

## **Understanding of MHE Power Generation Patterns by TSC Theory**

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The main MHE power generation pattern can be explained by the nuclear energy release of 4H/TSC WS fusion events at T-sites of Ni nano-cores by dynamic 4H cluster formation of 4 protons moved from O-sites under phonon excitations in GMPW (global mesoscopic potential well) of Ni-nano-islands. This is the major process of power (about 20W in our runs). In addition minor excess power (about 4 W) is considered being continuously released by 4H/TSC WS fusion events at SNHs (sub-nano-holes) on surfaces of Ni-nano-cores. This minor process remains after H/Ni ratio is saturated. We found a method of MHE power re-activation by the RCV (reaction chamber valve) close-to-open method after H/Ni loading ratio becomes nearer to saturation. When RCV is opened, pulse thermal power generation happens by 4H/TSC WS fusions at SNHs, which induces H-gas desorption-burst from T-sites of Ni-nano-cores. This trigger event produces empty T-sites in Ni-nano-cores and slow H-loading to T-sites restarts with relatively large generation of 4H/TSC WS fusion power (10-15 W) for considerably long time (about one day in our trigger-trial runs). This re-activation/trigger process can be repeated in-situ. We succeeded to trigger more than ten times.

Prediction by the TSC theory seems working very well. Some brief historical aspects of “cold fusion” or MHE research evolution are of portion in Introduction.

**Key Words: metal hydrogen energy, heat pattern, TSC theory, H-loading ratio**

### **1. Introduction**

We are convinced of our latest results [1-11] that we have now found very reproducible generation of high energy density excess thermal power in long lasting continuation by the nano-composite metal meso-catalyst and hydrogen (D or H) gas interaction at elevated temperature. The original aspect of underlying phenomena was published in our ICCF20 paper [12].

We gave up to continue the F-P type electrolysis experiments, due to very difficult reproducibility of AHE, in around 2000 (New Century). We thought that the FPHE (Fleischman-Pons Heat Effect) phenomenon could happen by the 4D/TSC formation at arbitrary (by chance) formed surface nano-structure sites (SNH: sub-nano-holes) and/or T-sites of FCC lattice of Pd (or Ni) metal [13] which would be difficult to be artificially conditioned in electrochemical methods. The co-deposition method (P. Boss et al [17]) surface analysis gave AT (Akito Takahashi) a hint for possible nano-structure formation. Next, the Arata-Fujita idea [18] of Pd nano-particles in zirconia gave AT a more functional hint to make a working material in systematic way. We have made spin-off to do the D-gas-loading experiments with mesoscopic size catalyst powder of Pd- or Ni-core binary nano-composite islands [19]. By knowing that pure Pd samples do not have capability to trap D(or H) particles in lattice sites or surface defects at elevated temperature ( $\gg 300$  deg C) necessary for energy source application. We have concentrated in Ni-core/Pd(or Cu)-shell meso-catalyst structures [1-16]. According to the 4D(or H)/TSC formation on surface SNHs (or inner sub-periodic potential wells of a global mesoscopic potential well: GMPW) of a nano-island, TS clusters formation were enhanced the more the higher D-loading ratio (we found 3.5 at most for PNZ) in meso-catalyst islands[13, 19]. We have tried to design PNZ or CNZ type samples of mesoscopic catalysts.

Using our new experimental system (called D-system [9]) of MHE (nano-metal hydrogen energy) reaction, it became able to measure and to evaluate more clearly the anomalous heat effect (AHE) by the elevated temperature interaction of nano-composite metal sample and hydrogen-gas. Two findings of new characteristics of AHE excess power by the MHE reaction are reported [10]. After starting initial heating by W2 (100 -160W) heater, excess thermal power by MHE is steeply generated from around 300 degree C of CNZ-sample powder outer region temperature. Excess power suddenly starts to increase when H/Ni loading ratio reached at around 1.0. This timing is considered to be the time that H-loading at O-sites of Ni core becomes full to attain H/Ni =1.0 in about 20-60 minutes in our runs (Phase-1 process: Fast H-Loading). After that turning point, relatively high excess power generation continues (for about 3 days) until the elapsed time region where H/Ni loading ratio saturates to be far greater than 1.0; H/Ni =2.2 was the saturated value in some run. This is the second phase H-loading by T-sites loading in Ni core: (Phase-2 process: Slow H-Loading).

