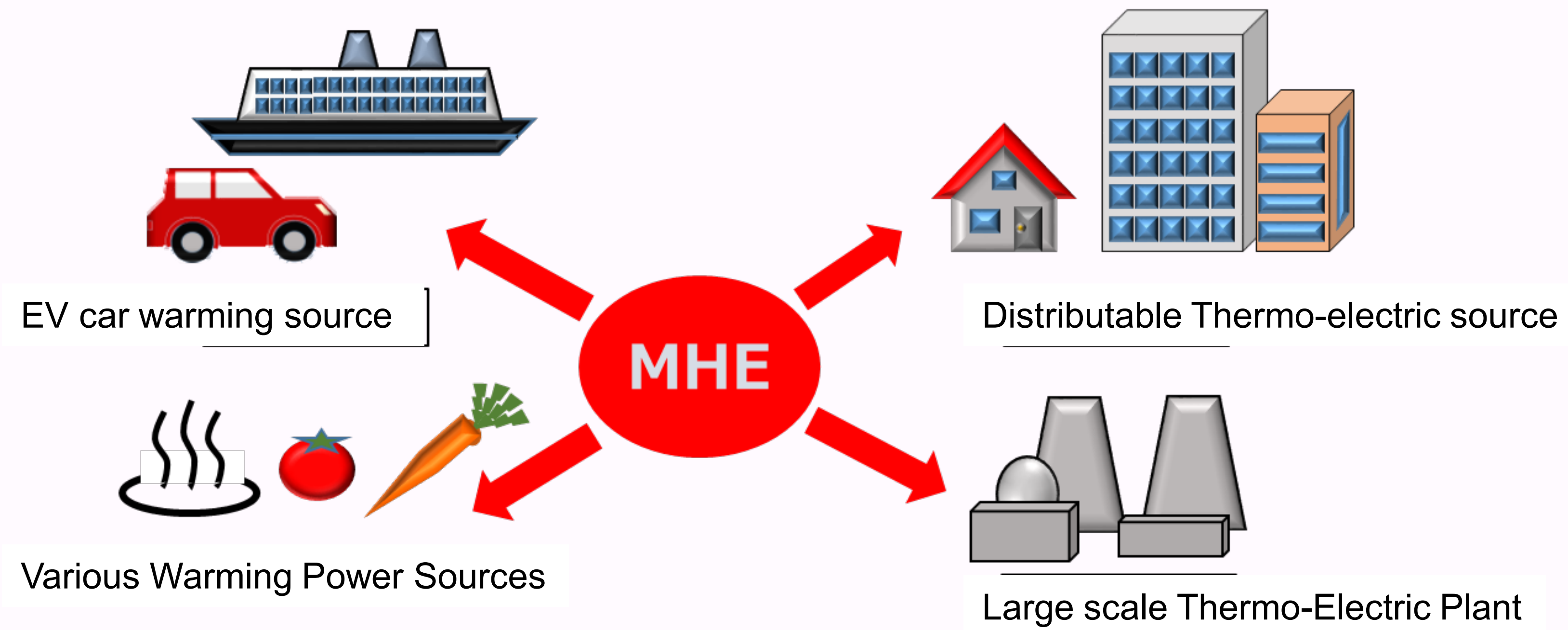
Issue 項 目	Oil 石油	Hydorgen 水素	Solar 太陽光	Nuclear R. 原子力	Fusion 高温核融合	MHE
E-density (Wh/ k g)	△ 1.2×10^4	△ 3.8×10^4	– –	◎ 2.3×10^{10}	◎ 7.5×10^{10}	◎ 1.5×10^{11}
Resource	△finite	○infinite	○infinite	△finite	○infinite	○infinite
CO_2 emission	× yes	○ no	○ no	○ no	○ no	○ no
PM emission	× yes	○ no	○ no	○ no	○ no	○ no
Nucl. Waste	○ no	○ no	○ no	× yes	△ little	○ no
Radiation	○ no	○ no	○ no	× yes	△ little	○ near no
Power Stability	◎	◎	×	◎	◎	◎
Economy	△	×	×	○	△	◎

MHE Technology will be ideal, if well realized

Applications to Society

Generated primary thermal-energy is applicable in various ways

Thermo-E : Room-warming, Water-warming
Distributed El. : El.-power Devices for home, smart-community
EV : warming, driving el.-power



Required Conditions to Application: COP, E-density, System-cost

Application	Power needed		E-density	System Cost (10kY)
応用先	必要発熱量（kW）	COP ※1	エネルギー密度（Wh/kg）	システムコスト（万円）
Home warming	3	>2	>150,000※2	5～10
Bath, Green House	100～1,000	>2	>150,000	100～1,000
EV warming	1	>2	>150,000	1～2
Home El-Power	5	>5	>150,000	50～100
Building El-Power	500～5,000	>5	>150,000	200～2,000
El.-P Smart Com.	1000～10,000	>5	>150,000	500～5,000
EV Driving	100 （Accel）	>5	>150,000	20～50
Present level ※3	0.005～0.025	1.2	50,000,000以上	------

※1 Coefficient of Performance） : Power-out / Power-in
※2 assumed 10 times of oil
※3 Lab-level : RC 500ml, nano-metal 100ｇ（ca.16ml）

2． NEDO-MHE Project, by 6 Parties

Project Name: Phenomenology and Controllability of New Exothermic Reaction between Metal and Hydrogen

Parties : Technova Inc., Nissan Motors Co., Kyushu U., Tohoku U., Nagoya U., Kobe U.

Period: October 2015 to October 2017

R. Fund : ca. 1.0 M USD

Aim : To verify existence of anomalous heat effect (AHE) in nano-metal and hydrogen-gas interaction and to seek controllability of effect

Done : New MHE-calorimetry system at Tohoku U.
Collaboration experiments to verify AHE
Sample material analyses before and after runs
Study for industrial application

Major Results Obtained

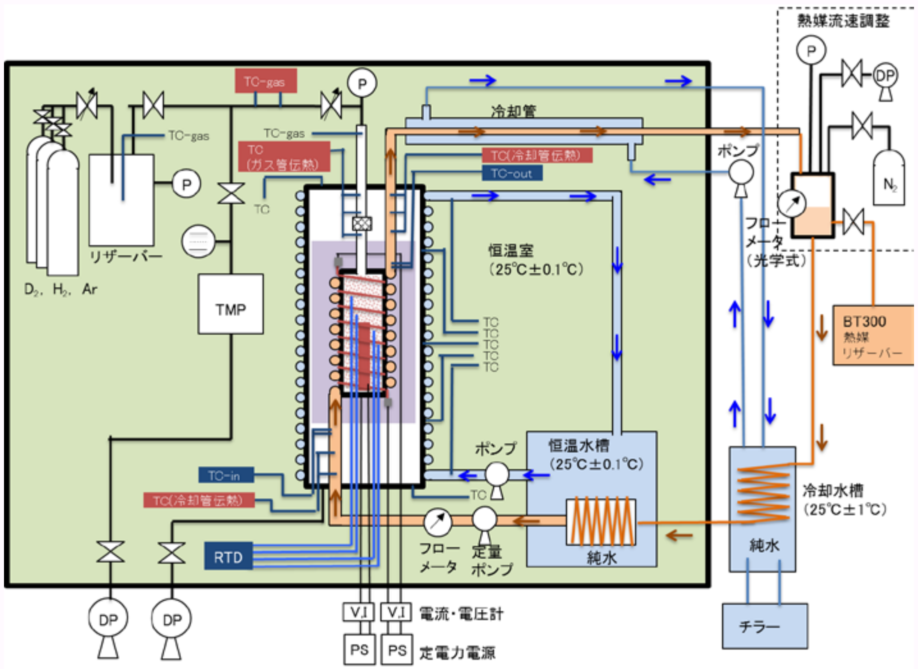
1. Installation of new MHE calorimetry facility and collaborative tests

2. 16 collaborative test experiments to have verified the existence of AHE (Pd-Ni/ZrO_2, Cu-Ni/ZrO_2)

3. generation of 10,000 times more heat than bulk-Pd H-absorption heat, AHE by Hydrogen, ca. 200 MJ/mol-D is typical case

4. Confirmation of AHE by DSC-apparatus with small samples

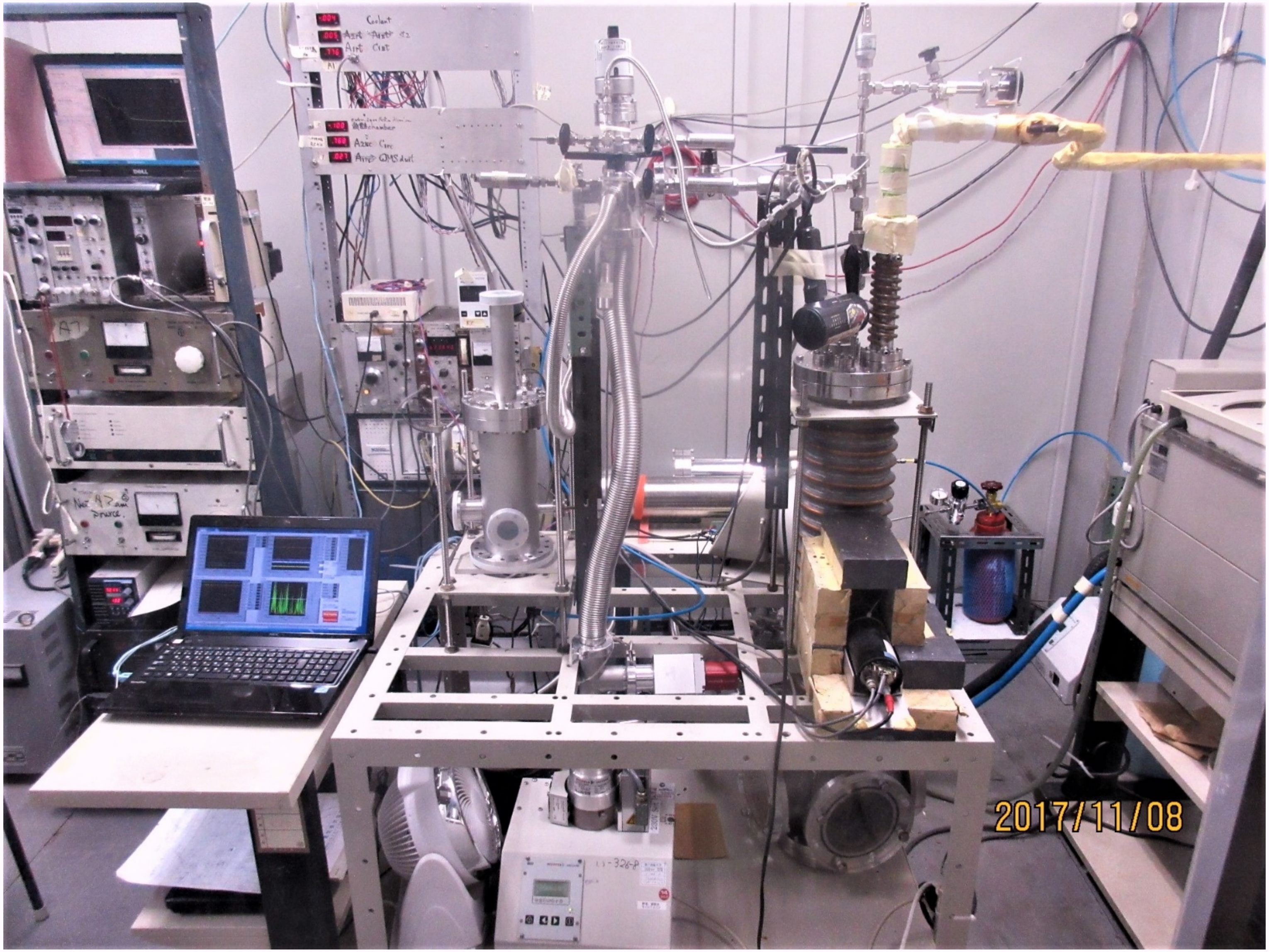
New MHE Facility at ELPH Tohoku U.



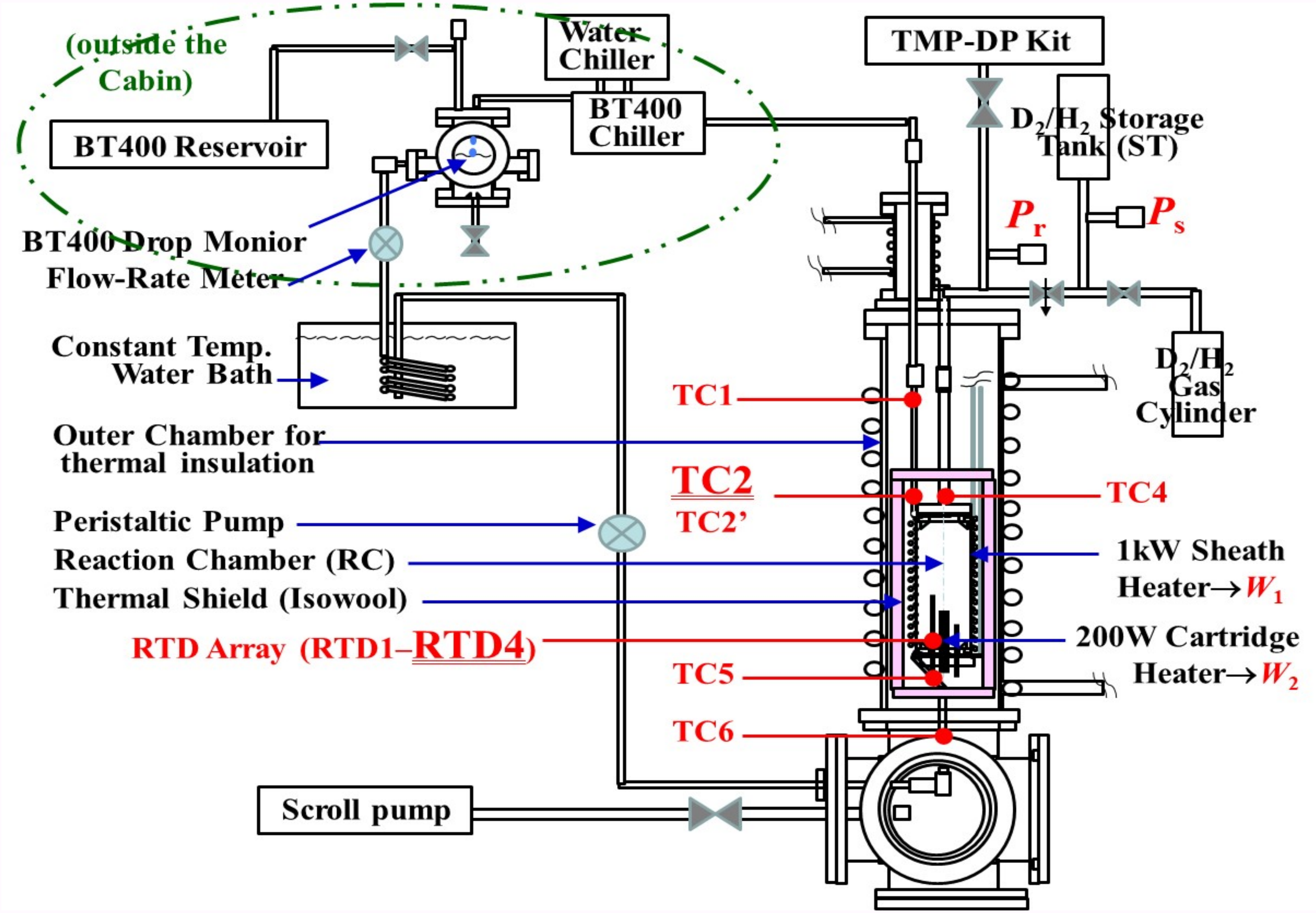
Schematics of MHE-Facility

Photo View

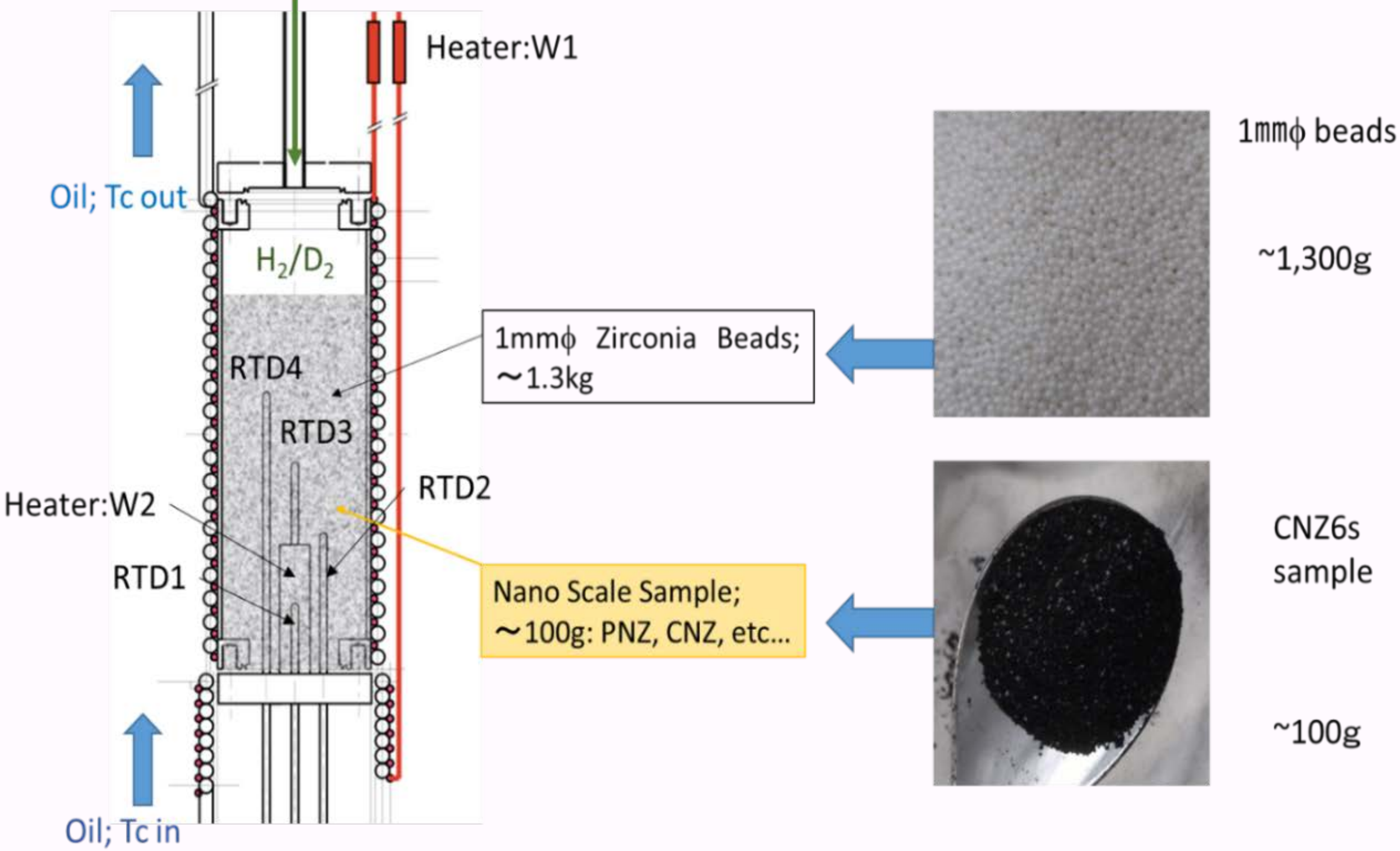
MHE Calorimetry Test System at Kobe University, since 2012



