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Anomalous Heat Generation in Charging of Pd Powders with High Density Hydrogen Isotopes

(I) Results of absorption experiments using Pd powders

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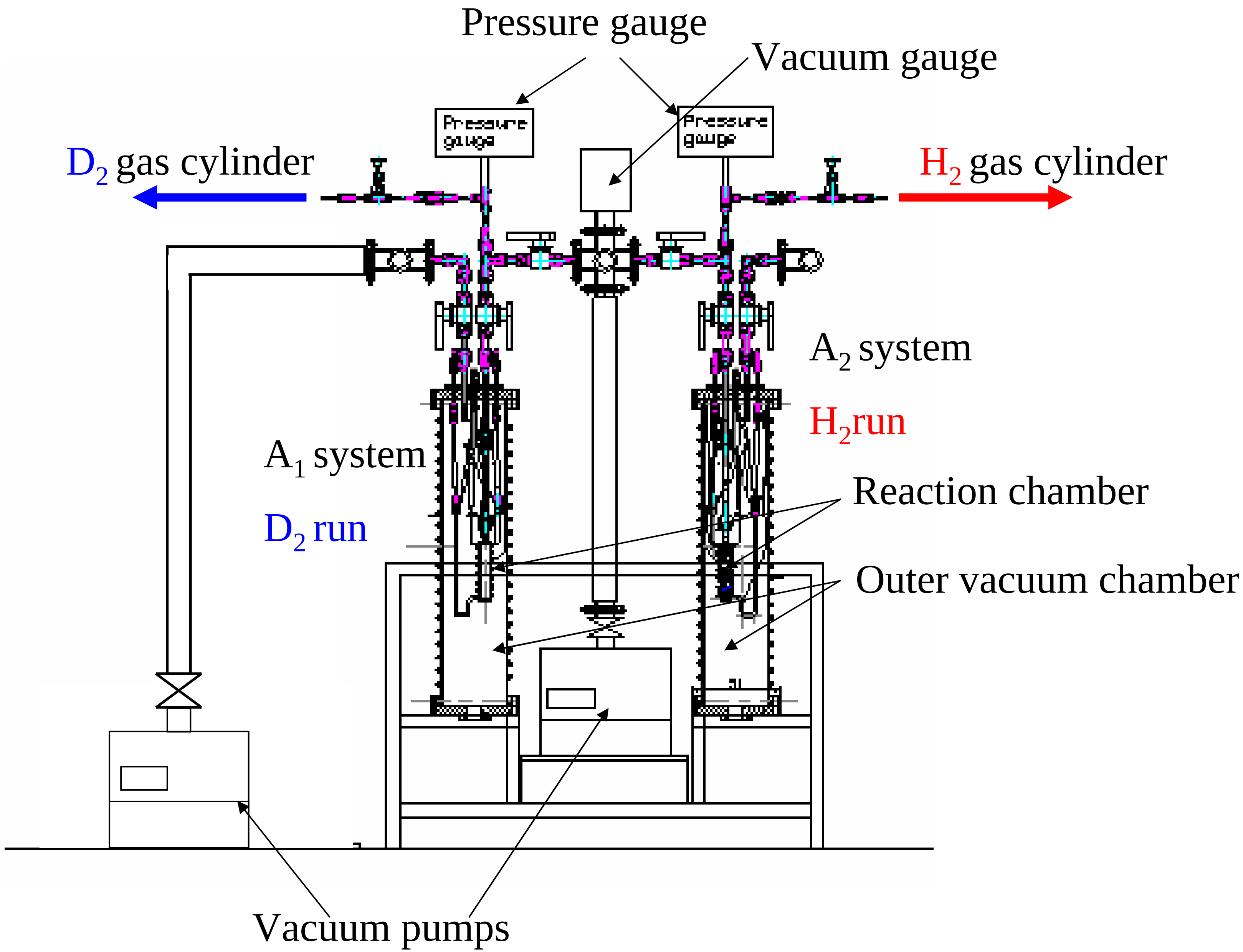
Aim

It has been reported in ref. [1] that charging of highly pure D2 gas into Pd nano-powders in the form of Pd/ZrO2 nano-composite contained in a stainless-steel vacuum vessel has induced significant excess heat.