The main MHE power generation pattern can be explained by the nuclear energy release of 4H/TSC WS fusion events at T-sites of Ni nano-cores by dynamic 4H cluster

formation of 4 protons (associating 4 electrons) moved from O-sites under phonon excitations in GMPW (global mesoscopic potential well) of Ni-nano-islands [13, 19]. This is the major process of power (about 20W in our runs). In addition minor excess power (about 4 W) is considered being continuously released by 4H/TSC WS fusion events at SNHs (sub-nano-holes) on surfaces of Ni-nano-cores. This minor process remains after H/Ni ratio is saturated.

We found a method of MHE power re-activation by the RCV (reaction chamber valve) close-to-open method after H/Ni loading ratio becomes nearer to saturation [9, 10]. When RCV is opened, pulse thermal power generation happens by 4H/TSC WS fusions at SNHs, which induces H-gas desorption-burst from T-sites of Ni-nano-cores. This trigger event produces empty T-sites in Ni-nano-cores and slow H-loading to T-sites restarts with relatively large generation of 4H/TSC WS fusion power (10-15 W) for considerably long time (about one day in our trigger-trial runs). This re-activation/trigger process can be repeated in-situ. We succeeded to trigger more than ten times.

We have to mind that our latest reports [9, 10] at the JCF-22 Meeting would be shocked to old authority of CF/LENR studies based on heavy water electrolysis with Pd cathode and based on ideas of some deuteron induced fusion reactions. We were convinced of our characteristics data of close correlation between excess power evolution and H/Ni loading ratio exceeding 1.0, by the elevated temperature interaction of light hydrogen and mesoscopic nano-metal catalyst. We are also convinced that the results by light hydrogen is taking place by the same underlying physics mechanism of our former results using deuterium gas and meso-catalyst interaction at room temperature and elevated temperature [1-11]. Both of light hydrogen and deuterium reactions observed look matching very well with AT's 4H/TSC WS fusion and 4D/TSC fusion theories. The common underlying physics is the condensed cluster fusion (CCF) of hydrogen isotopes in dynamic ordering process of condensed matter (to be mesoscopic catalyst) [7, 13, 16, 20]. So our results for light hydrogen results are theoretically consistent with the old observations by heavy water/gas and Pd metal interaction. Both results showed energy generation density of more than 1000 times of conventional chemical reaction energies, to conclude nuclear origin. We understand we are seeing, at least, one rational solution of "cold fusion" puzzles. There might come out other rational solutions by other efforts, we may hope however. We think we can go ahead to the R&D stage for industrial application to clean portable energy devices of primary nuclear energy source.

## 2. Correlation between Excess Thermal Power and H/Ni Loading Ratio

Typical example of raw data by the new D-system MHE experiment [9, 10, 21] is shown in Fig.1. Blank calibration runs for calorimetry were carried out for three dummy samples, namely zirconia beads, zirconia fine powder and “dead” CNZ7rrr sample. For estimating excess power generation by active sample runs, we found that the blank data of the dead sample are most accurate for estimating increased amounts of temperatures in each points of D-system. Estimation of excess thermal power by active sample (CNZ9 series and CNZ8 series in this paper) was made by using H<sub>2</sub>-gas temperature in reaction chamber (RC) in current data [9, 10].