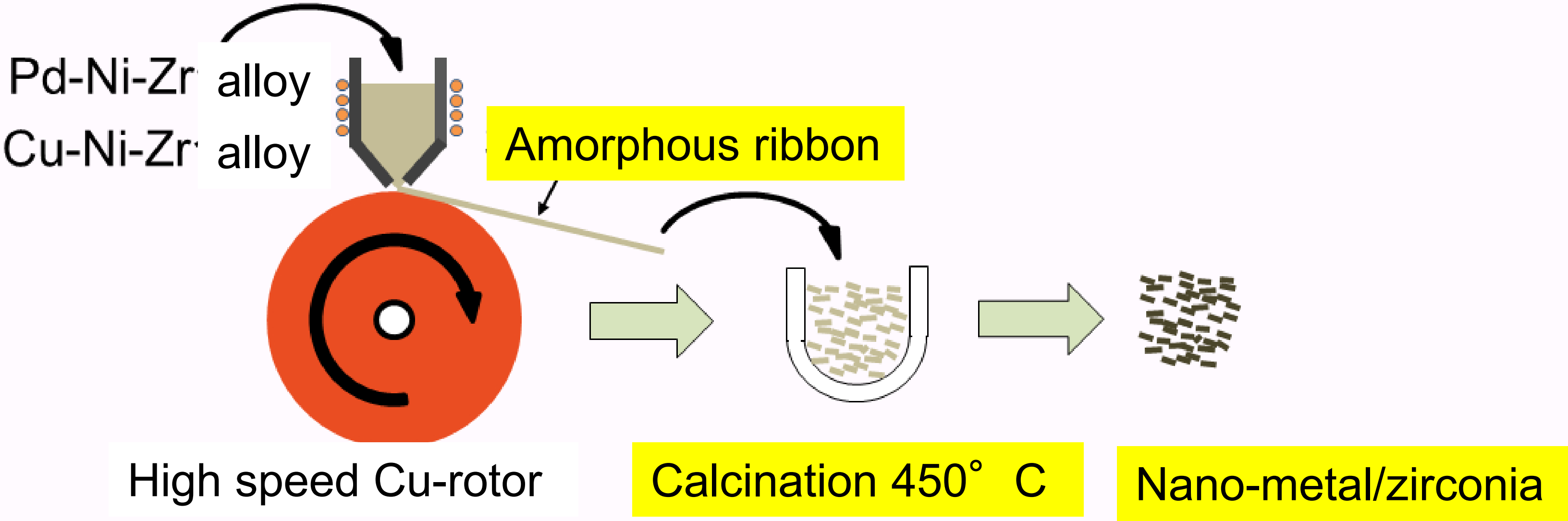
Schematics of MHE Calorimetry Test System at Kobe University, since 2012

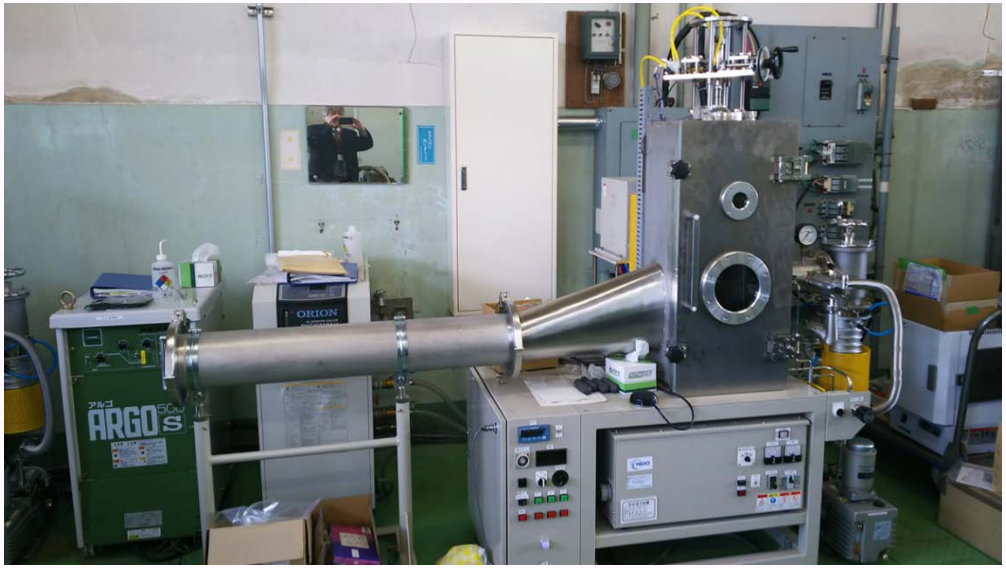


Reaction Chamber (500 cc) and filler + sample
; common for Tohoku and Kobe



Melt-Spinning/Oxidation Process for Making Sample





Atomic composition for Pd_1Ni_{10}/ZrO_2 (PNZ6, PNZ6r) and Pd_1Ni_7/ZrO_2 (PNZ7k)

16 cc in volume

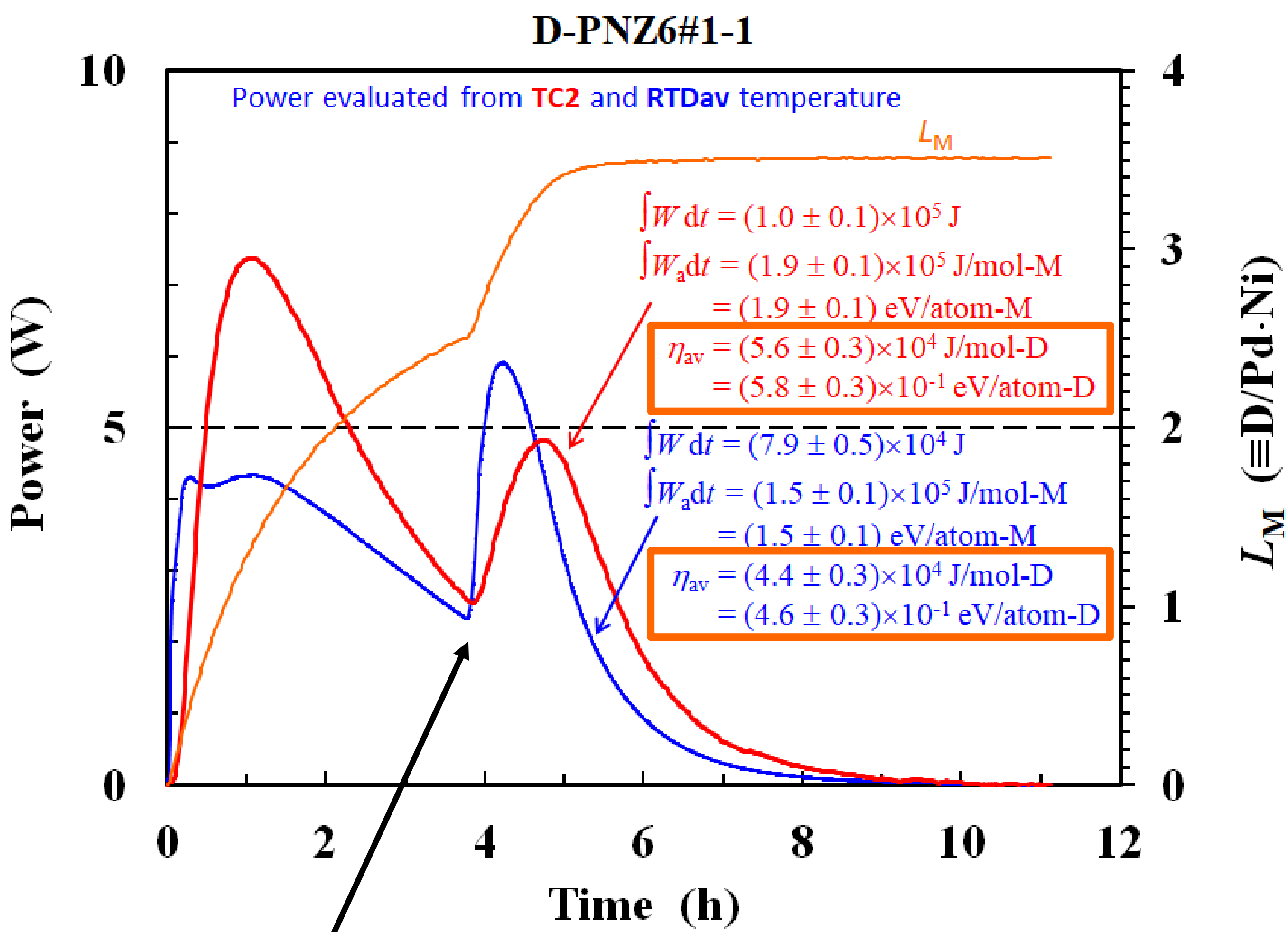
Sample	Mass (g)	Molar ratio				ZrO_2 filler mass (g)
		Ni	Pd	Zr	O	
PNZ6	124.2	**0.318**	**0.032**	**0.650**	0.240	1377
calcined at 450°C·60h		10 : 1				
PNZ6r	131.9	**0.318**	**0.032**	**0.650**	1.03	1378
recalcined at 450°C·60h		10 : 1				
PNZ7k	99.8	**0.306**	**0.044**	**0.650**	0.274	1531
calcined at 450°C·60h		7 : 1				

95% of 500-cc RC was filled with ZrO_2 filler

6 Collaborative Experiments

test	Date	Place	Sample	Gas	Temp.	Power, Integrated Heat Data
1	H28.01.13-22	**Kobe**	PS3 (Pd/SiO2)	D	Room T 200-300℃	RT 23W、35kJ/mol-D ET zero
2	H28.03.07-18	**Kobe**	PNZ3 (PdNi7/ZrO2)	D	Room T 200-300℃	RT 2.5W、73kJ/mol-D(＃1), 48kJ/mol-D(＃2) ET 10W、7,700kJ/mol-D
3	H28.05.09-18	**Kobe**	PNZ3r (re-oxidized)	H	Room T 200-300℃	RT 0.6W、 95kJ/mol-H ET 8W、2MJ/mol-H
4	H28.06.10-20	**Kobe**	CNZ5 (CuNi7/ZrO2)	H	Room T 200-300℃	RT 0.3W、 50kJ/mol-H ET 3.3W、3.6MJ/mol-H
5	H28.07.04-22	**Tohoku**	PNZ4s (PdNi7/ZrO2)	D	Room T 160-300℃	RT 10W、 55kJ/mol-D ET 3.3W、1.4MJ/mol-D
6	H28.08.05-19	**Tohoku**	CNZ5s (CuNi7/ZrO2)	H	Room T 160-250℃	RT not done ET 5W、6.5MJ/mol-H
7	H28.9.15-11.4	**Kobe**	PSf1 (Pd/SiO2-covered)	D	Room T 200-300℃	RT 2.5W、49kJ/mol-D(＃1) ,18kJ/mol-D(＃2～) ET zero
8	H28.10.20 -11.16	**Tohoku**	PSn1 (Pd/meso-Si)	D	Room T 200-300℃	RT 4.2W、106kJ/mol-D(＃1) ,24kJ/mol-D(＃2) ET zero
9	H28.11.21 -H29. 1.23	**Kobe**	CNS3 (CuNi10/SiO2)	H	Room T 200-400℃	RT 0.1W、56kJ/mol-H(＃1) ,56kJ/mol-H(＃2) ET 4.4W、67 MJ/mol-H
10	H28.12.21 -H29.2.4	**Tohoku**	CNS3s (CuNi10/SiO2)	H	Room T 150-300℃	RT not done ET 4.2W、11MJ/mol-H
11	H29.2.6-3.16	**Kobe**	PNZ5 (PdNi7/ZrO2)	D	Room T 250-350℃	RT 8W、63kJ/mol-D(＃1) ,40kJ/mol-D(＃2) ET 4.2W, 7.6MJ/mol-D
12	H29.3.1-4.16	**Tohoku**	CNZ6 s (CuNi7/ZrO2)	H	Room T 150-300℃	RT not done ET 2.1W、5.3MJ/mol-H
13	H29.5.22	**Kyushu**	PNZ3	H	RT-450℃	DSC、TPR
14	H29.5.24-6.30	**Kobe**	PNZ6 (PdNi10/ZrO2)	D	Room T 250-350℃	RT 7.5W、58kJ/mol-D) (＃1) ,37kJ/mol-D(＃2) ET 25W, 200MJ/mol-D

Typical hydrogen evolution of L_M and power in PNZ6#1-1 phase at Room Temp.

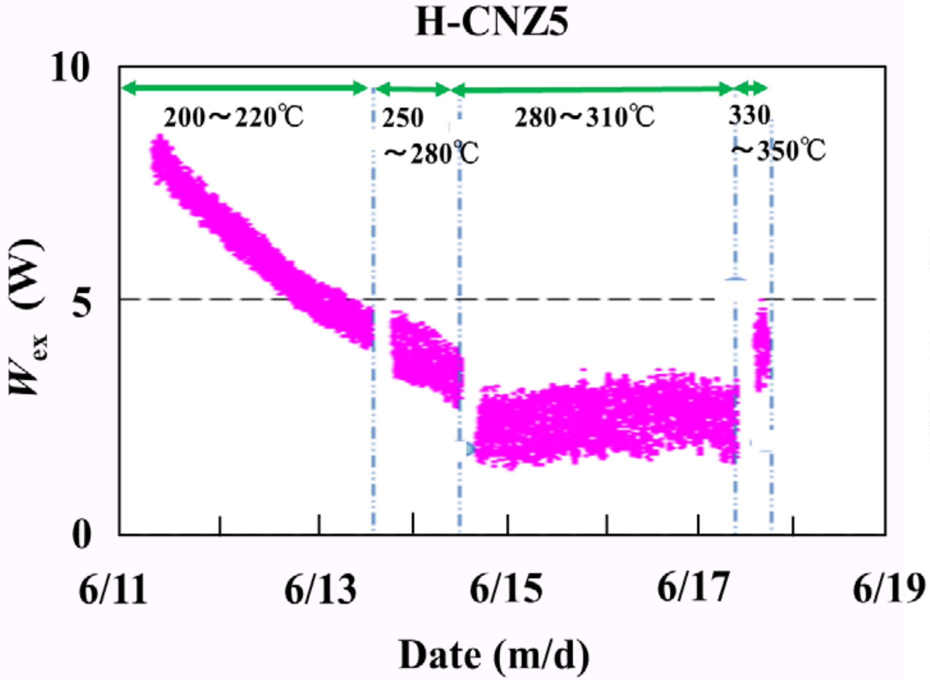


#1
1:D2 fill
1':refill

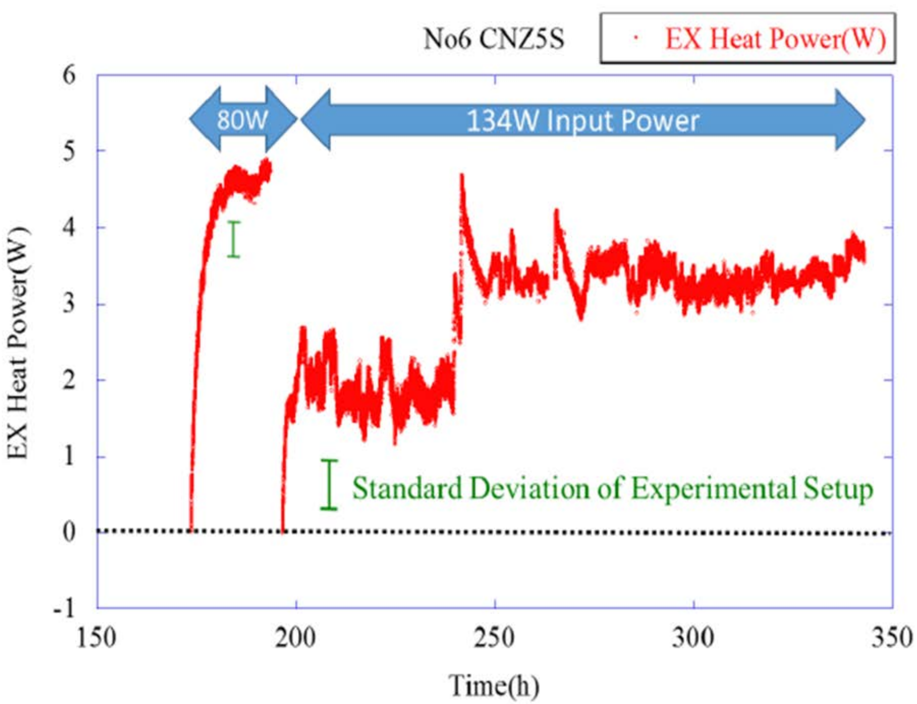
- Deuterium resupplied to ST
- 20% difference between the integrated values evaluated from TC2 and those from RTDav : due to inhomogeneity of the 124.2-g sample distributed in the ZrO_2 filer