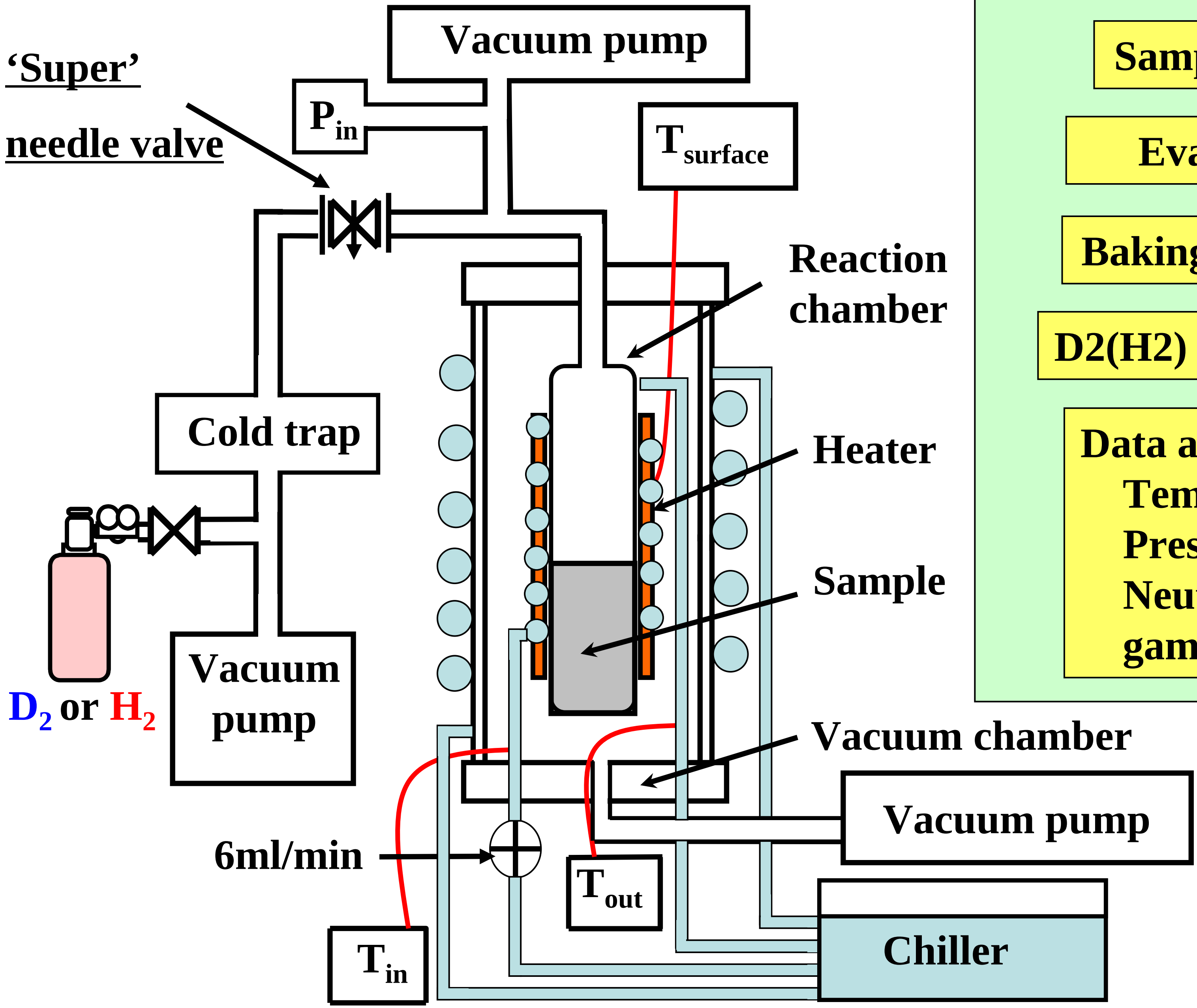
we have constructed an experimental system to confirm the phenomenon of heat and ^{4}He generation by calorimetry and investigate the underlying physics.

[1] Y. Arata, et al.; The special report on research project for creation of new energy, J. High Temperature Society, No. 1. 2008.

Reduced view of the twin system A1A2



Functional view of the A_1 A_2system



Experimental procedure

Sample set-up

Evacuation

Baking (340K 3h)

D2(H2) gas charging

Data acquisition
- Temperature
- Pressure
- Neutron
- gamma-ray etc.

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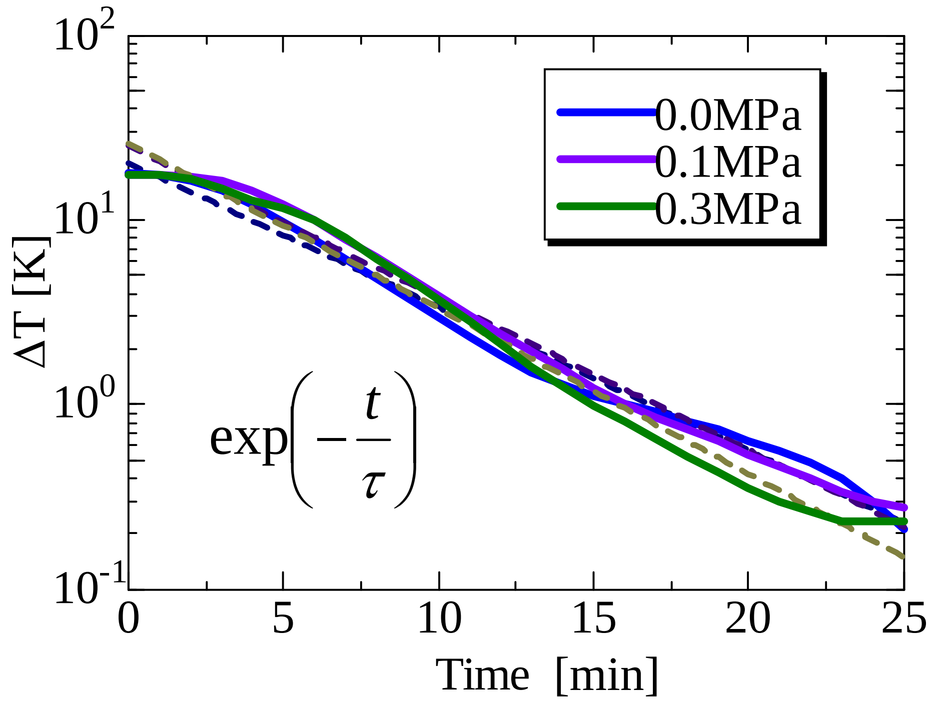
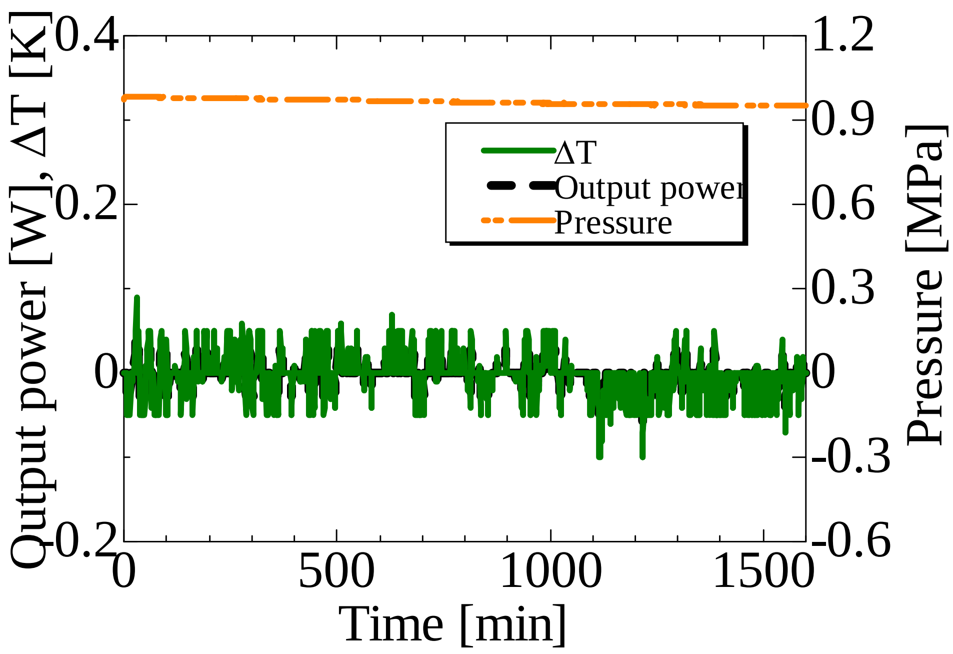
Performance of calorimetry