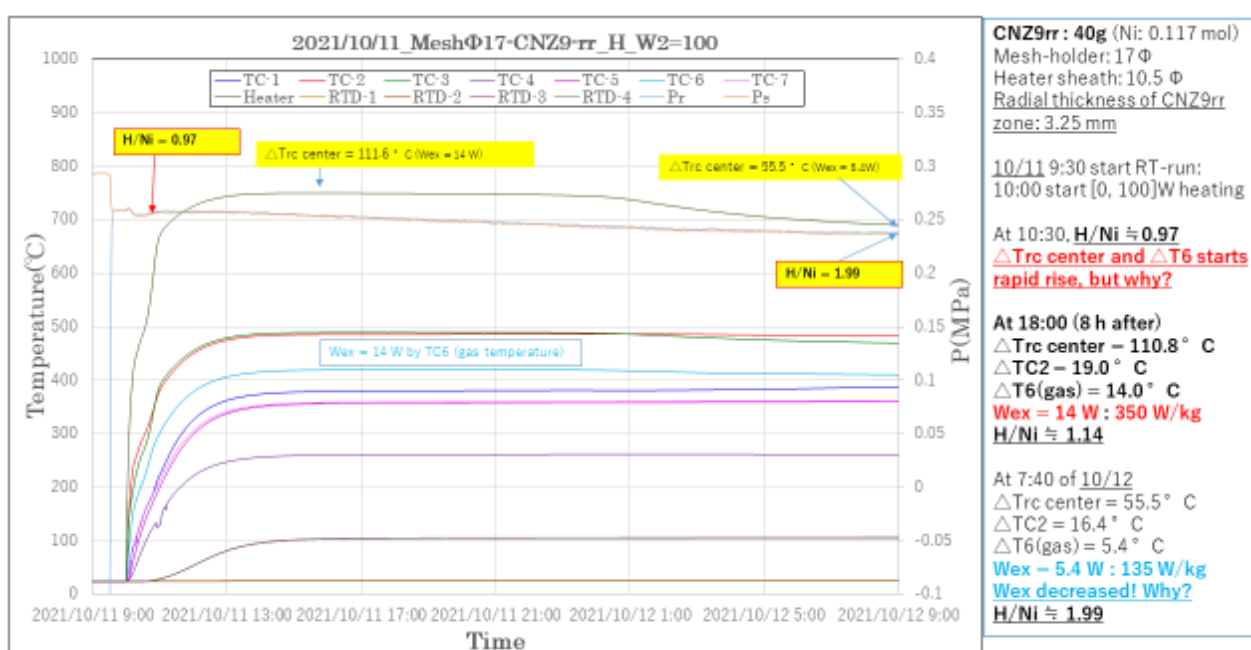


Fig.1: Typical example of raw data by the D-system MHE experiment for re-calcined sample