(cf.: 1 eV/atom-M = 0.96E+05 J/mol-M)

Using Same Samples divided (CNZ5=Cu_1Ni_7/ZrO_2) 100g, parallel tests



Kobe U (4-th Coll. test)

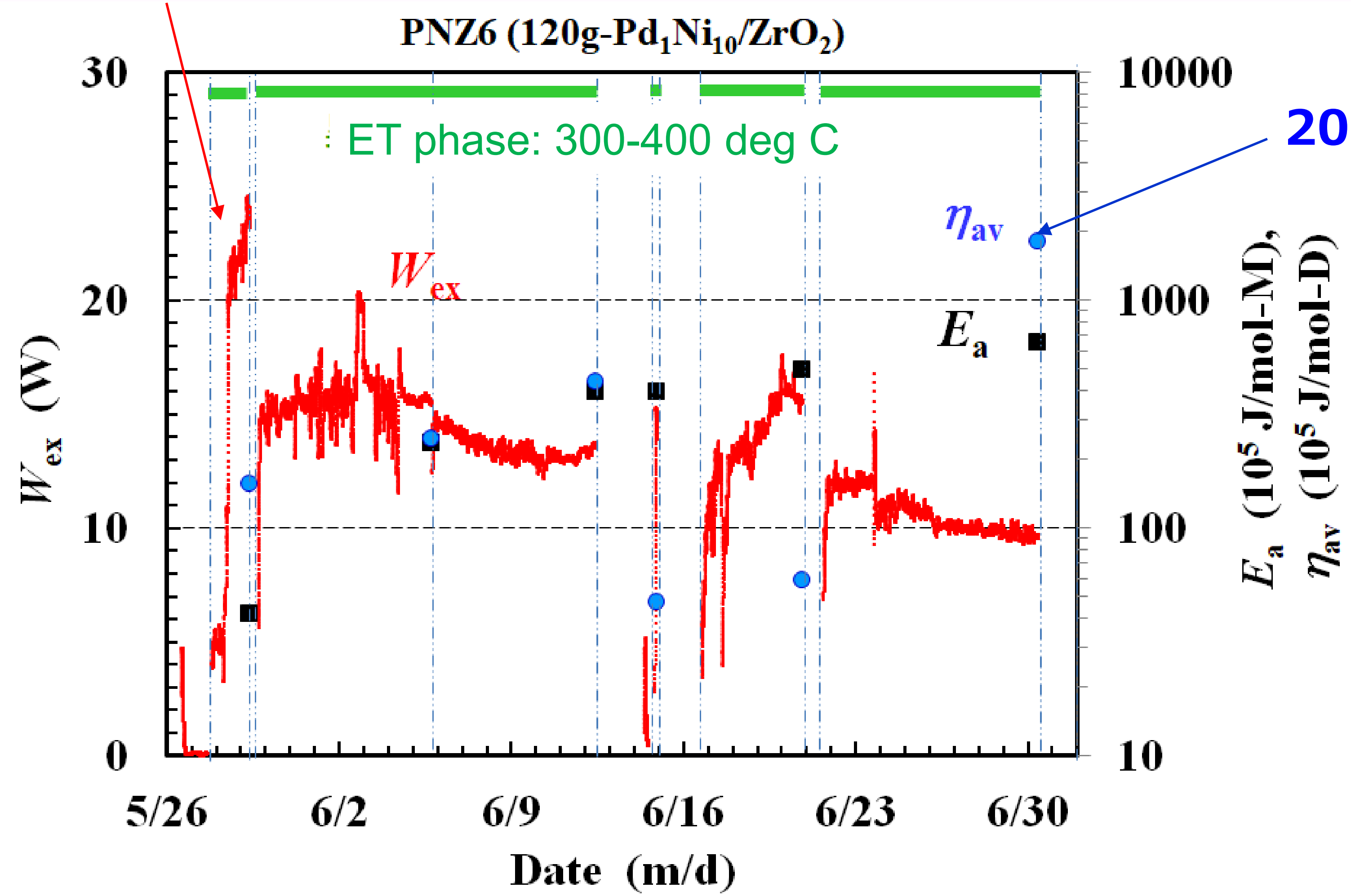


Tohoku U (6-th Coll. test)

2～8W of AHE lasted for a week at Elevated Temp. (H-gas)

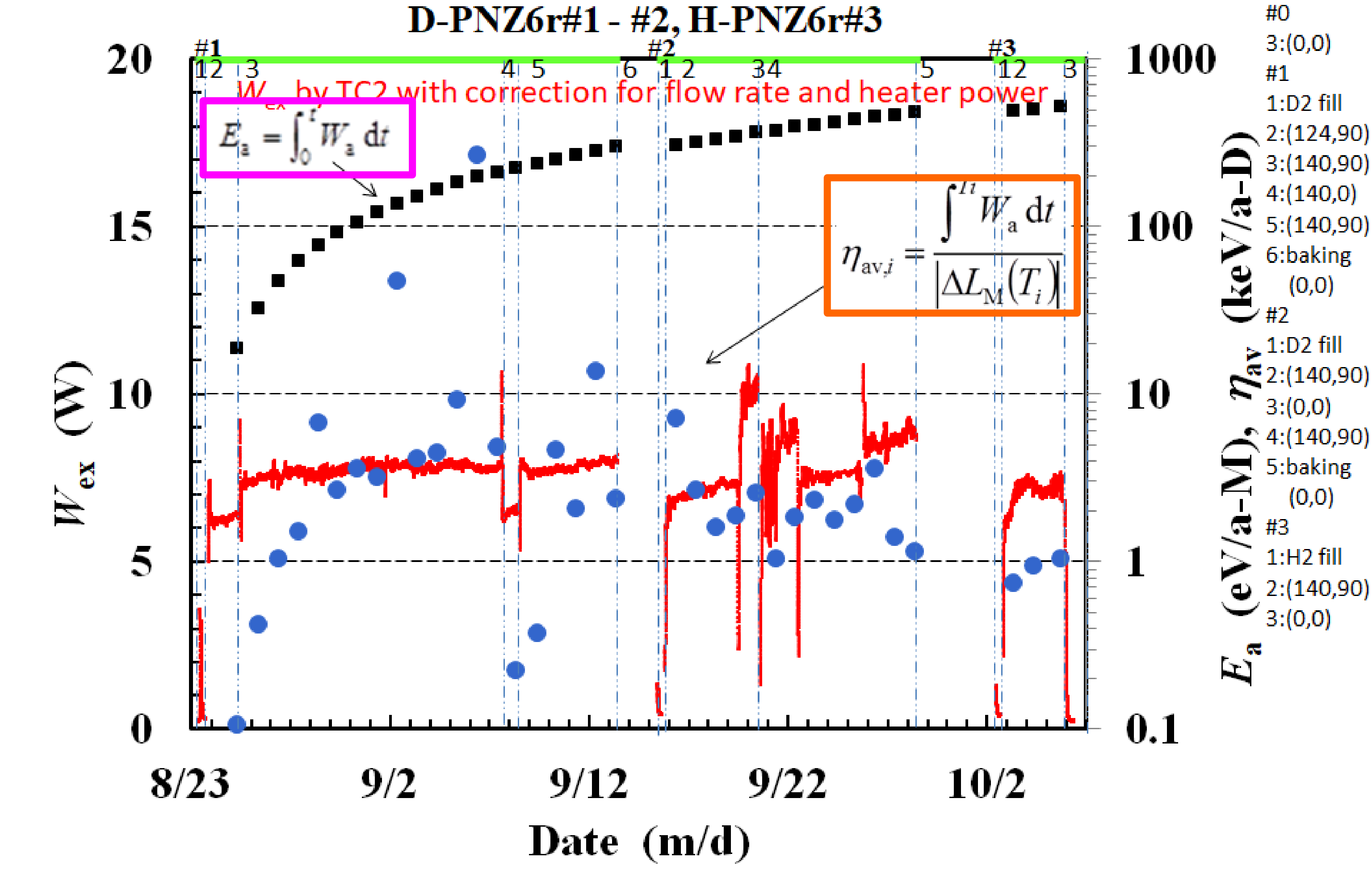
14-th Coll. Test（PNZ6）: Largest AHE Data

W_{ex}: 20W to 10W level excess-power lasted for a month



Cf. known chem. 600 ~ 2000 times

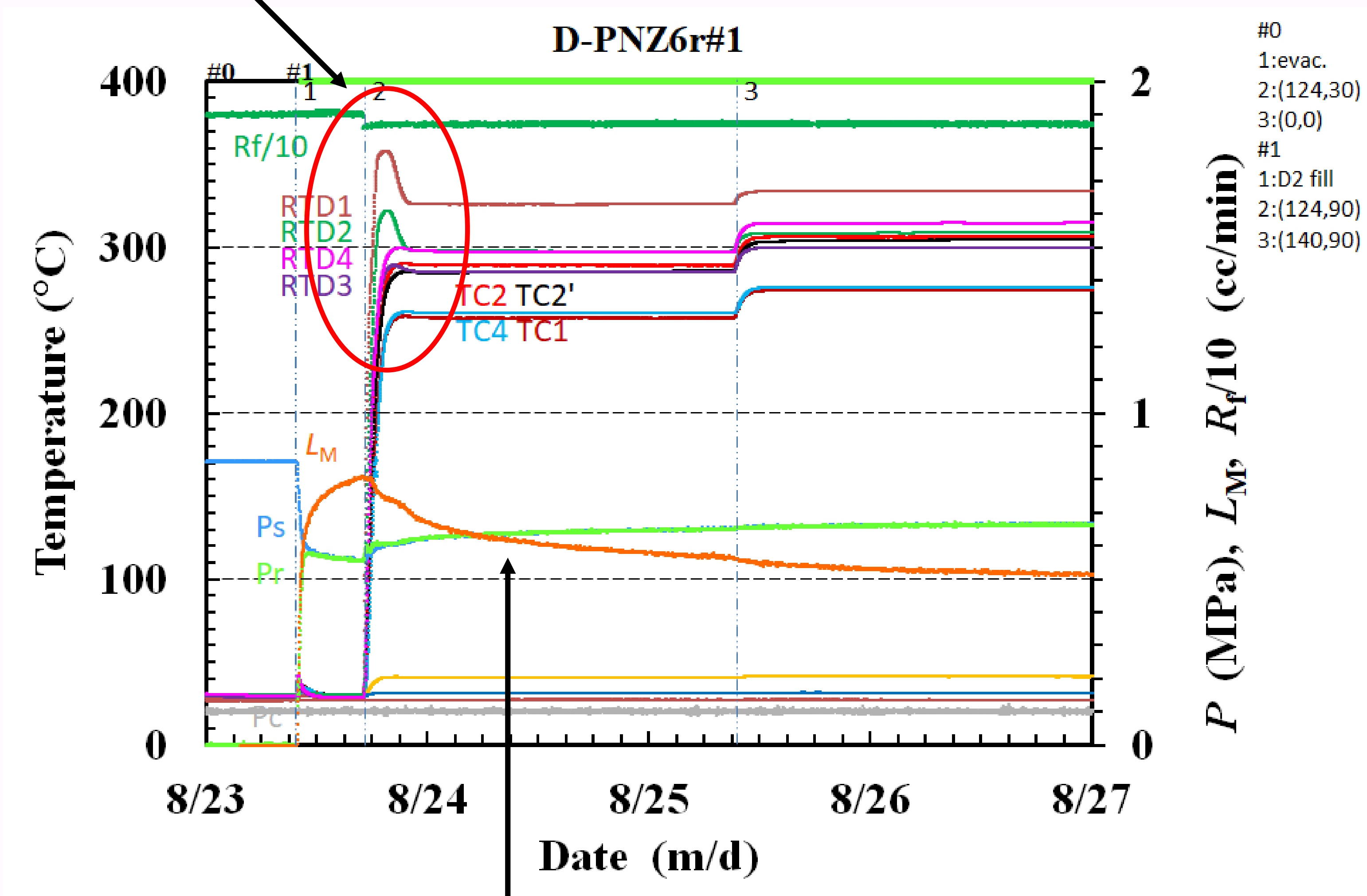
Excess power, W_{ex}, integrated excess heat per metal atom, E_a (keV/a-M), and excess energy per hydrogen isotope atom absorbed/desorbed, $\eta_{av,j}$ (keV/a-D(H)), in RT and ET phases evaluated by TC2 temp. Re-calcined PNZ6



▪large values of η_{av} making it realistic to assume nuclear origin of the excess heat

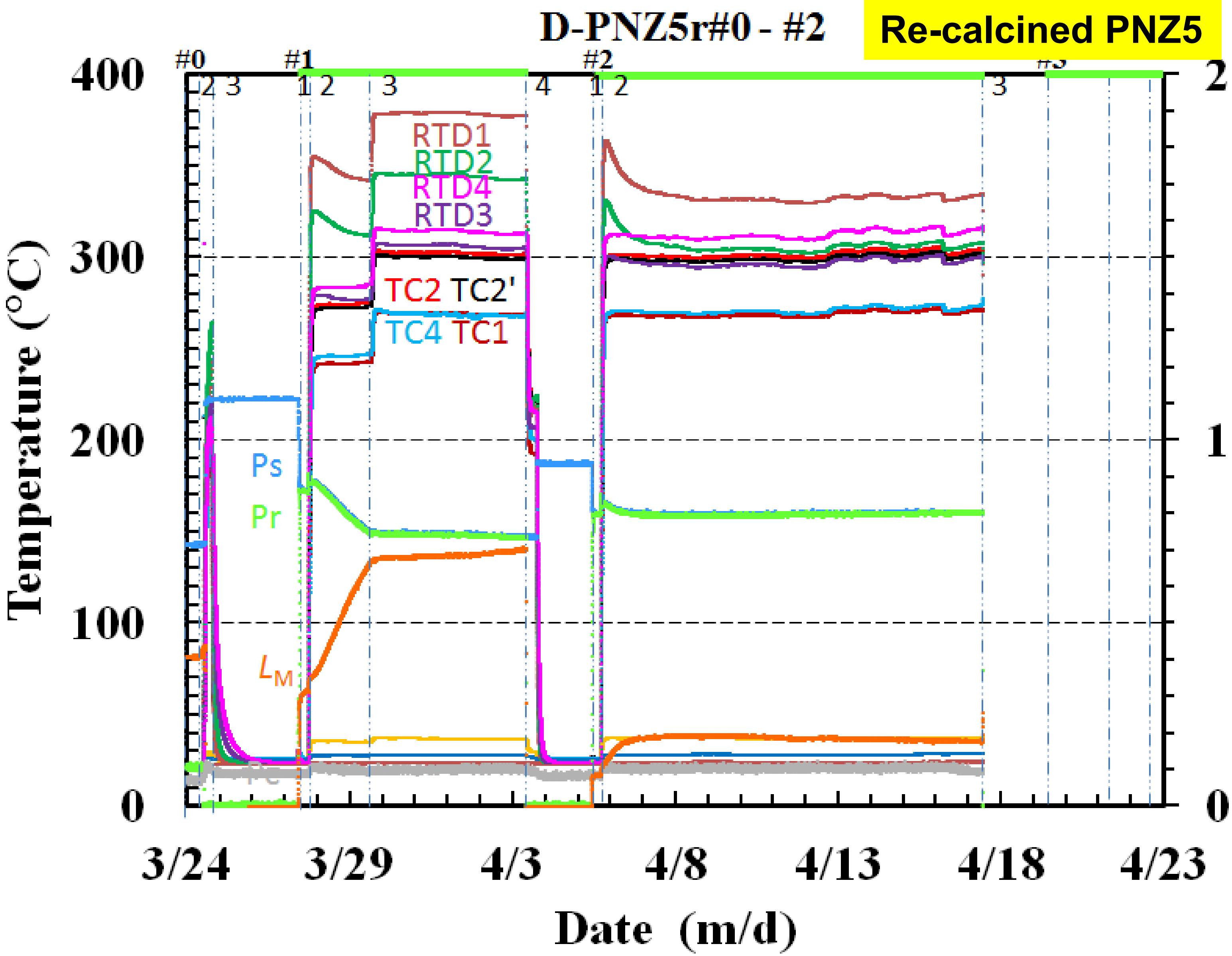
(cf.: 1 eV/atom-M = 0.96E+05 J/mol-M) Technova Inc.