Time resolution : 5 min



Accuracy : ± 14 mW



Samples

- ϕ100 nm Pd (**PP**); This is a Pd powder diameter of particle is 100 nm, purity is 99.5%.

- Pd-black (**PB**); This is a 300 mesh powder and purity is 99.9%

- Santoku Pd (**PZ**); This is a nano-sized(**8 nm** and **10.5 nm**) powder of mixed-oxides of Pd and Zr (fabricated by Santoku Corporation)

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TEM Image of Santoku Pd (10.5 nm)

(By courtesy of the Nuclear Science and Engineering Institute and Particulate Systems Research Center at the University of Missouri-Colombia; Prof. R. Duncan *et al.*)

TEM images of Palladium nanoparticles from Japan (sample # 2)

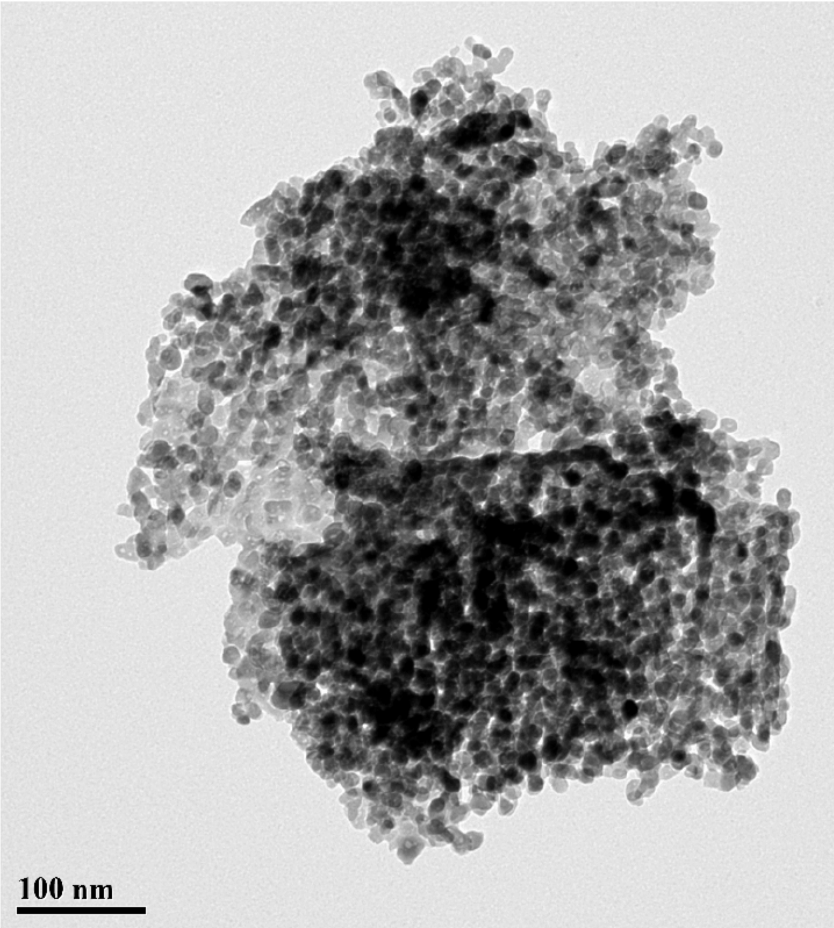
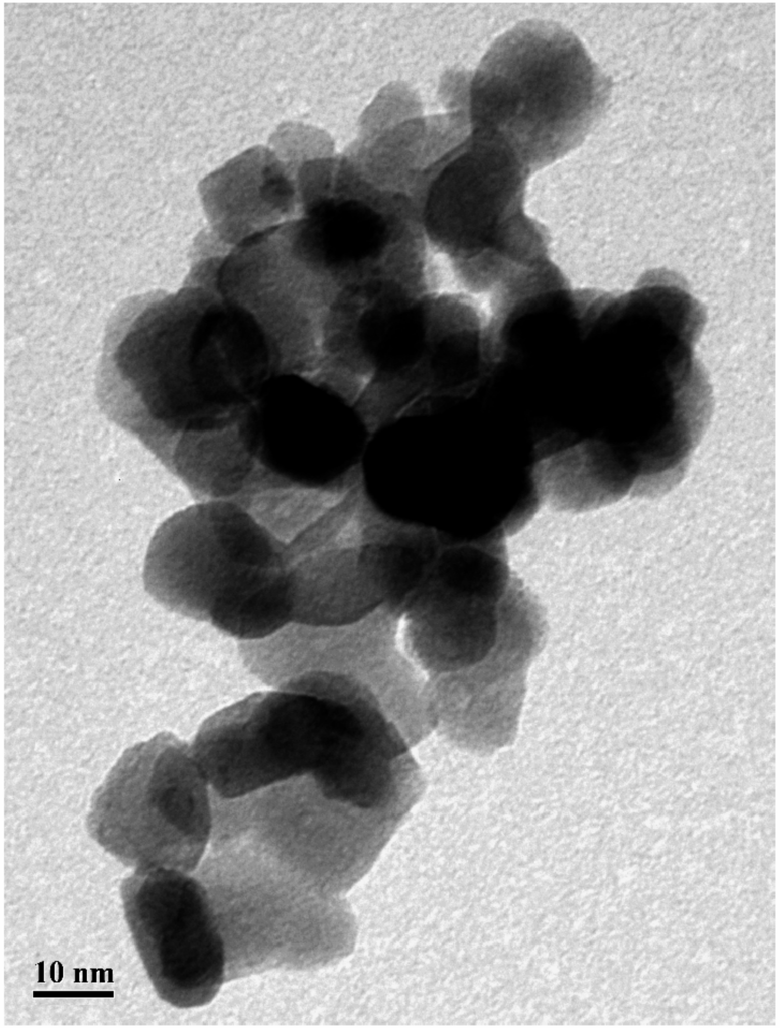
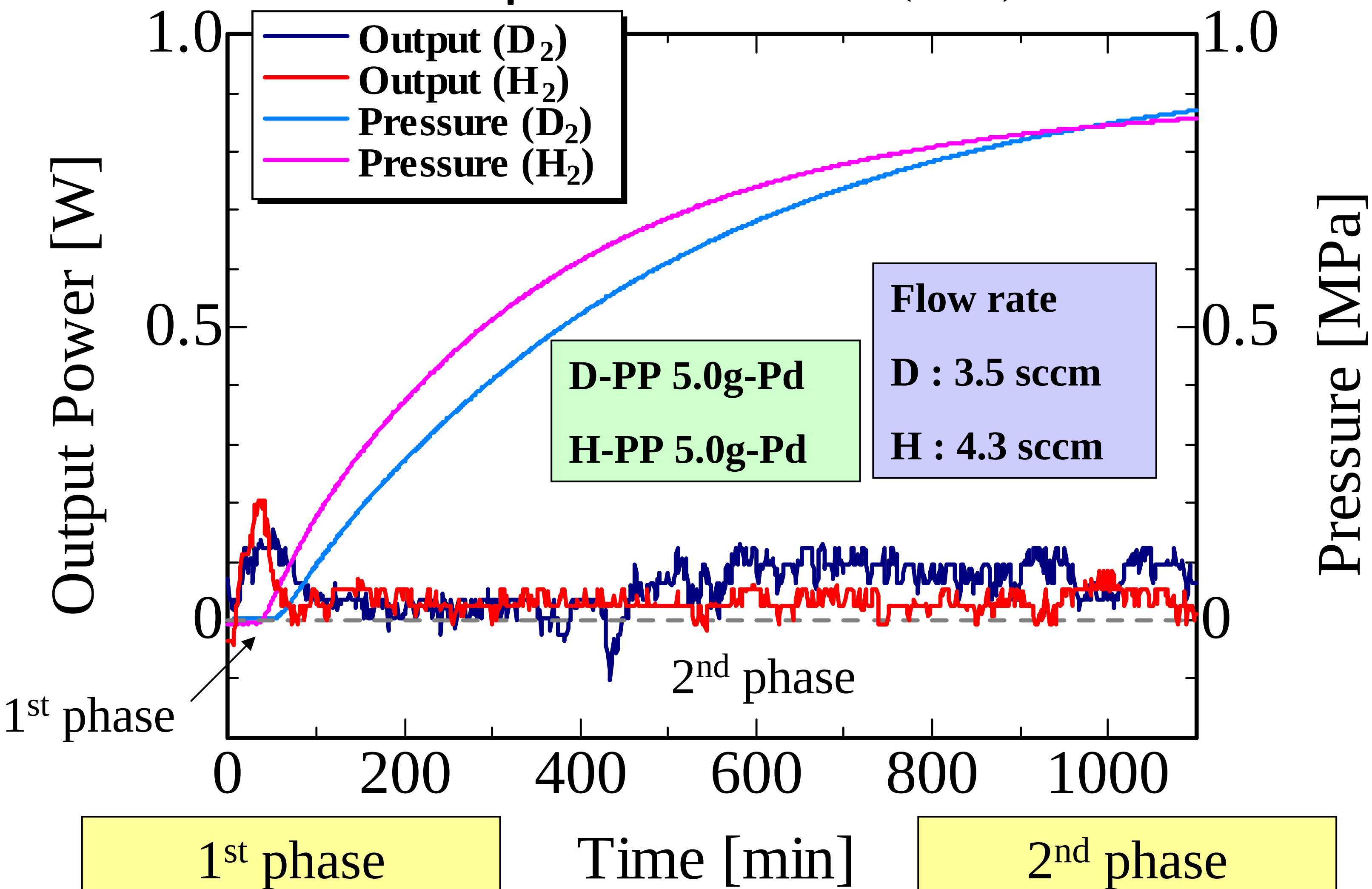