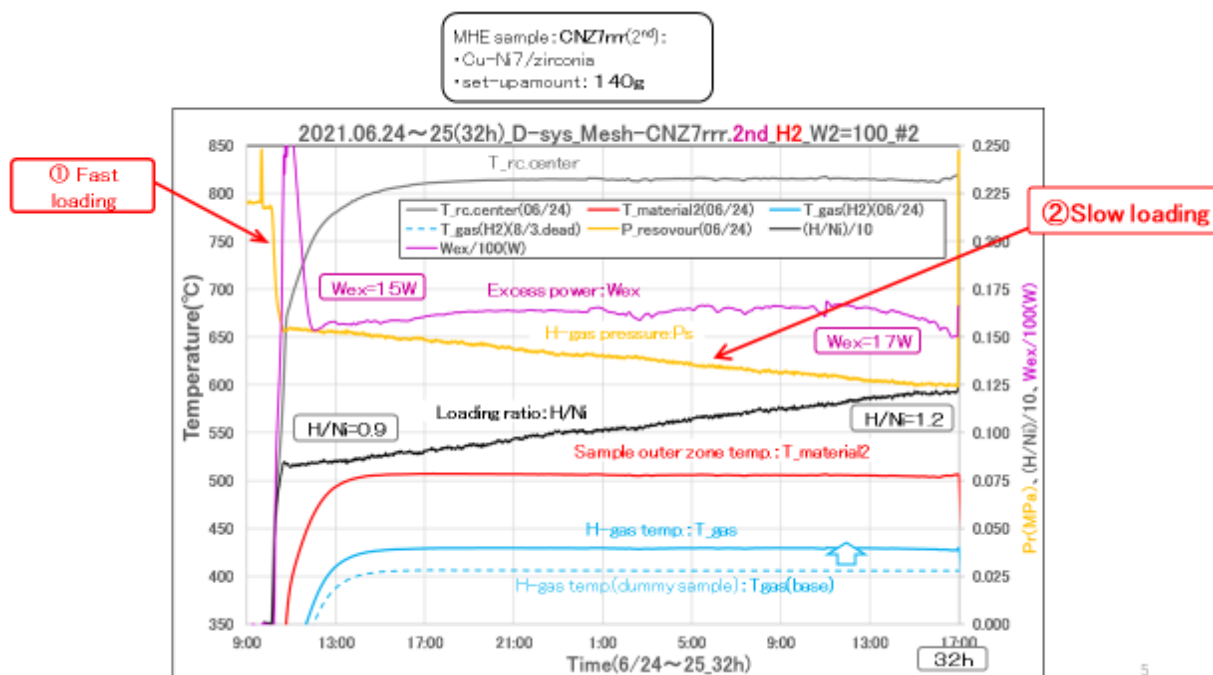


Fig.2: Typical data showing correlation between excess power ( $W_{ex}$ ) evolution and H/Ni loading ratio evolution, for ET run of CNZ7rrr sample which was still active for MHE reaction.

We have found for every initial ET (elevated temperature) run of CNZ-type sample after re-calcination that excess power was rising up very steeply when H-loading ratio (H/Ni) exceeded near 1.0 value. Relatively high excess power level (14 W in Fig.1) of plateau continued for many hours (0.5 to 3 days, depending on sample type) and started to decay with slowly saturating H/Ni loading ratios (around 2.0 in real runs). Why there happened such pattern of excess power evolution? We have found also that temperature data at the RC center (Trc-center) was most sensitive to the evolution of excess thermal power generation. However for estimating excess power value, increment of H-gas temperature in RC ( $\Delta T_6$ ) from the “dead sample” blank data is conceived appropriate in this study, considering that gas temperature in RC should reflect in average trend. We have oil mass flow calorimetry data by radiation heat recovery in the D-system. Due to very slow response of oil outlet temperature, the present oil mass flow system does not show accurate time evolution data of excess power, but estimation of integrated heat for long run is effective.

In Fig.2, we show typical example of correlation data between excess thermal power evolution and H/Ni loading ratio evolution. As for H/Ni loading, there happened the fast

loading phase to reach at H/Ni 0.9 in ca. 30 minutes from the start of W2 heater on (100 W constant power supply in this case), and turned to the very slow H-loading phase lasting for a few days to reach saturated value around 2.0. As for excess thermal power evolution, we see a burst-like peak [3] after the fast H/Ni loading finished and rather plateau-like power level (15-17W) continues with the slow H/Ni loading phase for many hours. Why there happens such patterns of H/Ni loading and excess power in close correlation?

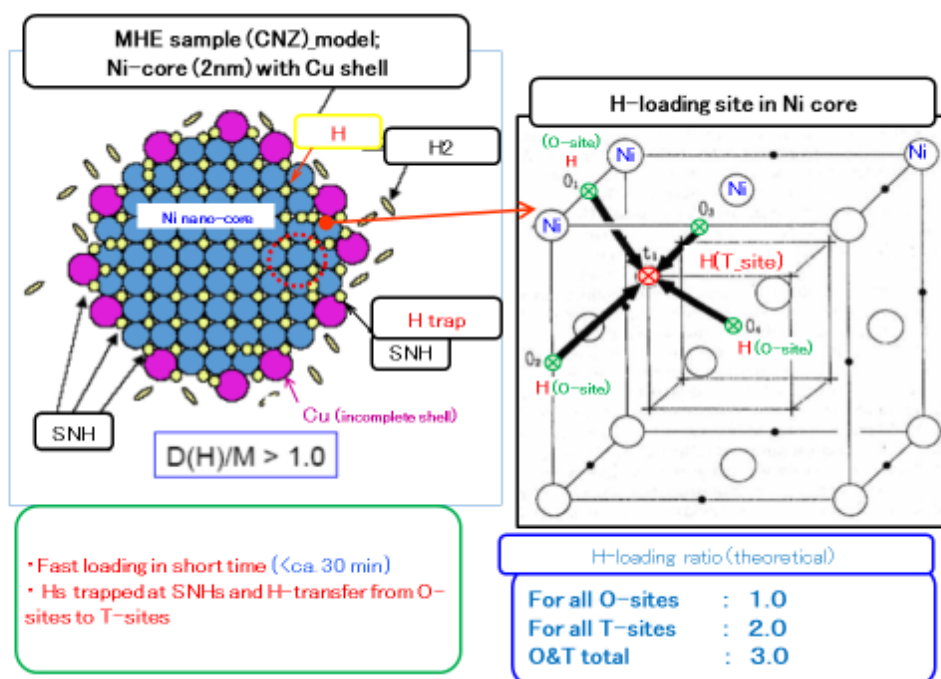


Fig.3: Model of hydrogen loading to a Ni-core/Cu-incomplete-shell nano-composite meso-catalyst particle [13, 19]