Peculiar evolution of temperature in D-PNZ6r#1-2 phase: Re-calcined PNZ6



- **Desorption under elevated temperatures similar to other samples, but with exceptionally large time constant; Generation of AHE**

PNZ5r sample: baking (#0) followed by #1 – #3 run (R_f = 20 ccm mostly)

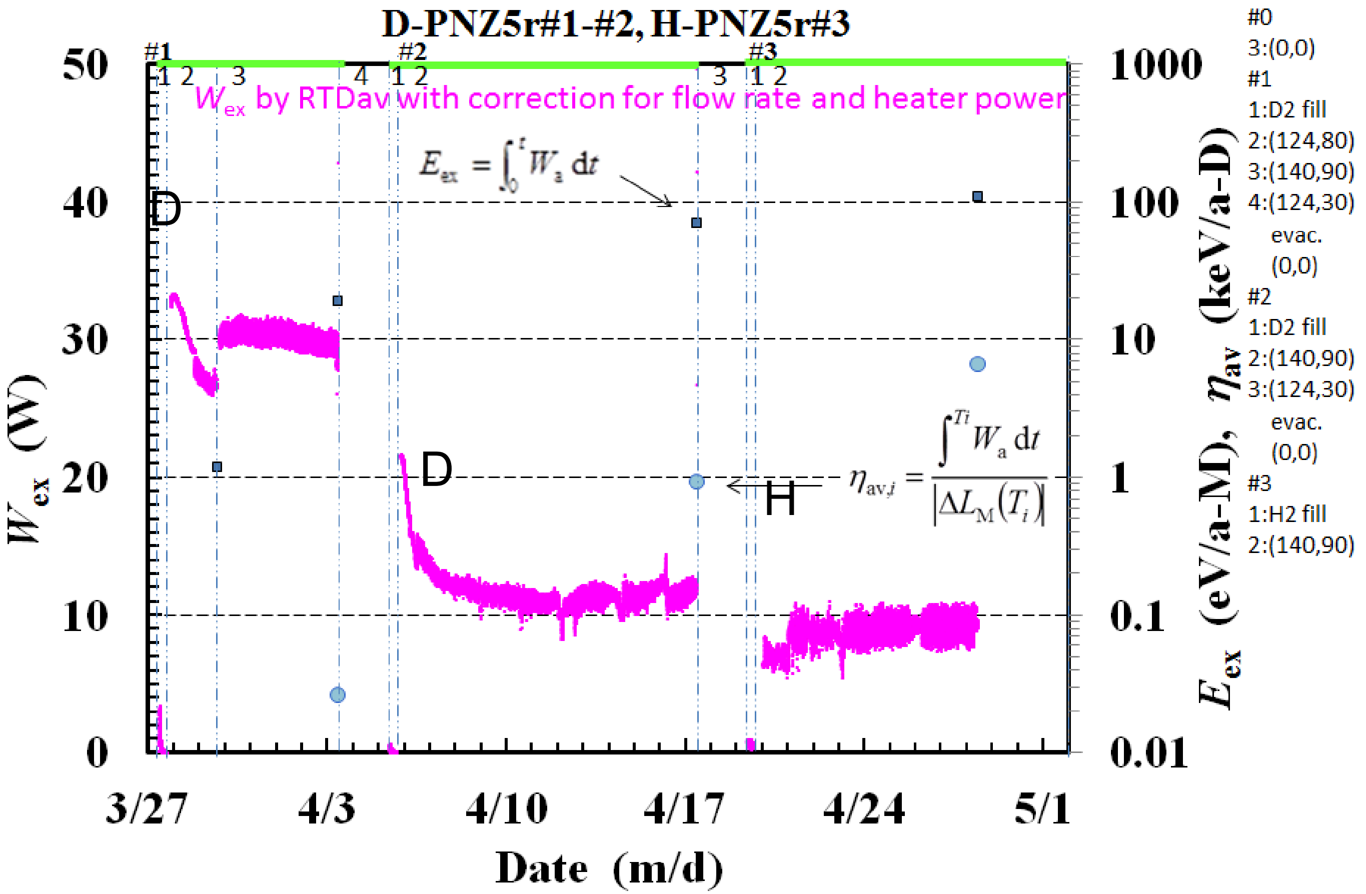


#0
1:evac.
2:(124,30)
3:(0,0)
#1
1:D2 fill
2:(124,80)
3:(140,90)
4:(124,30)
evac.
(0,0)
#2
1:D2 fill
2:(140,90)
3:(124,30)
evac.
(0,0)
#3

Local large heat：Pd/Ni=1/7, after re-calcination of PNZ5

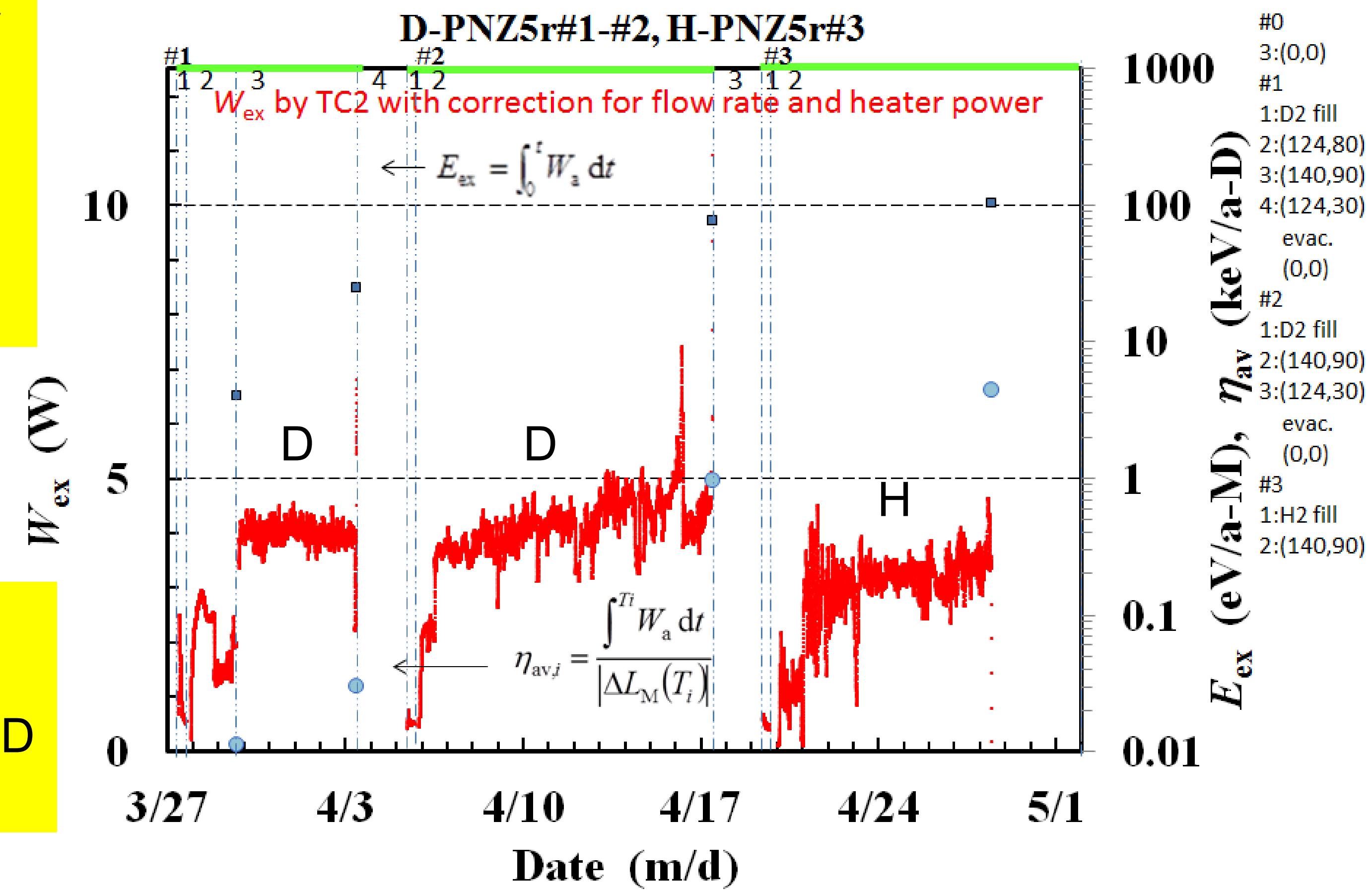
Local excess power by PNZ5r sample with D-gas and H-gas (Kitamura, et al, this WS)

Local
Larger
Power
Generation
In RC
Lower zone



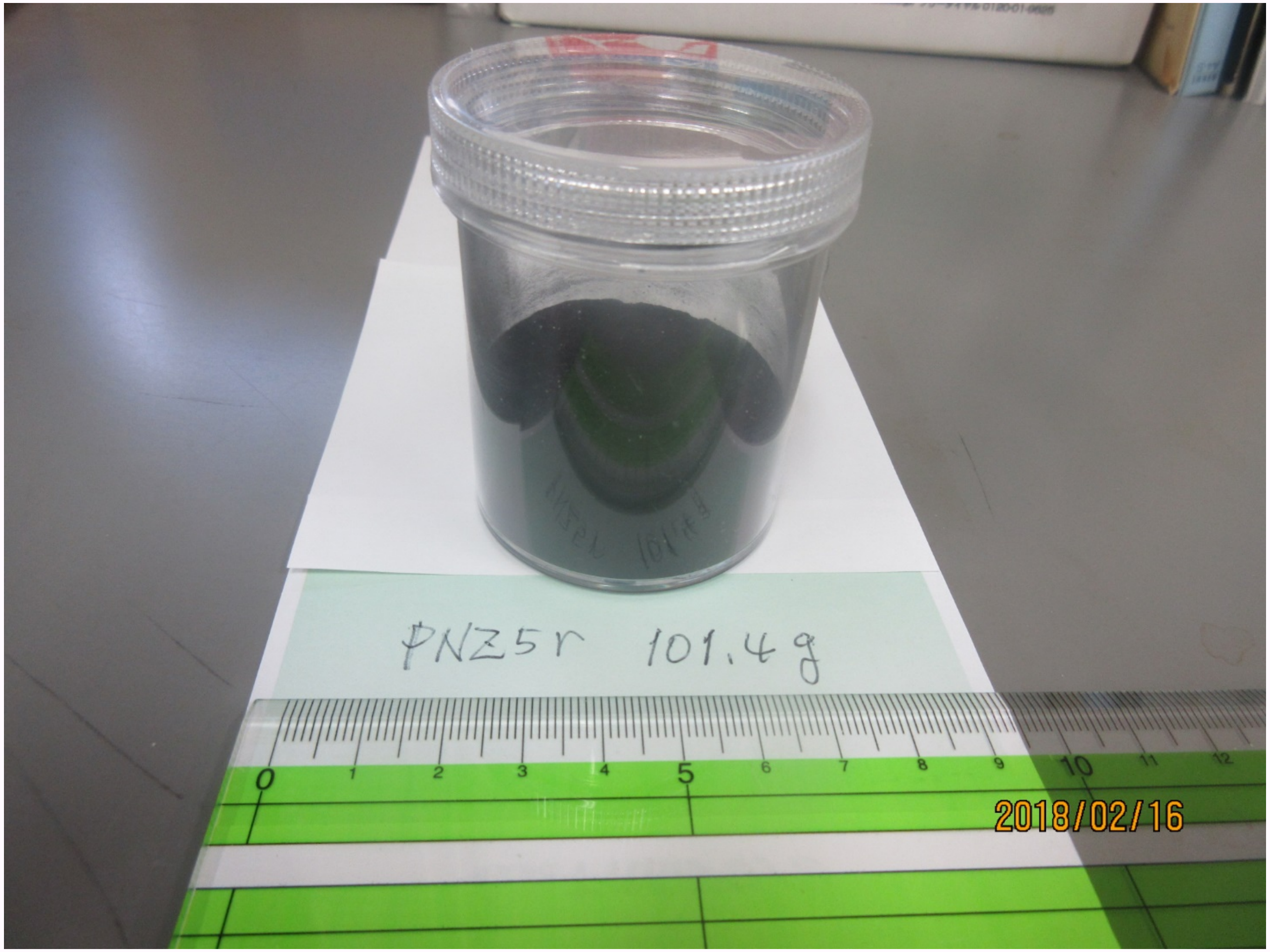
Excess heat-power evolution for D and H gas: Re-calcined PNZ5

Total power
Of
Reaction
Chamber
By oil flow
calorimetry

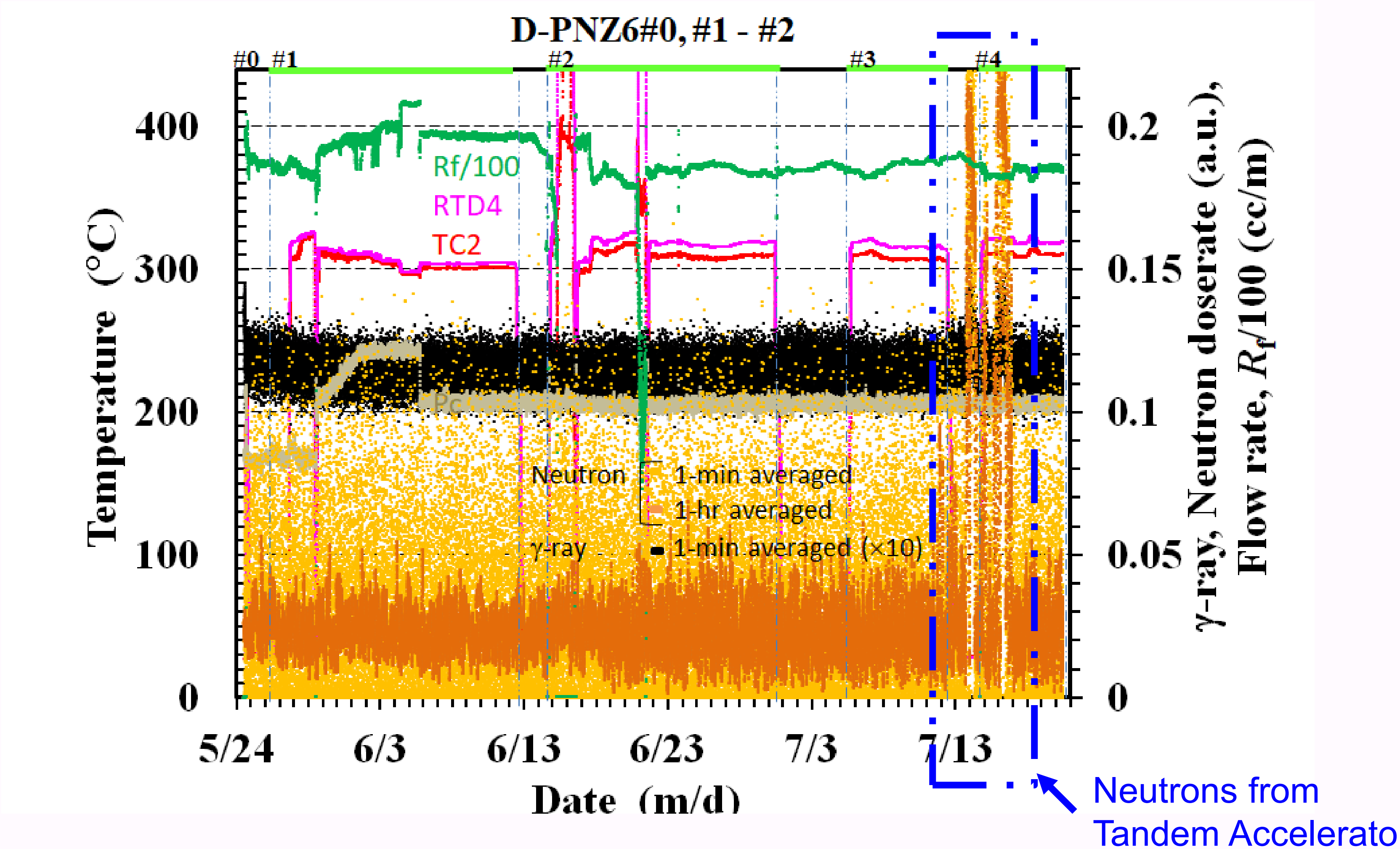


AHE of
8 MJ/mol-Ni
100 MJ/mol-D
Generation

About 15 cc 100g PNZ5r powder + D_2 gas generated
Over 100 MJ/mol-D anomalous excess heat:
Which is 5,000 times of 0.02 MJ/mol-D by PdD formation!

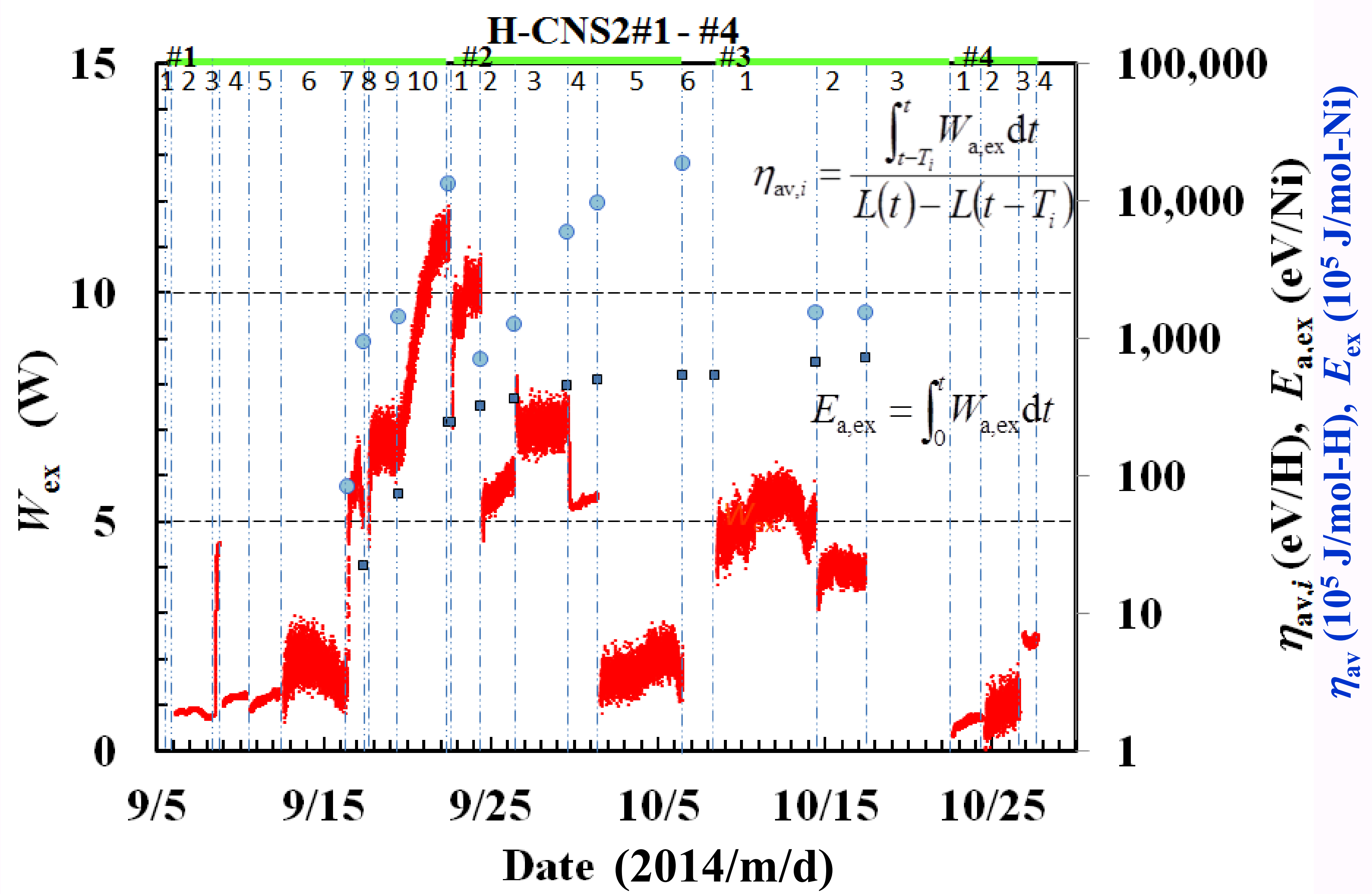


Radiations and flow rate of coolant BT400; n and gamma levels are natural BG

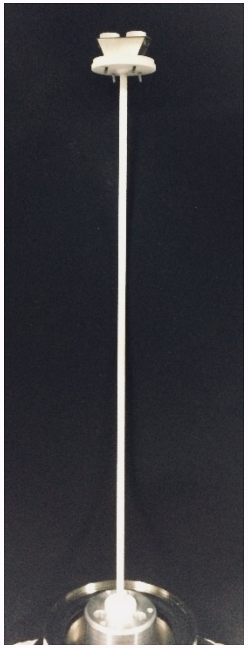


▪Radiation dose rates during large-excess-power phases are almost the same as those during inactive phases, *e.g.*, Jn. 30 – Jy. 5.