Image at 25000X magnification



ϕ100nm Pd (PP)



1st phase		2nd phase
D_2 : 0.10kJ/g-Pd	D/Pd=0.43	D_2 : 0.79kJ/g-Pd
H_2 : 0.08kJ/g-Pd	H/Pd=0.45	H_2 : 0.53kJ/g-Pd

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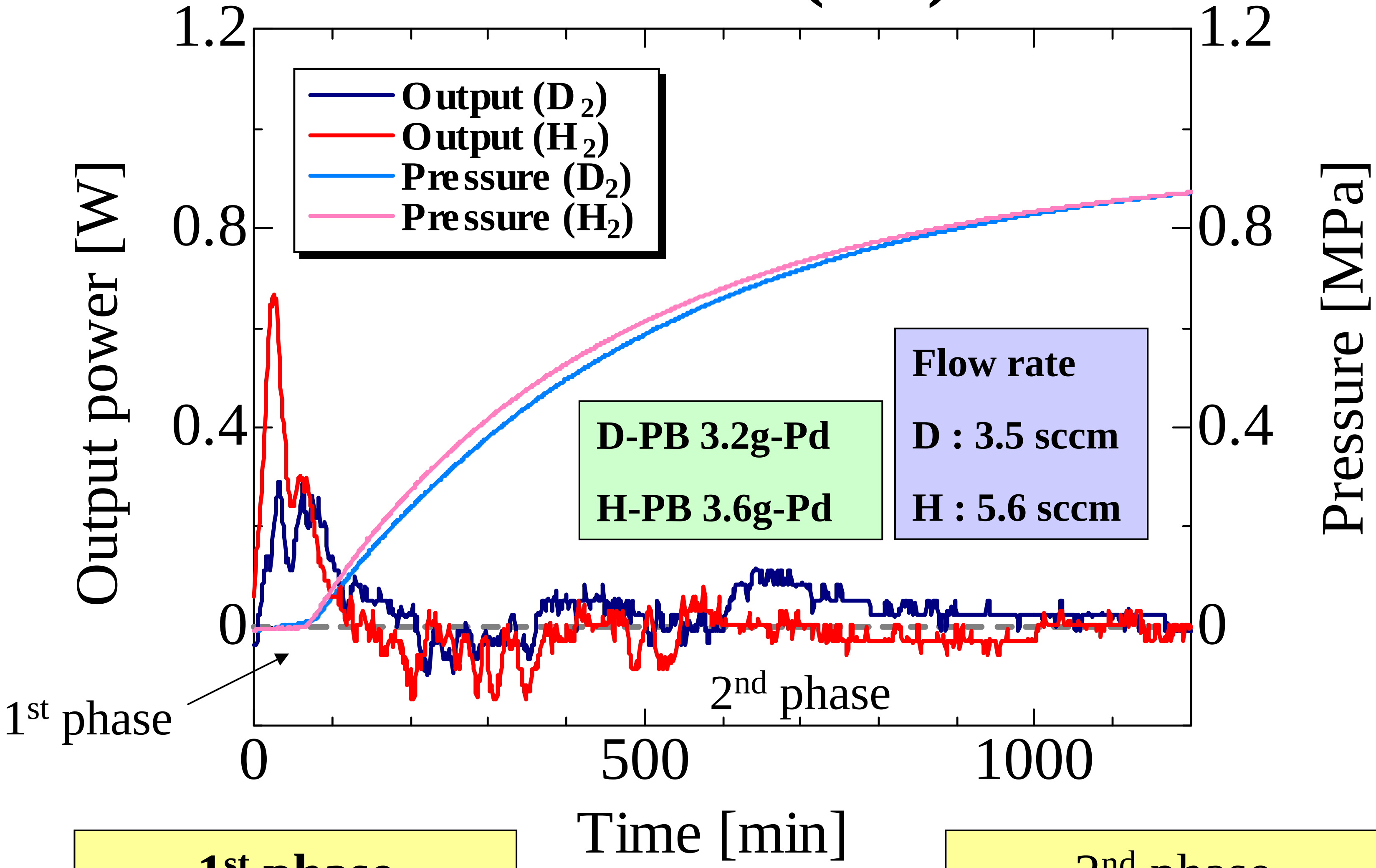
Pd-black (PB)



1st phase
D_2 : 0. 54kJ/g-Pd
H_2 : 0.45kJ/g-Pd

D/Pd=0.85

H/Pd=0.78

2nd phase
D_2 : 0.65kJ/g-Pd
H_2 : -0.62kJ/g-Pd

Santoku Pd (PZ1,2#1)