We have found that H-loading ratio can become very high as 3.5 when we used nano-composite metal particles of Pd and Pd-Ni binary particles in ceramics supporter flakes [19] at room temperature. Here we consider that high H-loading over H/Ni = 1.0 can be formed for Ni-core/Cu-incomplete-shell nano-composite meso-catalyst, especially at elevated temperature, probably by the endothermic H-absorption process to Ni-core lattice, as shown in the model in Fig.3. H<sub>2</sub> gas molecules may be trapped first by electron dangling bonds at sub-nano-holes (SNHs) on surface of Ni-core with Cu (defect points), and dissociated to protons to enter into Ni nano-core lattice for occupying octahedral sites (O-sites) of Ni FCC lattice. When all O-sites are occupied by protons, H/Ni loading ratio becomes 1.0. After that fast loading phase, very slow H-loading to tetrahedral sites (T-

sites) of Ni FCC core lattice goes on by excited phonon states of protons at O-sites under elevated temperature condition. As the T-site H-trapping potential is with shallow well on potential hill of FCC structure, efficient excitation of proton oscillator phonon at O-site is needed. The non-linear coupled proton oscillations to realize high phonon states can be expected in the global mesoscopic potential well (GMPW) with inner fine FCC Bloch potentials of O-sites, under elevated temperature [19]. Maximum partial loading ratio to T-sites is 2.0. Total loading to be saturated is therefore 3.0 as sum of O-sites and T-sites H-occupations, theoretically. Experimentally observed value 0.9 in Fig.2 can be regarded as 1.0 nominal value, namely we conceive 90 % meso-catalyst state of CNZ7rrr sample, and we know that bulk Ni metal sample cannot absorb Hs over 1.0.

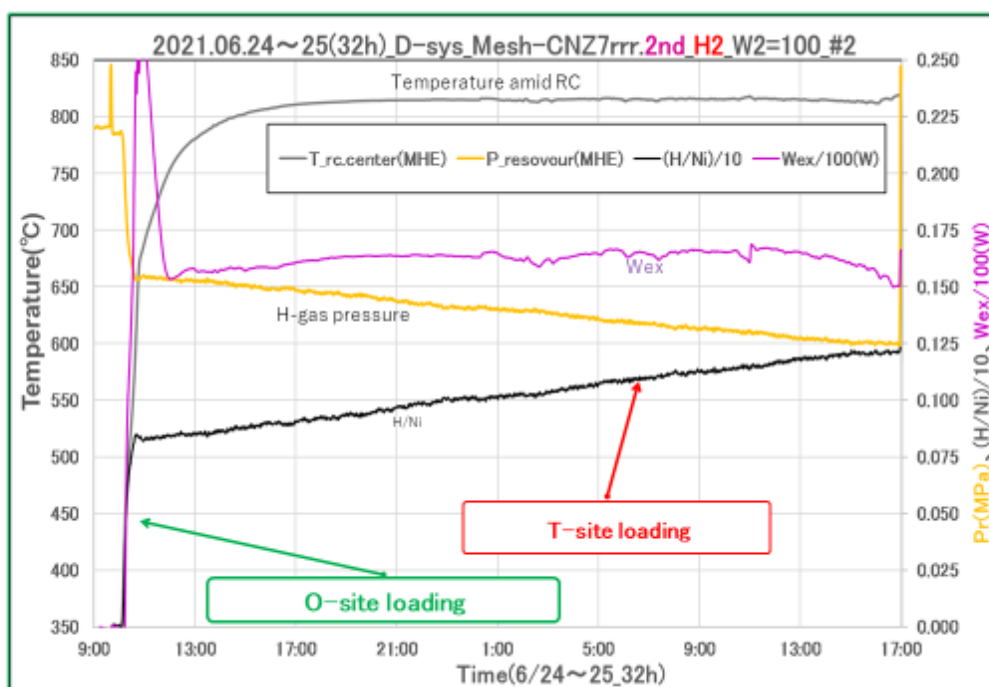


Fig.4: Explanation of two (fast and slow) phase H-loadings to  $\text{Cu}_1\text{Ni}_7/\text{zirconia}$  nano-composite sample powders, in close correlation with  $W_{ex}$  (excess thermal power).