Excess Power Evolution by CNS2(Cu1Ni7/meso-silica)



Sample Holder/Temperature-Detection of DSC Apparatus
Kyushu University; M. Kishida, et al.



DSC Measuring Conditions: Kyushu University

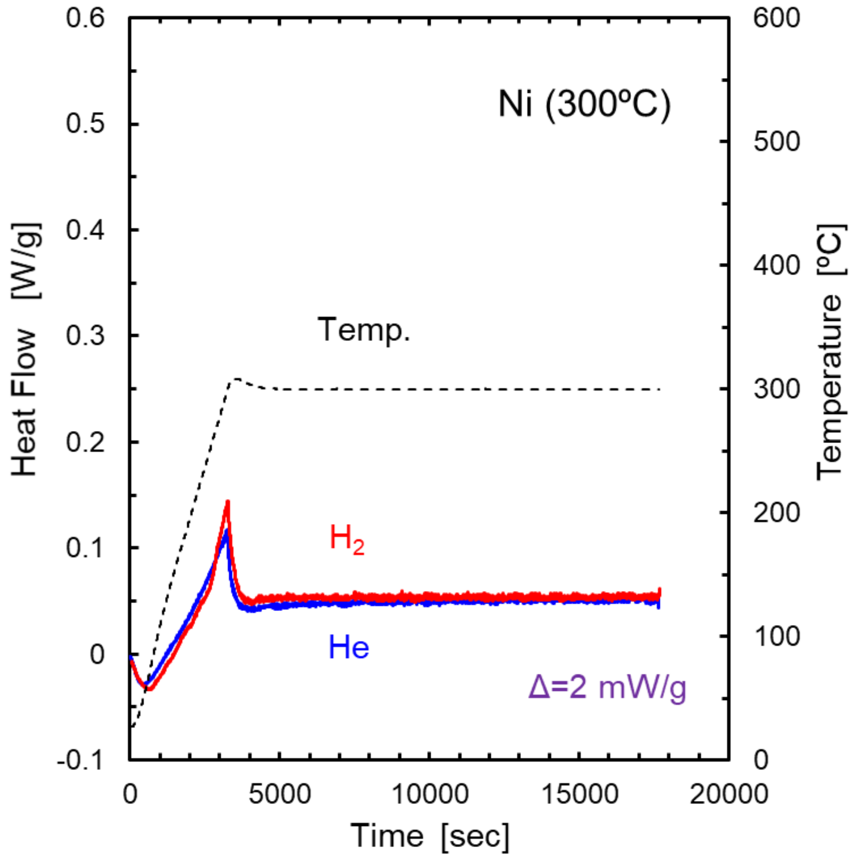
Sample Amount:	40～100 mg
Temperature :	25 ～ 550 °C
Temp. Rise Rate:	5 °C/min
Hydrogen Flow:	70 ml/min
Keeping Temp.:	200～550 °C, mainly 450°C
Keeping Period:	2 hr ～ 24 hr, mostly 2hr

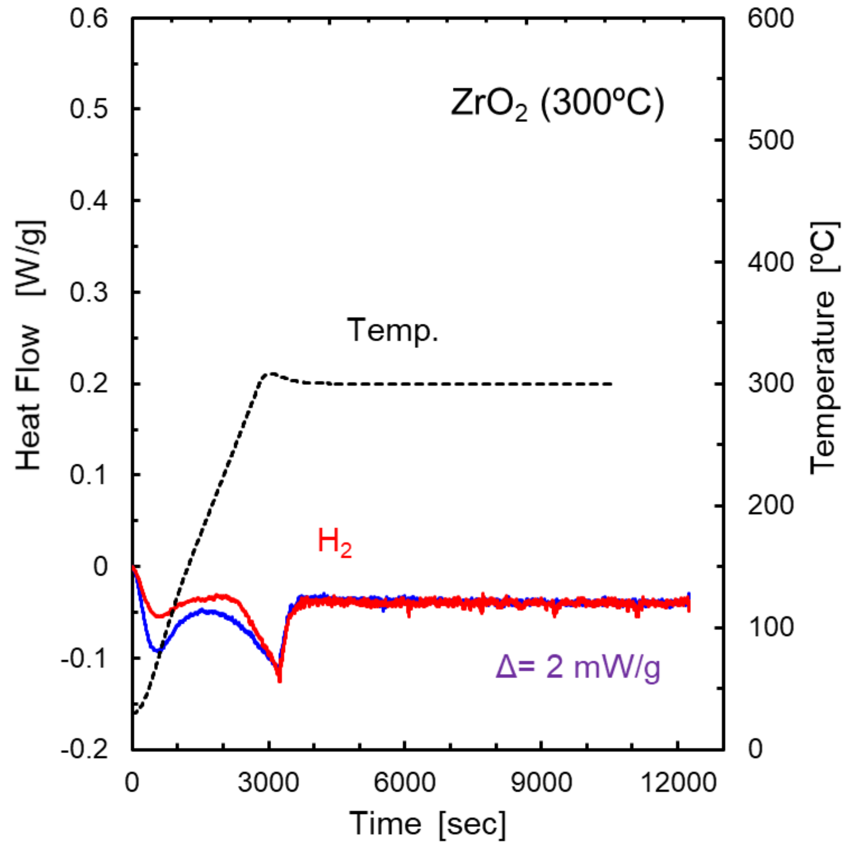
Blank Runs : He gas flow

Foreground Runs: H_2 gas flow

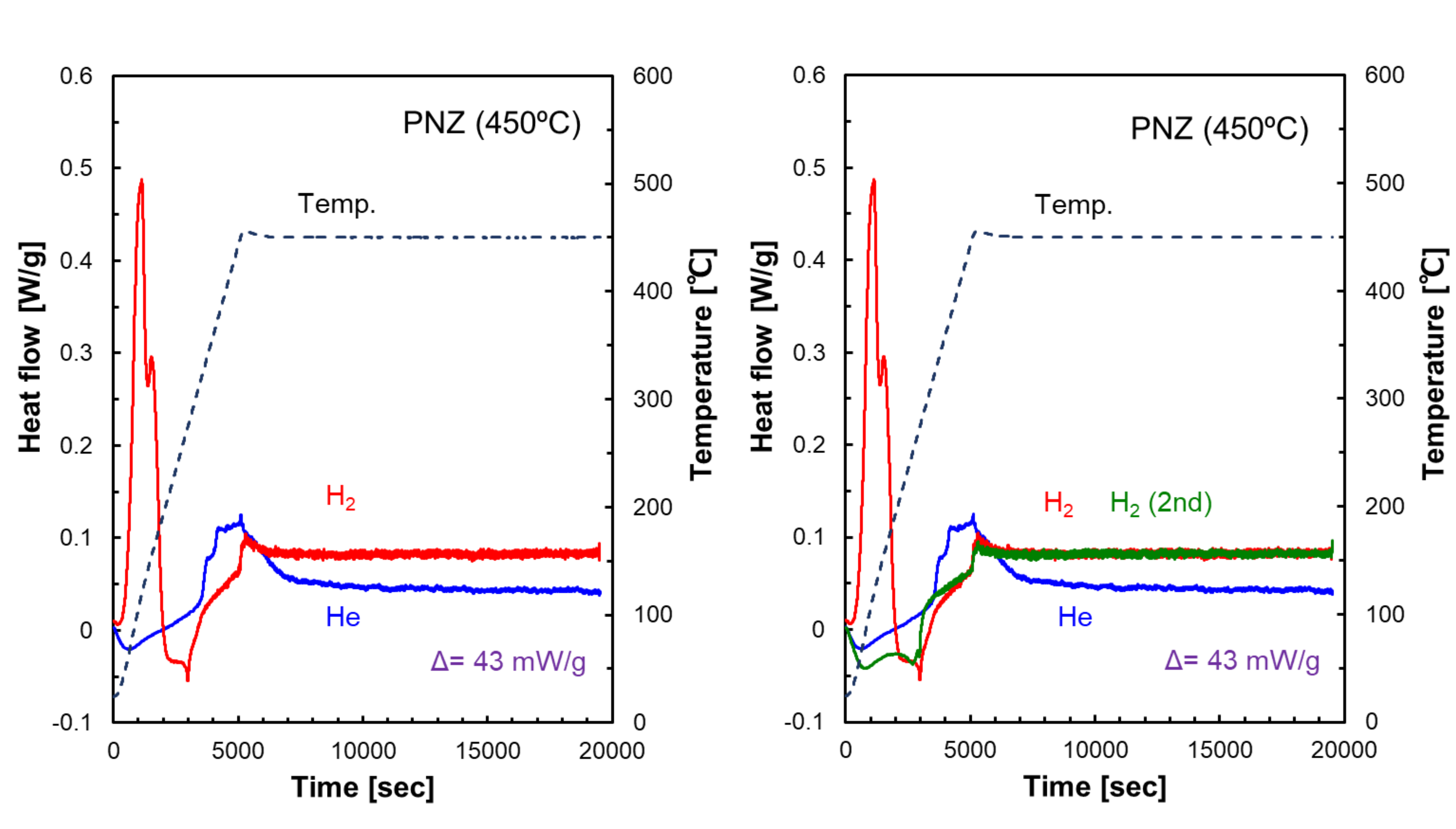
DSC Experiments at Kyushu University

No Anomalous Heat was observed for Ni and ZrO_2 samples

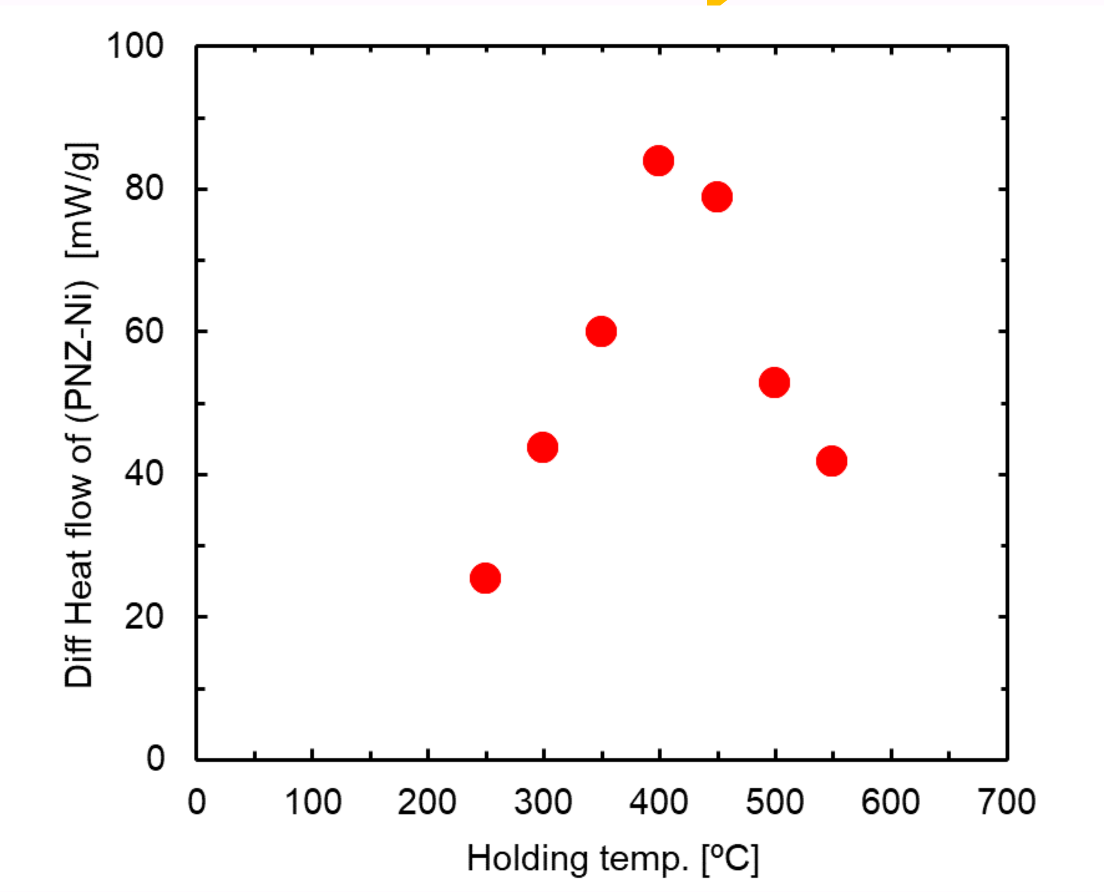




DSC Experiments at Kyushu University
Anomalous Heat was observed for PNZ(Pd_1Ni_7/ZrO_2)samples

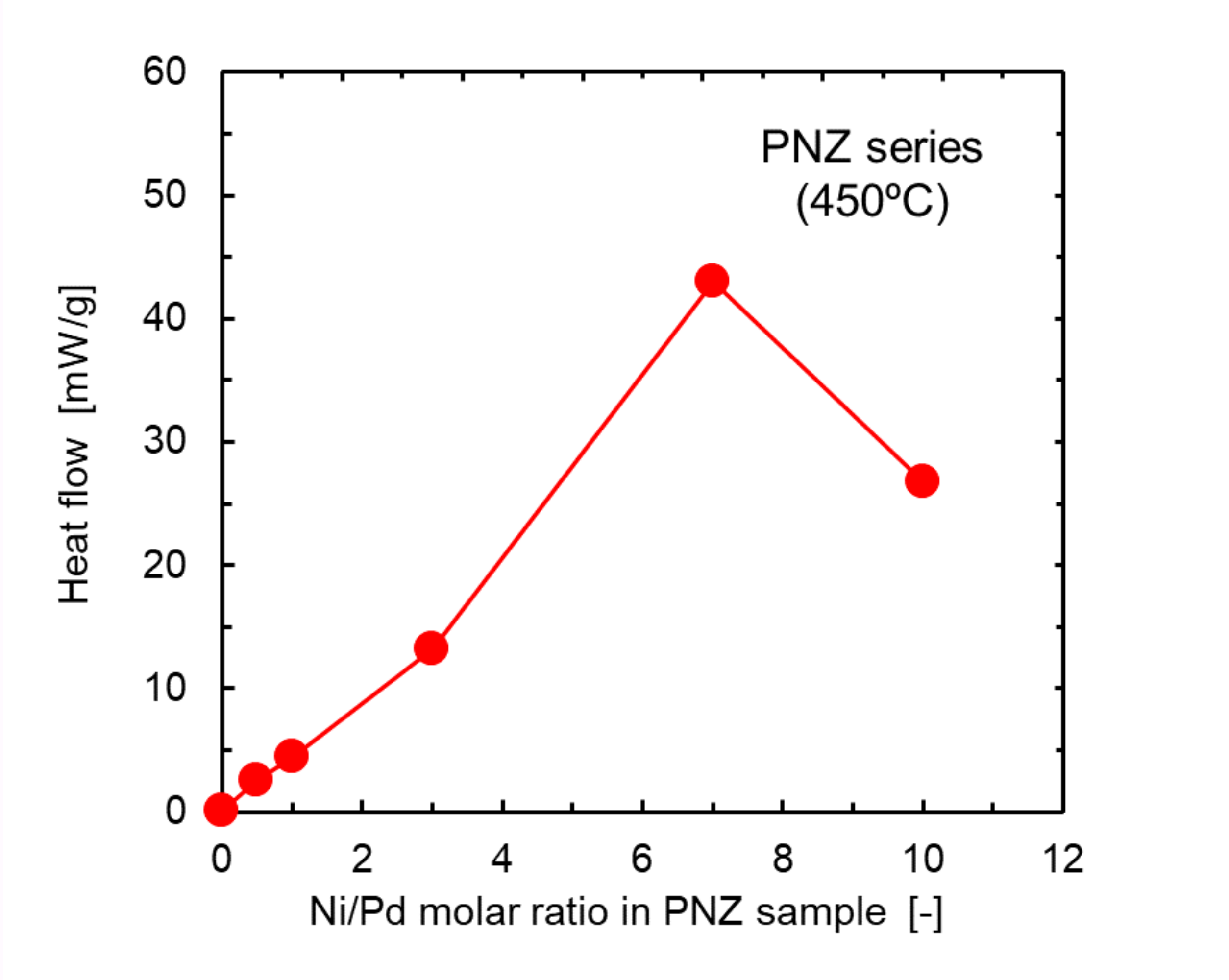


Results by DSC experiments: Optimum running temperature
For Pd_1Ni_7/zirconia sample