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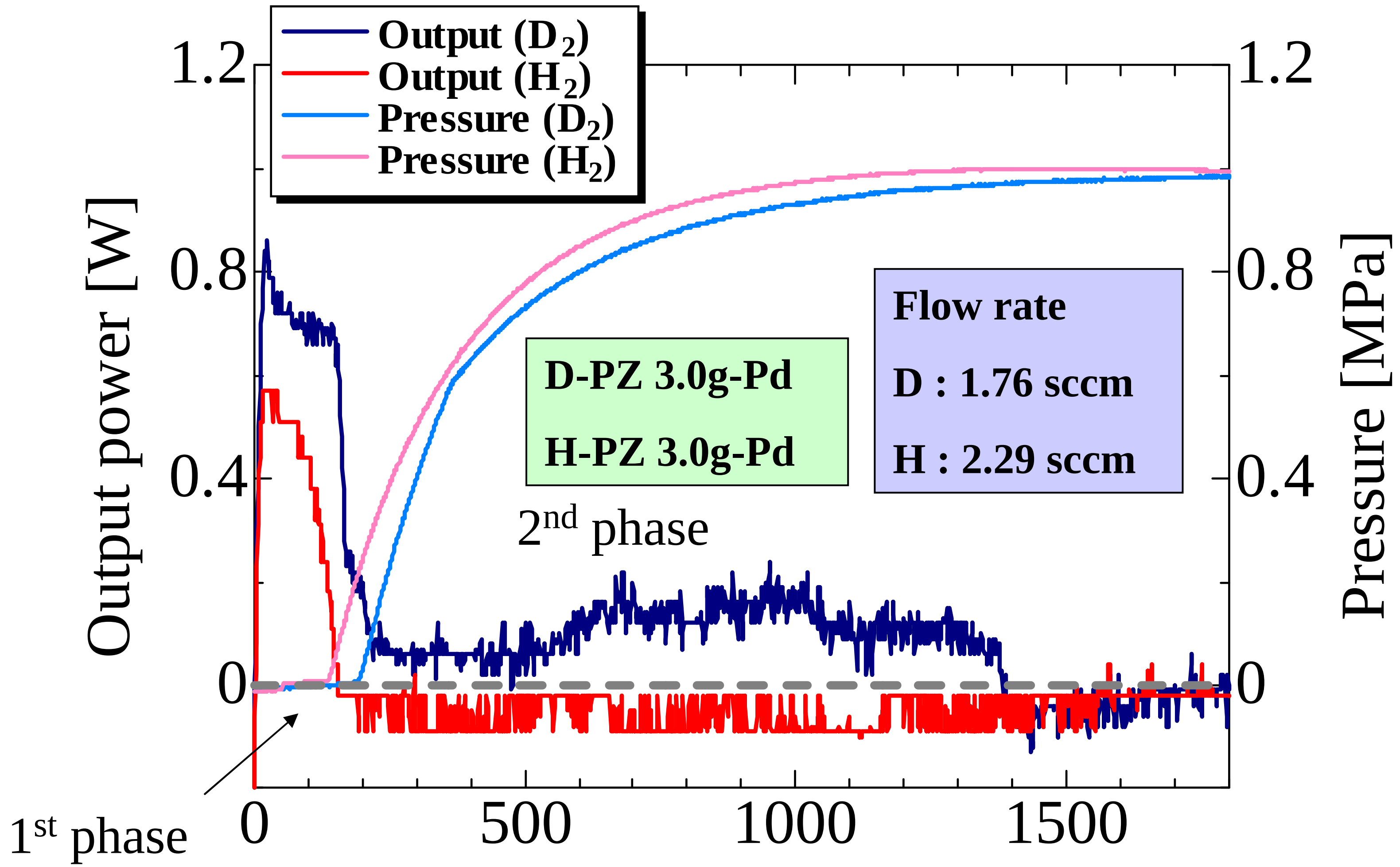

1st phase

D_2 : 1.3 kJ/g-Pd

H_2 : 1.0 kJ/g-Pd

D/Pd= 1.08

H/Pd= 1.00

2nd phase

D_2 : 1.9 kJ/g-Pd

H_2 : -1.3 kJ/g-Pd

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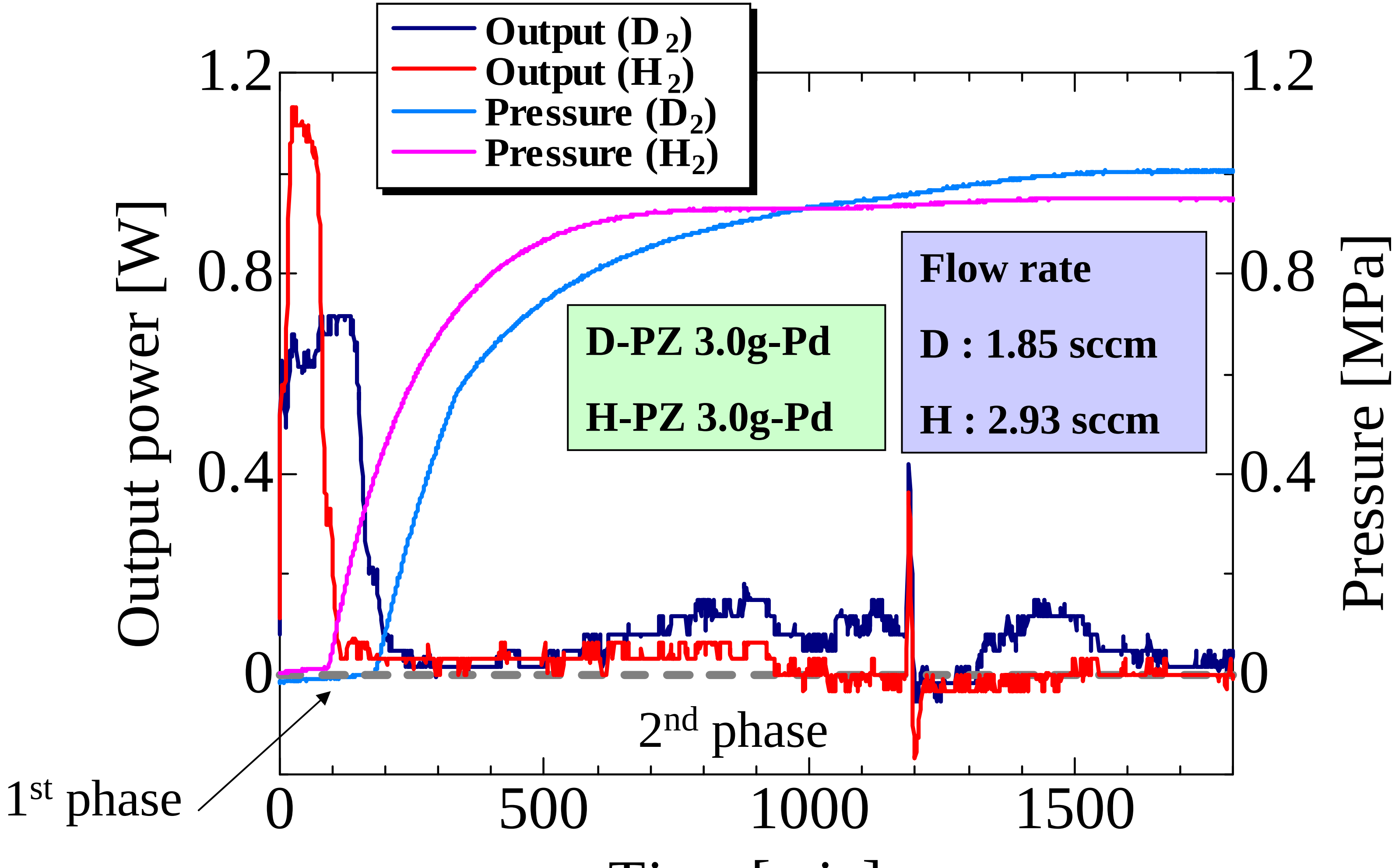
Santoku Pd (PZ3,4#1)