As shown in Fig.4, observed H-loading patterns with excess thermal power correlation can be explained as the O-site H-loading for the fast loading phase and the T-site H-loading for the slow loading phase. Next question is why the excess power pattern correlates closely to the evolution of H/Ni loading ratio.

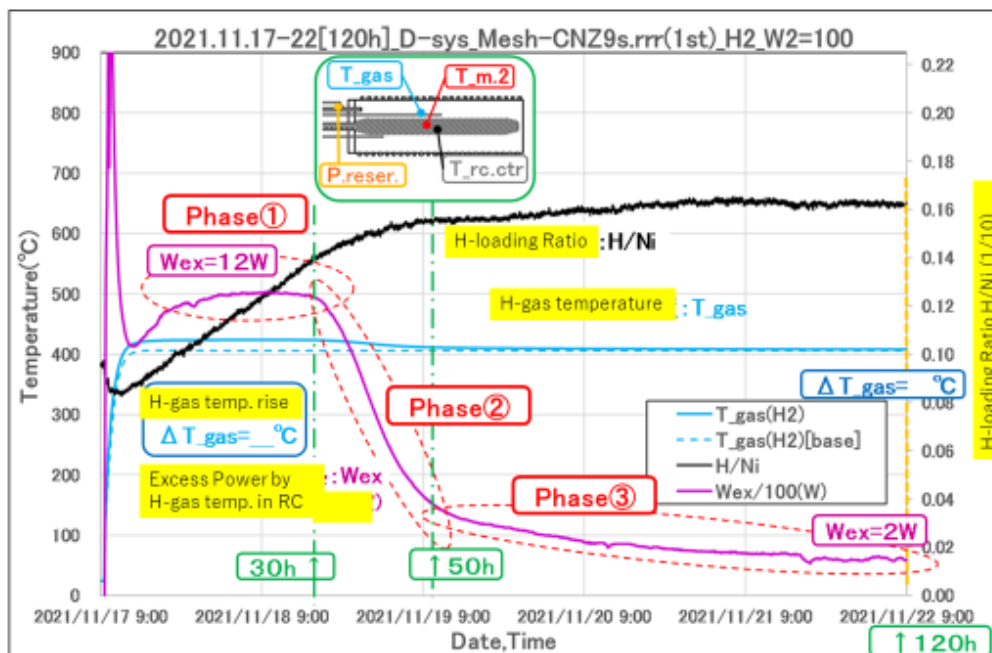


Fig.5: Evolutional correlation of H/Ni loading ratio and excess thermal power, as typical example by CNZ9s rrr sample (140g) after the third re-calcination (rrr).