450° C
Is
Calcination
Temperature
For PNZ Making

Results by DSC experiments; Optimum Pd/Ni Ratio

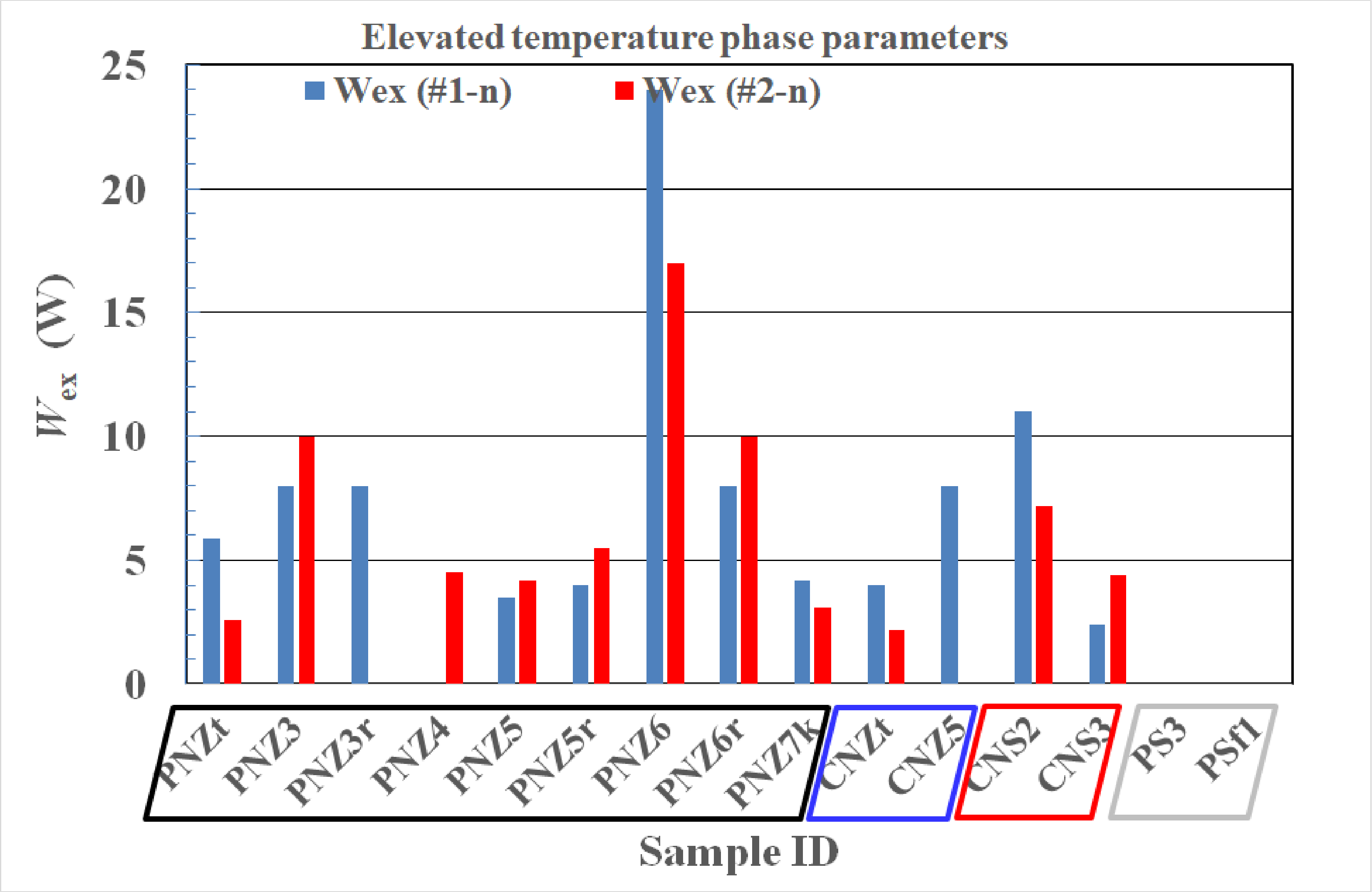


Summary Table of Integrated Data for Observed Heat at RT and ET

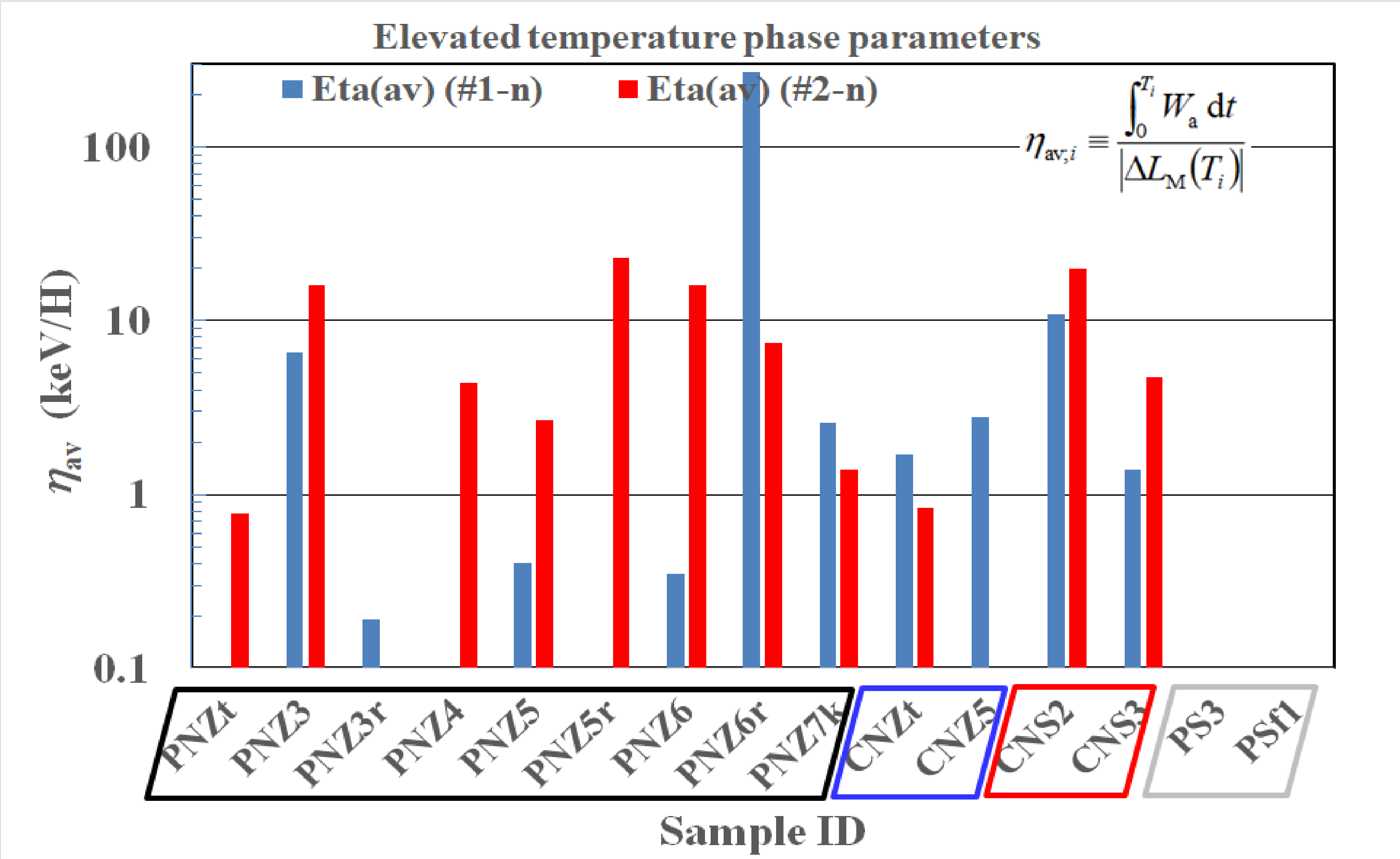
Sample ID	M (Ni or Pd) content	Pd/Ni or Cu/Ni	D or H	Room temp.						Elevated temp. (> 250°C)							
				L_M		$E_t \equiv \int W_a dt$		η_{av}		L_M		W_{ex}		η_{av}		$E_{ex} \equiv \int W_a dt / L_M$	
	(g)					(kJ/m-M)		(eV/H)				(W)		(keV/H)		(MJ/m-H)	
(collab)				#1	#2<	#1	#2<	#1	#2<	#1	#2<	#1	#2<	#1	#2<	#1	#2<
PNZt	6.4	1/7	D(H)	(1.1)	2.2	220	81	(2.1)	0.39	1.5	0.15	5.9	2.6	(0.29)	0.77	(7.8)	4.3
PNZ3	20.0	1/7	D(H)	3.4	1.6	200	62	0.61	0.43	2.8	1.1	8.0	10	6.5	16	3.7	5.7
PNZ3r	18.8	1/7	H	0.11	(5.3)	6.0	0	0.62	0	2.1	(7.4)	8.0	---	0.19	---	2.0	---
PNZ4	23.0	1/7	D	3.5	1.8	180	73	0.56	0.43	3.1	1.1	---	4.5	---	4.4	---	3.0
PNZ5	41.1	1/7	D	3.5	1.1	210	43	0.63	0.4	3.1	0.55	3.5	4.2	0.4	2.7	1.1	7.6
PNZ5r	40.7	1/7	D(H)	0.32	0.085	16	1.4	0.53	0.17	0.7	0.2	4.0	5.5	0.03	23	2.5	9.0
PNZ6	27.2	1/10	D(H)	3.5	1.2	190	48	0.58	0.41	2.8	0.62	24	17	0.35	16	14	44
PNZ6r	25.2	1/10	D	0.8	0.25	39	0.086	0.51	0.34	0.5	0.25	8	10	270	7.5	54	85
PNZ7k	20.8	1/7	D	3.4	1.3	190	49	0.56	0.38	2.6	0.7	4.2	3.1	2.6	1.4	2.5	3.4
CNZt	9.1	1/7	H(D)	0.19	0.19	6.7	3.7	0.37	0.2	1.7	0.2	4.0	2.2	1.7	0.83	11	150
CNZ5	22.0	1/7	H	0.2	===	9.8	===	0.50	===	1.9	===	8.0	===	2.8	===	2.6	===
CNS2	12.1	1/7	H	0.01	===	0	===	0	===	1.1	0.15	11	7.2	11	20	23	190
CNS3	11.4	1/10	H	0.03	0.02	1.5	1.5	0.57	0.65	0.8	0.16	2.4	4.4	1.4	4.7	6.0	90
PS3	17.3	∞	H(D)	2.1	1.3	130	25	0.60	0.20	0.9	0.7	===	< 1.7	0	0	0.0	0
PSf1	8.4	∞	D	2.6	1.6	130	29	0.51	0.19	1.6	0.7	< 1	< 2.2	0	0	0	0

(1eV/H ≈ 100kJ/mol-H)

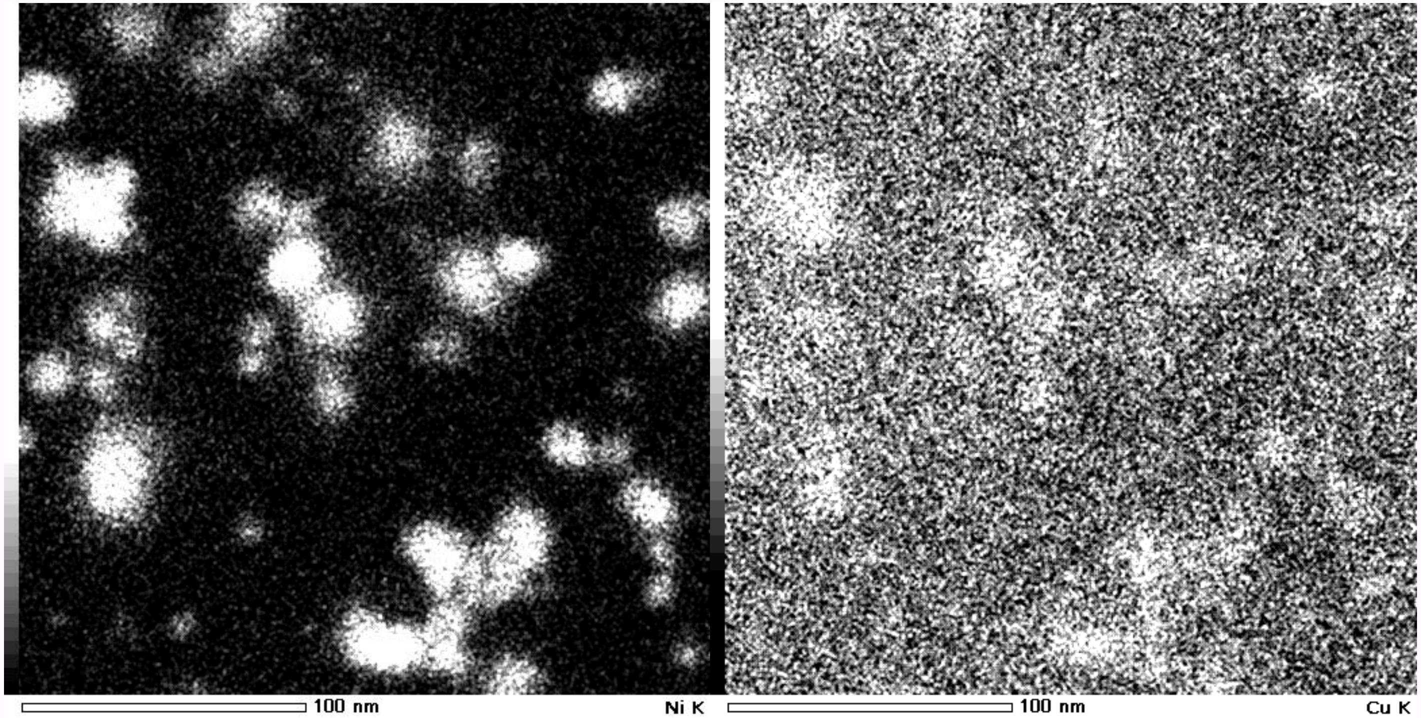
Largest excess power was observed by PNZ6 (Pd_1Ni_{10}/ZrO_2) 120g



Largest heat per transferred-D, 270 keV/D was observed by PNZ6r (re-oxidized)



STEM/EDS mapping for CNS2 sample, showing that Ni and Cu atoms are included in the same pores of the mp-silica with a density ratio approximately equal to the mixing ratio (Cu1/Ni7).



Ni

Cu

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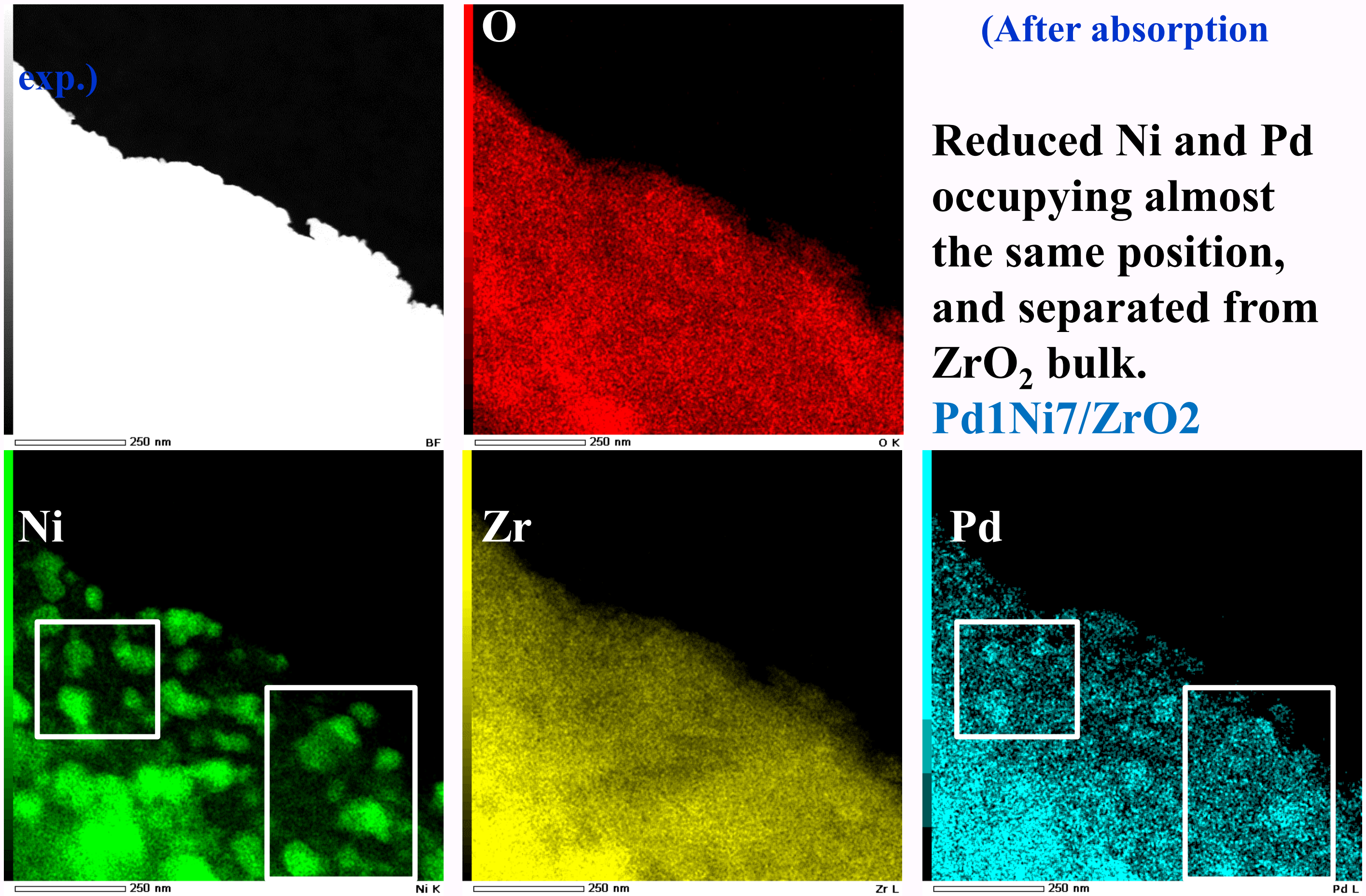
A. Takahashi ICCF21

Pd-Ni nano-structure components are only partial

One of the typical examples of STEM/EDS pictures : PNZ3r-A_000

(After absorption exp.)



Reduced Ni and Pd occupying almost the same position, and separated from ZrO_2 bulk.