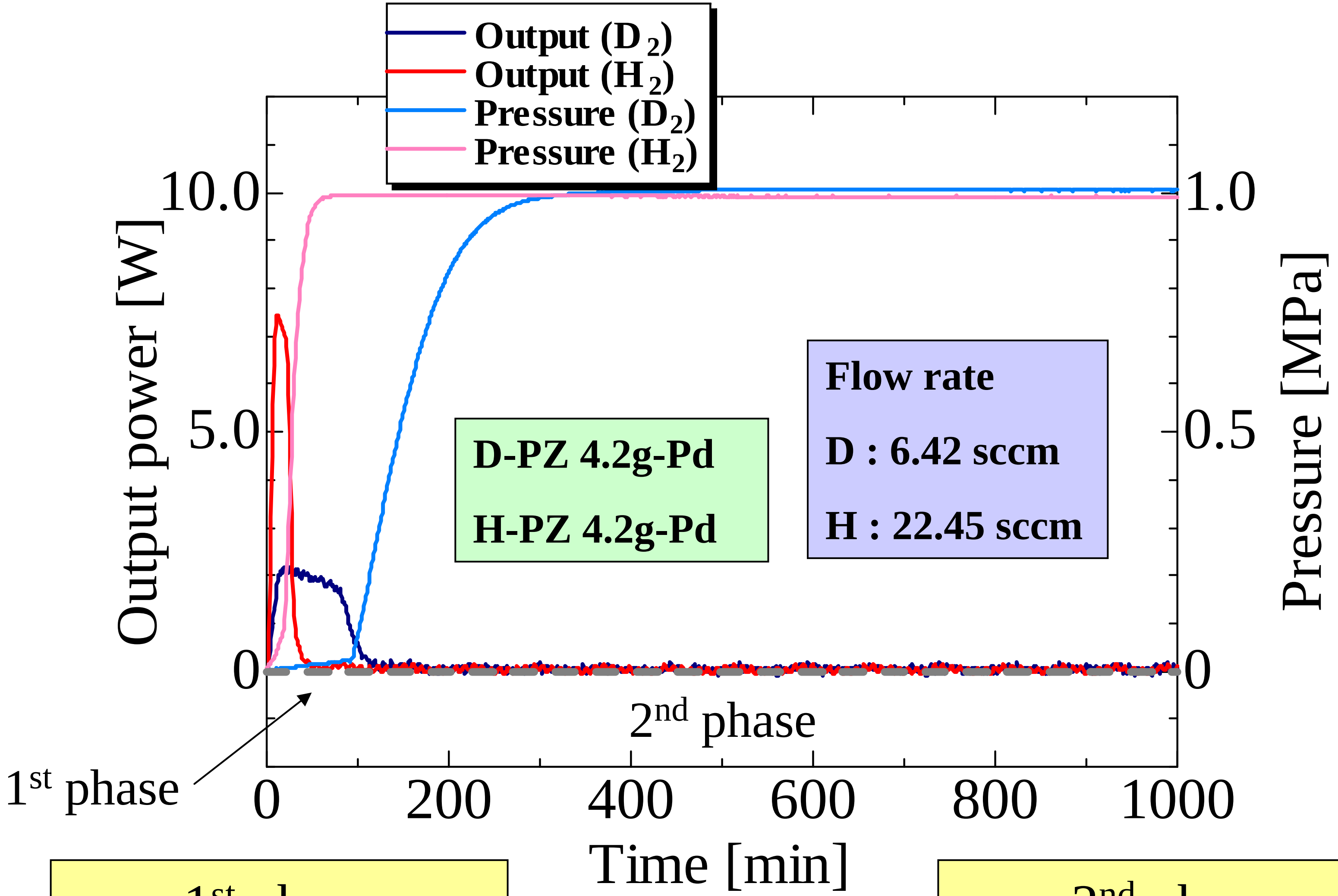
1st phase
D_2 : 2.13kJ/g-Pd
H_2 : 1.70kJ/g-Pd