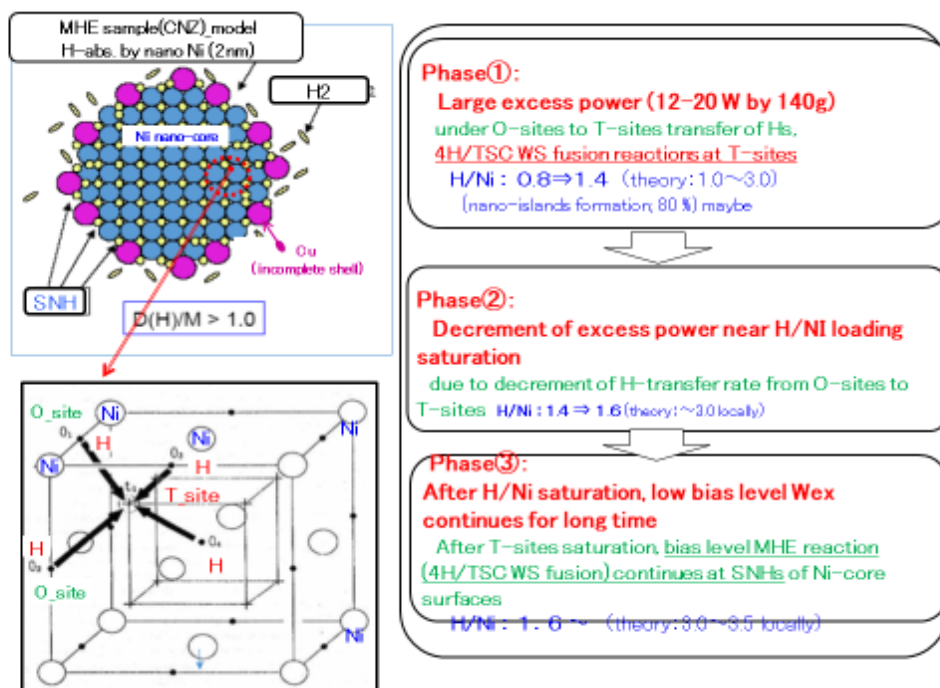


Fig.6: Explanation scheme of MHE power generation patterns with evolution of H/Ni loading ratio



In Fig.5: Typical three phase pattern of excess power generation is shown in correlation with H/Ni loading ratio evolution. Explanation by the 4H/TSC WS fusion theory (7, 13, 16) is shown by flow chart in Fig.6. The many hours lasting plateau of relatively high power level in Phase-1 is conceived to be produced by the 4H/TSC WS fusion reactions at T-sites. Under full O-sites occupation with protons, 4H-cluster formation probability is enhanced by high order proton-oscillation phonon in GMPW of Ni-nano-core. If the end-state oscillation of 4H/TSC condensation collapse continues more than 1.0 fs, about 3 % of 4H/TSC will produce the nuclear energy of WS fusion, as simple simulation scheme [16] is shown in Fig. 7. Detail data of simulation for 4H/TSC end-state oscillation is shown in [7].