Pd1Ni7/ZrO2

ICCF20 **250nm**

Obtained Knowledge

issue	knowkedge
condition	gas : AHE by H and D . CNZ for H Temp. : 150-350℃ (better for higher temp) Pressure : 1~10 atom
Nano-metal	: only-Pd; no AHE Pd-Ni, Cu-Ni, binary-metals needed
Heat	Power : more than several W (max. obs. 25W) Energy : more than several MJ (>100MJ/mol-D) period : more than 30 days
Others	・Ash:He to be confirmed. Less than BG for n and gamma ・AHE happens after H(D)-loaded (H/M: PNZ>CNZ> CNS、Power; PNZ=CNZ=CNS. AHE under H(D)-desorption) ・nano-composites of Pd-Ni and Cu-Ni, reaction sites; 2 binary nanometal surface and/or inside

3. Towards Application（next-R&D)

Issue	Subjective	Method
Increase Power	**Present ca.10W to 500W ～1kW or more**	**Increase reaction rate** **・temperature, pressure** **・increase sample nano** **・high density react. site**
Enhance COP	**Now 1.2; to 3.0～5.0**	
Control	**Find factors, theory**	**Speculation by experiments, construct theory**
Lower cost	**Low cost nano-composites**	**Optimum binary、lower cost fabrication**

Appendix

Brief View of Theoretical Models

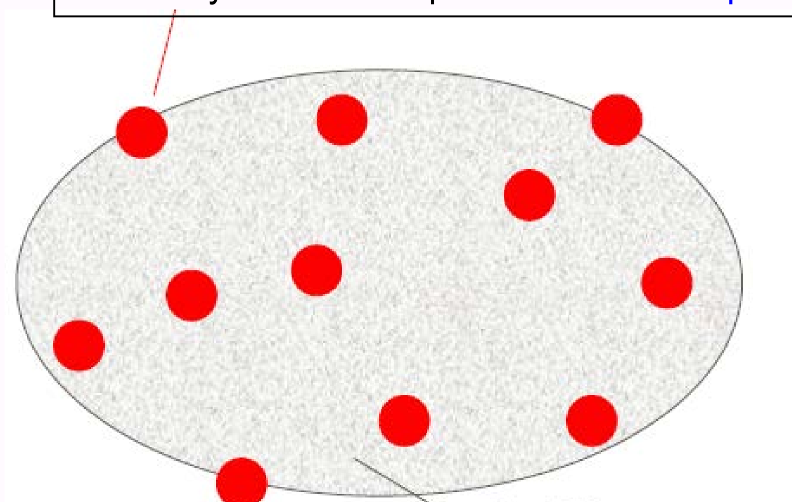
Akito Takahashi

Professor Emeritus Osaka U.

For appendix of 2016-9-8 NEDO hearing

The Making of Mesoscopic Catalyst To Scope CMNR AHE on/in Nano-Composite particles

Meso-Catalyst: as Core/"Incomplete"-Shell Structure
Mono-Metal (with oxide-surface layer)
Or Binary-metal nano-particles: mesoscopic size = 2-10 nm diam.



Ceramics Supporter: several microns flake
(ZrO_2, zeolite, γ-Al_2O_3, meso-porous SiO_2 etc.)

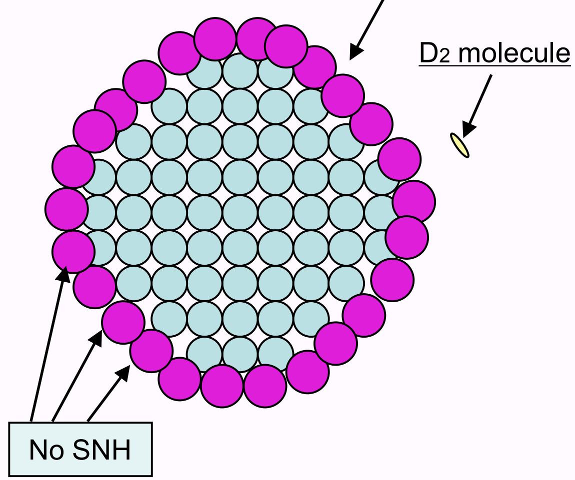
Binary-Element Metal Nano-Particle Catalyst

a) Complete-Pd-shell/Ni-core

Ni-atom; r_0 = 0.138 nm

Pd-atom; r_0 =0.152 nm

2nm diameter **Pd_2Ni_6** particle

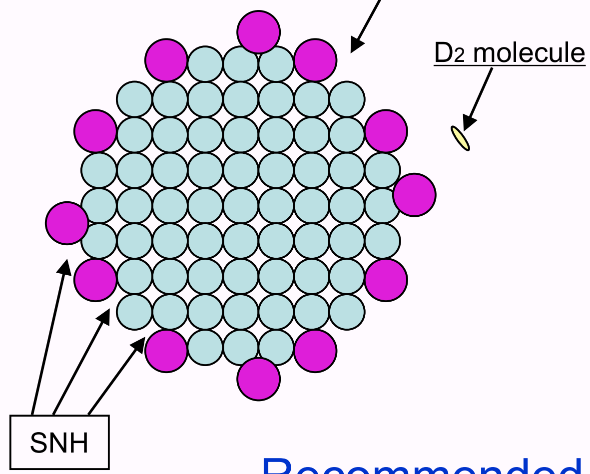


b) Incomplete-Pd-shell/Ni-core

Ni-atom; r_0 = 0.138 nm

Pd-atom; r_0 =0.152 nm

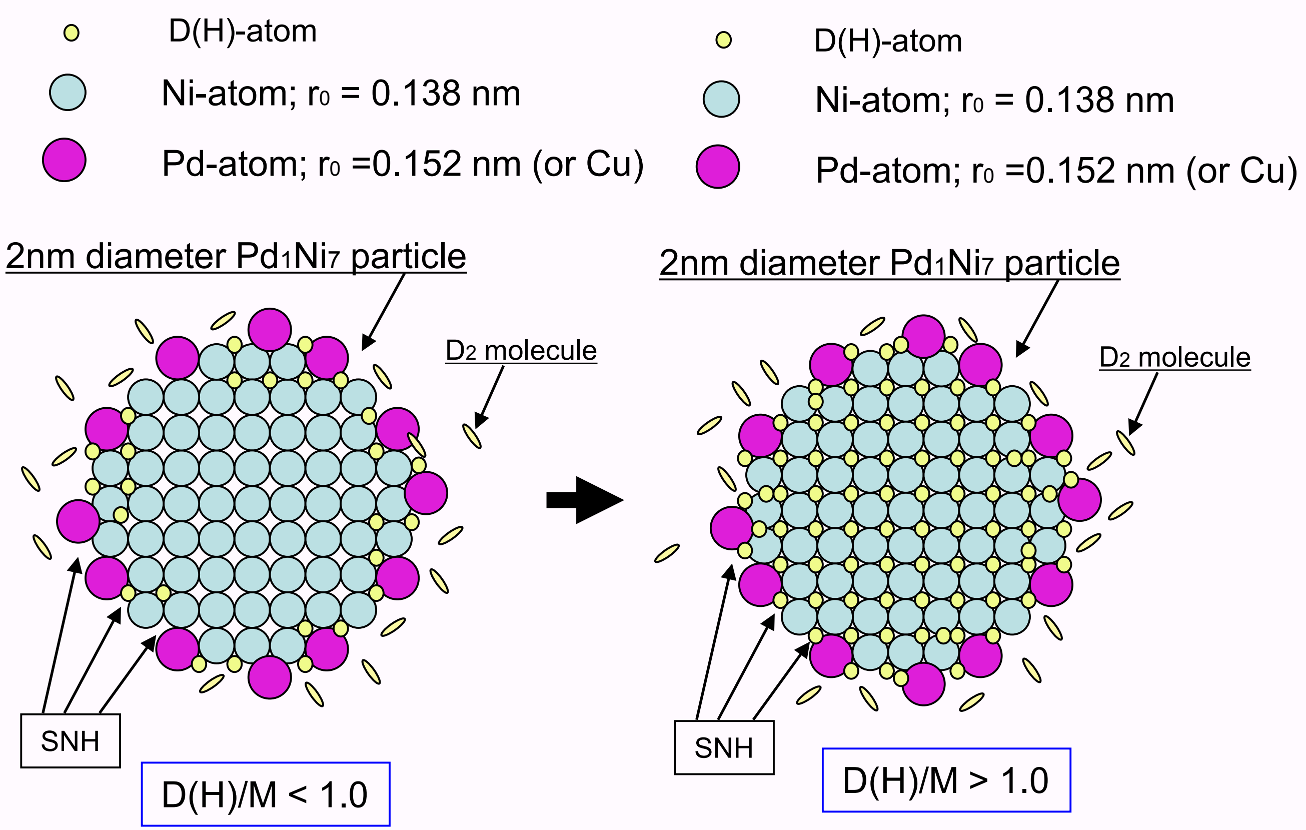
2nm diameter Pd_1Ni_7 particle



Recommended

SNH will be sites for TSC-formation

SNHs are prepared by O-reduction to start D(H) absorption (left)
And D(H)/M loading ratio exceeds 1.0 level (right)



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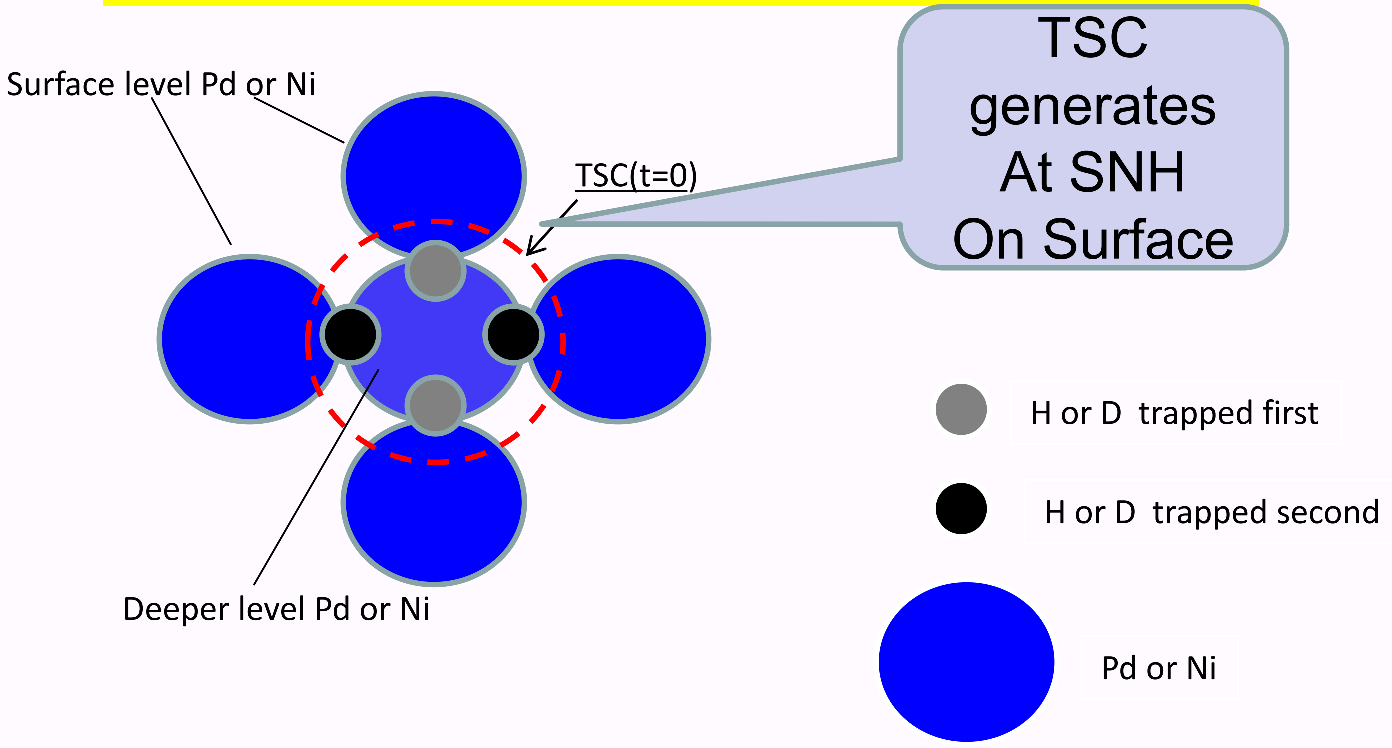
Freedom of rotation is lost for the first trapped D2, and orthogonal coupling with the second trapped D2 happens because of high plus charge density localization of d-d pair and very dilute minus density spreading of electrons.

Image on Formation of TSC(t=0) at **Sub-Nano-Hole** (SNH) Of Nano (**Mesoscopic) Catalyst**



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TSC Langevin Equation:

$$6m_d \frac{d^2\langle R_{dd}\rangle}{dt^2} = -\frac{11.85}{\langle R_{dd}\rangle^2} - 6\frac{\partial V_s(\langle R_{dd}\rangle; m, Z)}{\partial\langle R_{dd}\rangle} + 6.6\left\langle \frac{(R' - R_{dd})^2}{R_{dd}{}^4} \right\rangle$$

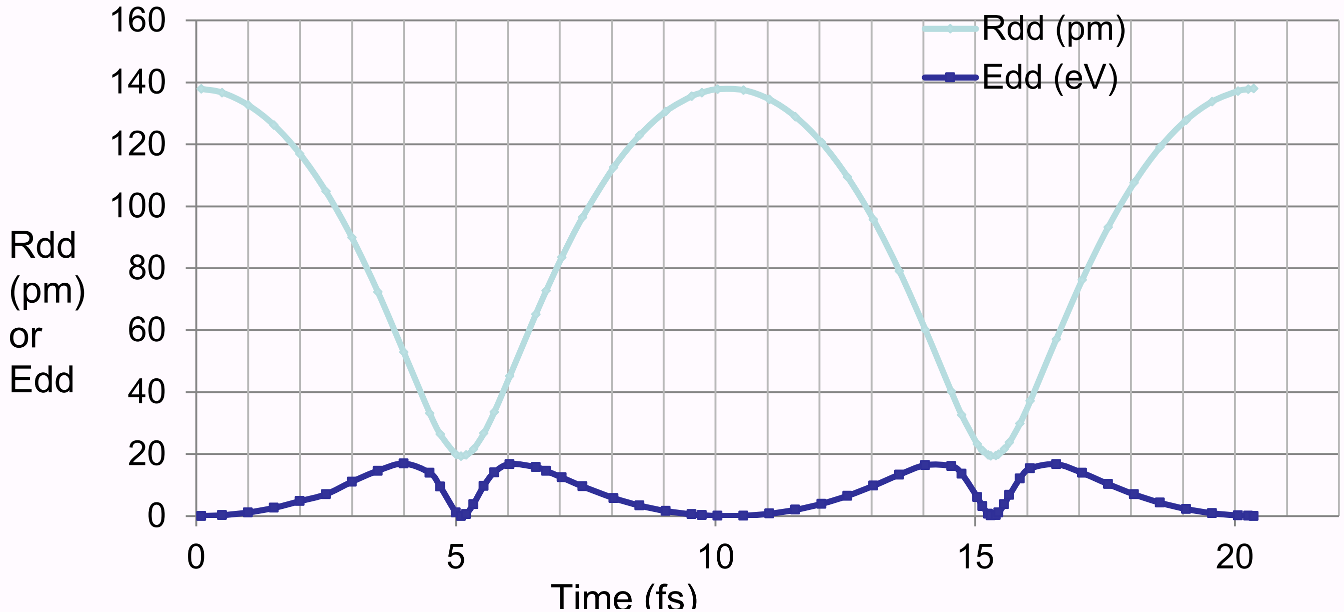
Coulombic
Centripetal
Force

Friction
By electron
Cloud

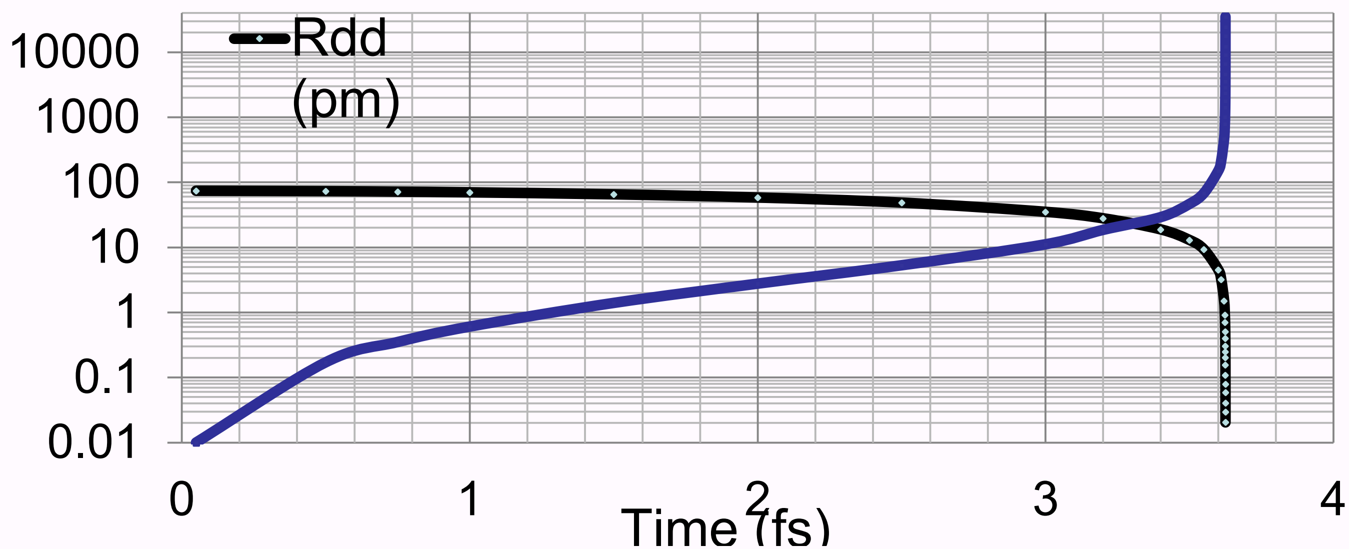
Deviation
From
Platonic symmetry

TSC Trapping Potential:

$$V_{tsc}(R': R_{dd}(t)) = -\frac{11.85}{R_{dd}(t)} + 6V_s(R_{dd}(t); m, Z) + 2.2\frac{|R' - R_{dd}(t)|^3}{[R_{dd}(t)]^4}$$



3D+
GS
Osci.