D/Pd=1.07

H/Pd=0.86

2nd phase
D_2 : 1.28kJ/g-Pd
H_2 : 0.26kJ/g-Pd

Santoku Pd (PZ9,10#1)



1st phase
D_2 : 2.39kJ/g-Pd
H_2 : 2.27kJ/g-Pd

D/Pd= 1.41

H/Pd= 1.02

2nd phase
D_2 : 0.91 kJ/g-Pd
H_2 : 0.91kJ/g-Pd

run	weight	Gas	flow rate	Output energy[kJ]		Specific output energy[kJ/g]		D/Pd	*E* per D/H
	[g]		[sccm]	1st phase	2nd phase	1st phase	2nd phase	or H/Pd	atom
D-PP1#1	5	D_2	3.5	0.5±0.4	2.5±4.1	0.10±0.07	0.52±0.83	0.46	0.24
D-PP1#2	5	D_2	4.3	0.5±0.2	4.0±4.4	0.10±0.05	0.79±0.88	0.43	0.26
H-PP2#1	5	H_2	6.8	0.4±0.2	2.6±3.9	0.08±0.003	0.53±0.8	0.45	0.20
D-PB1#1	3.2	D_2	3.5	1.7±0.3	8.3±4.5	0.54±0.1	2.6±1.4	0.85	0.69
H-PB2#1	3.6	H_2	5.6	1.6±0.3	-2.2±4.6	0.45±0.08	-0.62±1.3	0.78	0.63
D-PB3#1	20	D_2	2.9	9.3±1.1	1.1±0.5	0.47±0.06	0.058±0.023	0.78	0.66
D-PB3#2	20	D_2	0.8	3.3±0.5	3.4±2.6	0.17±0.03	0.17±0.13	0.23	0.79
H-PB4#2	20	H_2	1.9	3.2±0.2	14±4.6	0.16±0.01	0.68±0.23	0.22	0.80
H-PB4#3	20	H_2	1.5	16±2.4	-4.8±8.1	0.79±0.01	-0.24±0.40	0.20	4.42
D-PB3#3	20	D_2	1.1	14±1.7	-2.2±1.1	0.68±0.01	-1.1±0.54	0.22	3.51
D-PB3#4	20	D_2	1.1	3.1±0.4	0.3±4.7	0.16±0.02	0.016±0.23	0.24	0.71
D-PZ1#1	10	D_2	1.76	7.0±0.2	6.8±1.3	1.3±0.04	1.9±0.31	1.08	2.39
H-PZ2#1	10	H_2	2.29	3.6±0.1	-5.1±1.4	1.0±0.03	-1.5±0.32	1.00	1.33
D-PZ3#1	10	D_2	1.85	6.4±0.2	5.5±0.8	2.13±0.0	1.2±0.2	1.07	2.20
H-PZ4#1	10	H_2	2.93	5.1±0.1	1.1±0.9	1.70±0.0	-1.3±0.2	0.86	2.18
D-PZ3#2	10	D_2	1.66	0.17±0.03	9.89±1.48	0.03±0.070	2.3±0.35	0.29	0.13
H-PZ4#2	10	H_2	2.79	0.58±0.05	1.68±1.46	0.17±0.011	0.39±0.34	0.31	0.59
D-PZ3#3	10	D_2	1.69	0.29±0.04	-3.47±0.34	0.07±0.092	-0.81±0.35	0.25	0.29
H-PZ4#3	10	H_2	2.99	0.37±0.02	0.75±0.35	0.01±0.006	0.17±0.34	0.26	0.42
D-PZ5#1	10	D_2	2.02	7.14±0.15	1.26±1.36	2.37±0.035	0.29±0.32	1.04	2.51
H-PZ6#1	10	H_2	6.23	7.07±0.07	-0.23±1.44	2.33±0.018	-0.05±0.33	1.41	1.82
D-PZ5#3	10	D_2	9.93	0.54±0.025	0.23±1.51	0.18±0.008	0.08±0.50	0.25	0.74
H-PZ6#3	10	H_2	10.69	0.92±0.025	4.18±1.51	0.31±0.008	1.39±0.50	0.30	1.10
D-PZ9#1	14	D_2	6.42	10.23±0.10	3.81±1.51	2.44±0.024	0.91±0.36	1.41	1.87
H-PZ10#1	14	H_2	22.55	9.56±0.034	3.82±1.51	2.28±0.008	0.91±0.36	1.02	2.46

1st phase results

run	D/Pd or H/Pd	*E* per D/H atom [eV]
D-PP	0.46	0.24
H-PP	0.45	0.20
D-PB	0.82±0.05	0.67±0.02
H-PB	0.78	0.63
D-PZ	1.15±0.17	2.24±0.28
H-PZ	1.07±0.24	1.95.±0.49

average (arrows point to the D-PB, D-PZ and H-PZ rows)

•PP ; Loading ratios are bulk values, and specific heats are also bulk values.

•PB ; Loading ratios are 2-fold of bulk values, and specific heats are 3-fold of bulk values

•PZ ; Loading ratios are 2.5-fold of bulk values, and specific heats are 10-fold of bulk values

Conclusion

- **The twin system of D(H) gas loading is a useful tool.**
- **Nano-Palladium Zirconium-oxide composite generates 10-fold larger specific heat by D(H)-absorption, compared to that of bulk palladium.**
- **Nano-Palladium Zirconium-oxide composite generates excess heat in the phase-2 for D_2 gas charging.**
- **We need further to study dependence on flow rate, nano-particle size, and cell temperature.**
- **We need also study of other material samples.**
- **Analyses of ^4He production and nuclear particle emission are expected.**