4D/TSC
Collapse

Summary of Simulation Results

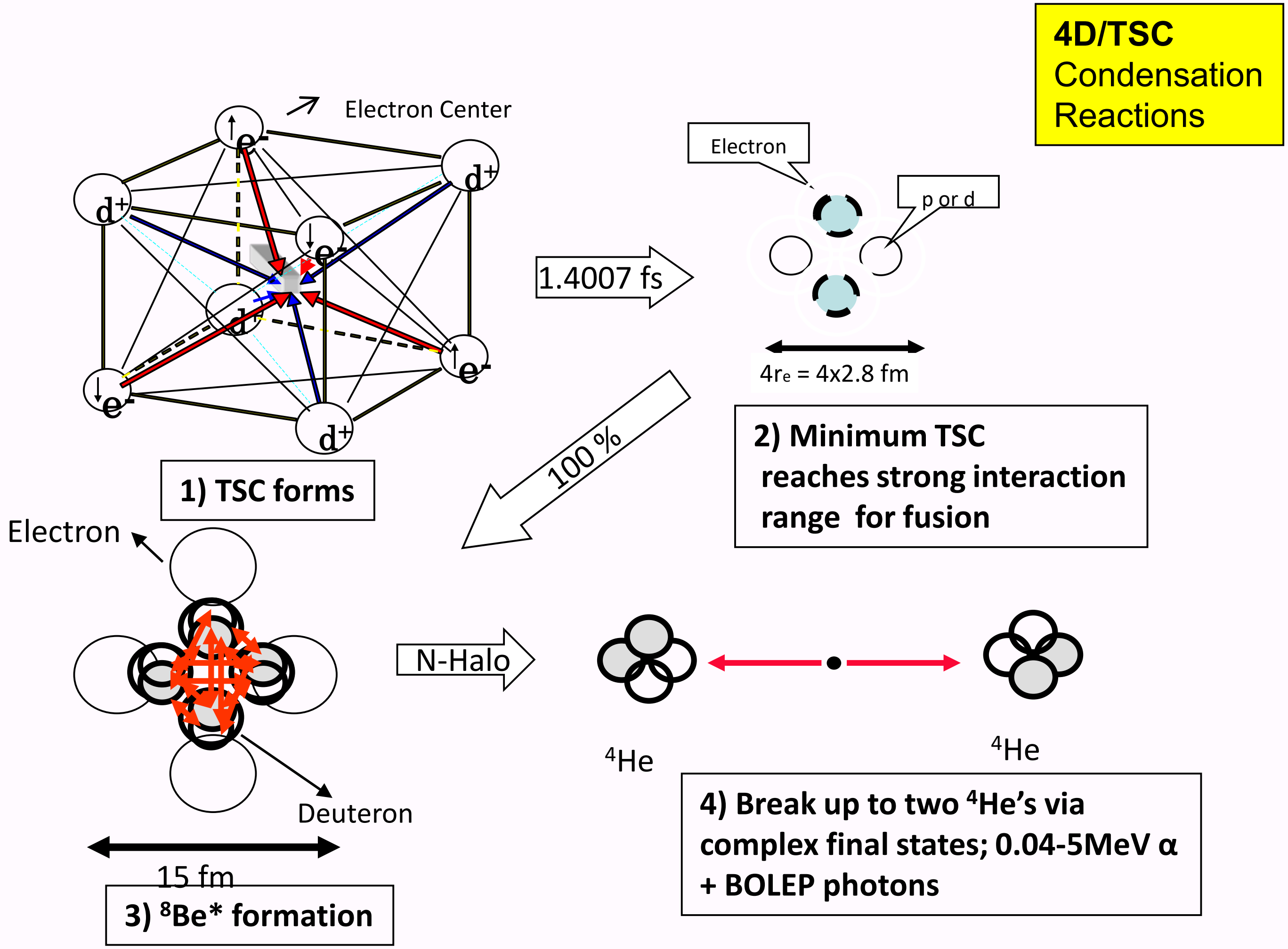
Cluster Type	Collapse? (Rdd-min ≦10 fm)	Rdd (gs)	Remarks
d-e-d (2D+)	N	138 pm	
d-μ-d	N	0.79 pm	DD fusion in 0.1ns
3D+	N	85 pm	
4D/TS	Y		100% 4D fusion
6D/RD	Y		100% 6D fusion
8D/RD	Y		100% 8D fusion or 4D fusion?
12D/RT	N	ca. 80 pm	
20D/RT	Y		What kind of fusion?

Trapped D(H)s state in condensed cluster makes very enhanced fusion rate.

Collision Rate Formula UNDERESTIMATES fusion rate of steady molecule/cluster.

Cluster	$R_{dd} = R_{gs}$ (pm)	Barrier Factor	Steady Cluster d-d Fusion Rate (f/s)	Steady Cluster 4d Fusion rate (f/s)	Fusion Rate for d-d collision formula (f/s)
D_2	74.1	1.0E-85	2.4E-66		3.6E-86 (4.0E-72)*
dde*(2,2)	21.8	1.3E-46	3.2E-27		1.0E-46 (1.0E-31)*
ddμ	0.805	1.0E-9	2.4E+10		1.5E-9 (1.0E+8)*
4D/TSC-minimum	0.021	1.98E-3		3.7E+20	

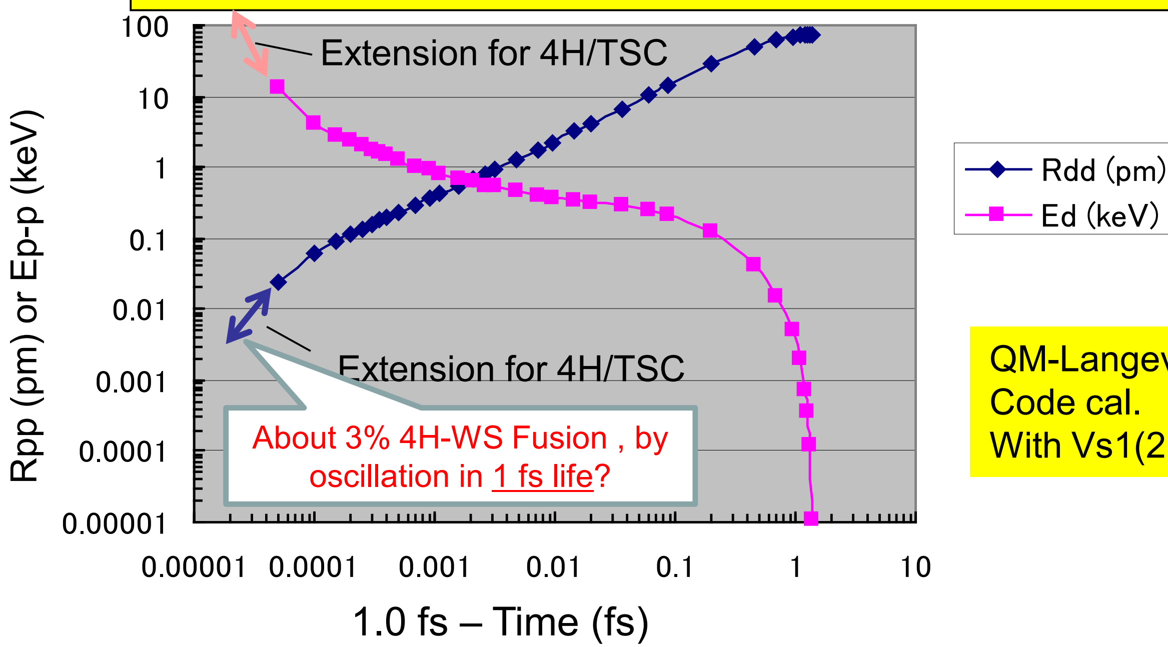
* Frequency of d-d pair oscillation by QM-Langevin calculation was considered.


4D/TSC
Condensation
Reactions
Electron Center
d+
e-
1) TSC forms
1.4007 fs
Electron
p or d
4re = 4x2.8 fm
2) Minimum TSC
reaches strong interaction
range for fusion
100 %
Electron
Deuteron
15 fm
3) 8Be* formation
N-Halo
4He
4He
4) Break up to two 4He's via
complex final states; 0.04-5MeV α
+ BOLEP photons

TSC Condensation Motion; by the Langevin Eq.:

Condensation Time = 1.4 fs for 4D and 1.0 fs for 4H

Proton Kinetic Energy INCREASES as Rpp decreases.



QM-Langevin
Code cal.
With Vs1(2,2)

Ep = 100 keV at Rpp = 2.4 fm,
Vtrap = - 1.2-2 MeV

Electrons Mean KE : 0.6-1MeV

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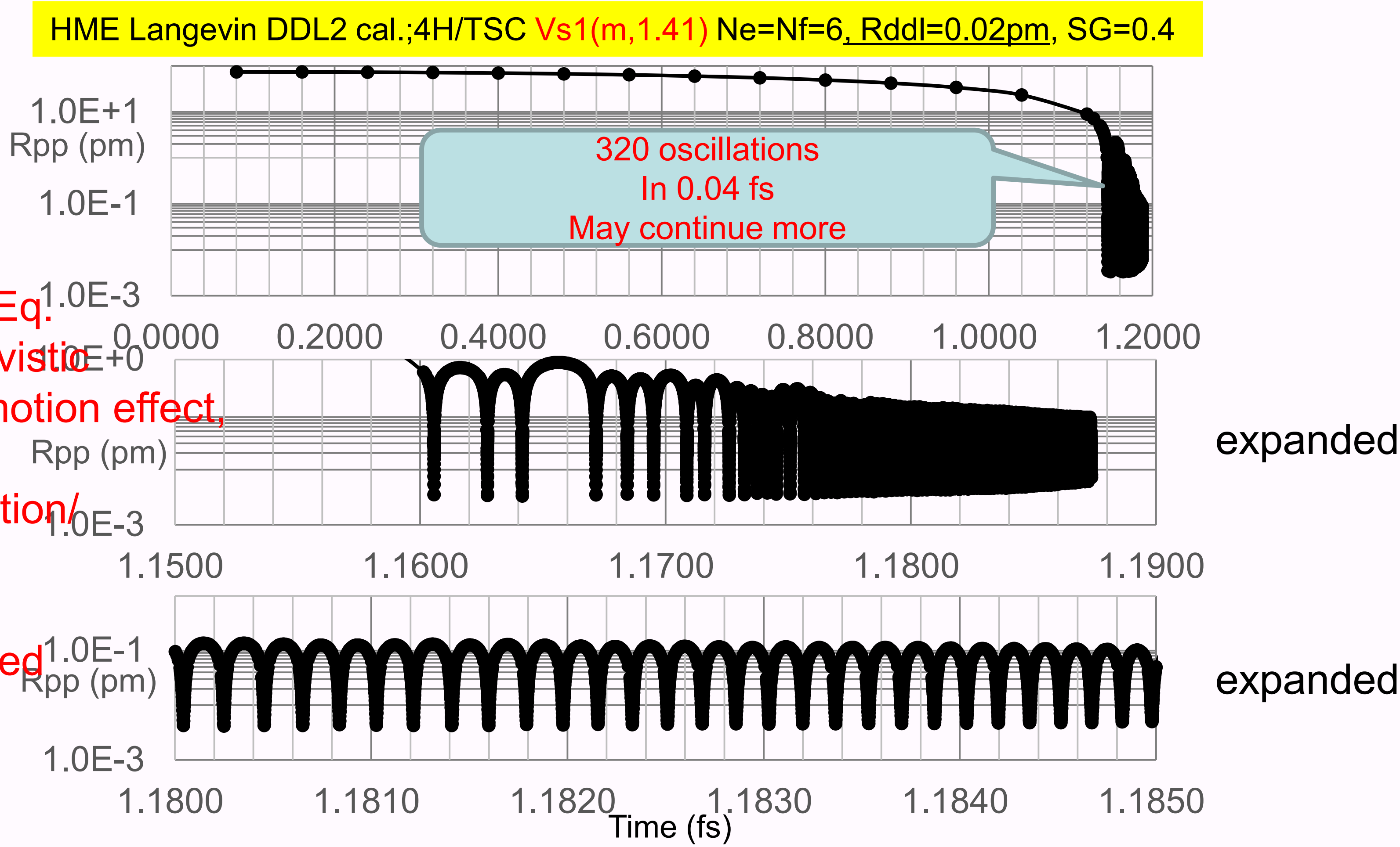
4H/TSC will condense and collapse under rather long time chaotic oscilation
Near weak nuclear force enhanced p-e distance

By QM-Langevin Eq.
With relativistic
Electron motion effect,
4H/TSC
Condensation/
Collapse
Dynamics
Is simukated



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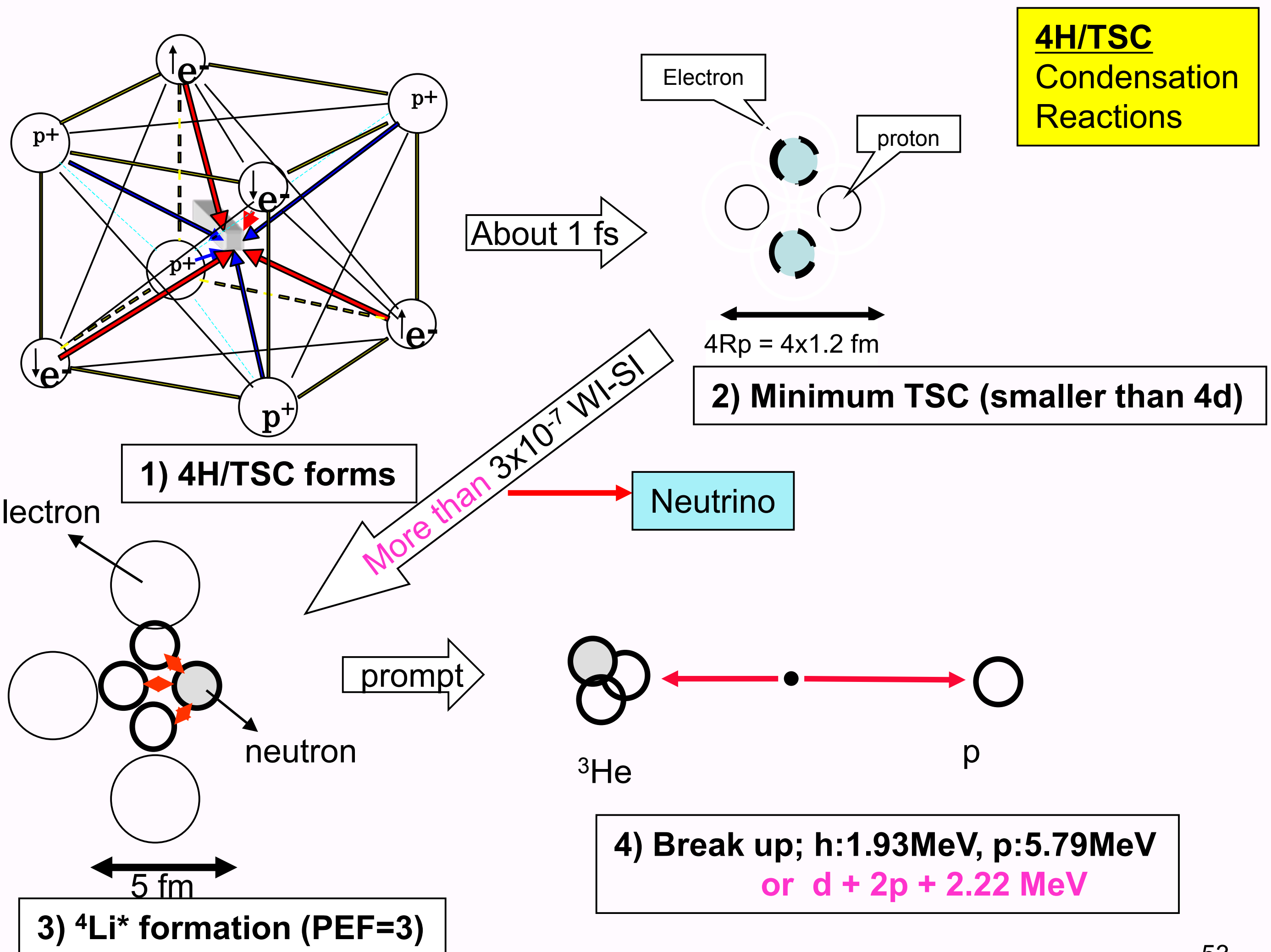
4H/TSC
Condensation
Reactions
e-
p+
1) 4H/TSC forms
About 1 fs
Electron
proton
4Rp = 4x1.2 fm
2) Minimum TSC (smaller than 4d)
More than 3x10-7 WI-SI
Neutrino
Electron
neutron
5 fm
3) 4Li* formation (PEF=3)
prompt
3He
p
4) Break up; h:1.93MeV, p:5.79MeV
or d + 2p + 2.22 MeV
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Principle is Radiation-Less Condensed Cluster Fusion

A. Takahashi / Journal of Condensed Matter Nuclear Science 15 (2014) 1–12

Table 1. Major experimental claims of cold fusion and predictions by the TSC theories.

	Claims by experiments	Predictions by TSC models
Metal Deuterium Energy (MDE)	Heat: 24 ± 1 MeV/^{4}He (Miles [1], McKubre et al. [2])	4D fusion ash with low-E alphas (46 keV)
	Weak alpha peaks (Lipson [14], Roussetski [15], etc.)	Minor alpha-peaks by nucleon halo BOLEP minor decay channels
	Weak neutrons (Takahashi, Boss [16], etc.)	High-E neutron by minor triton emission BOLEP in ca. 1.5 keV
	X-rays burst (Karabut et al. [13])	
Metal Hydrogen Energy (MHE)	Heat w/o n and gamma	4H/TSC WS fusion
	Unknown ash	2–7 MeV ^{3}He and d
	(Piantelli [3], Takahashi–Kitamura [20], Celani [5], etc.)	Very weak secondary gamma and n: ca. 10^{-11} of ^{3}He and d yield