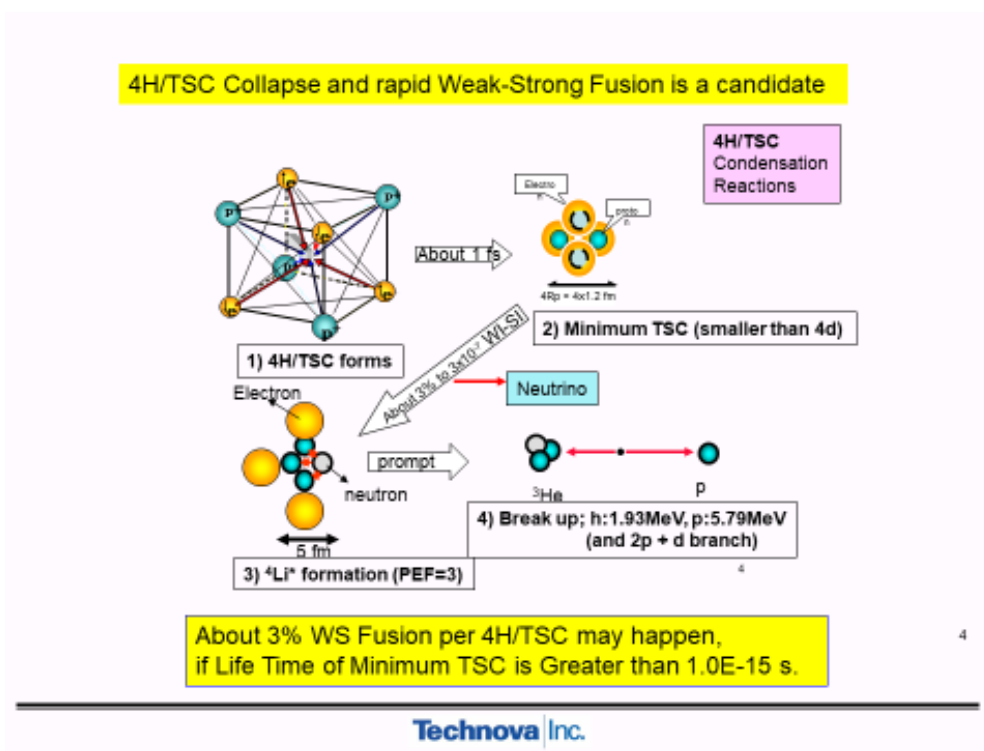


Fig.7: Simplified scheme of 4H/TSC WS fusion model [7, 16]  
 When density of remaining empty T-sites will rapidly decrease as H/Ni loading ratio is coming to be saturated, 4H/TSC WS fusion rates will decrease accordingly. This is the Phase-2 of Fig.5. After the saturated occupation of T-sites, smaller level of 4H/TSC WS fusion rates may continue at SNHs of Ni-nano-cores. This is the Phase-3 of Fig.5.

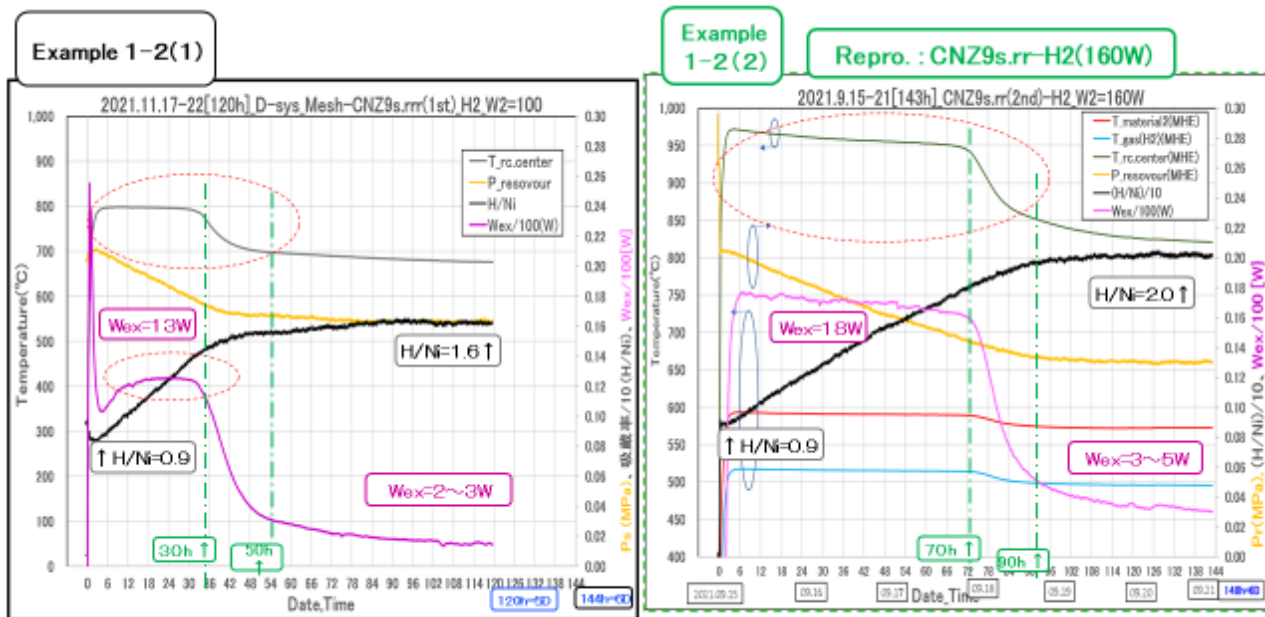
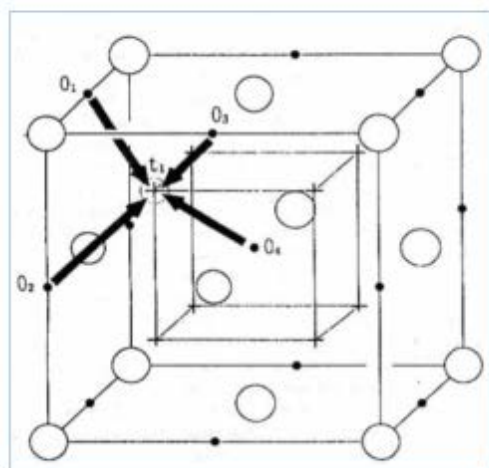


Fig. 8: Comparison of power generation patterns for the lower (100W) heating and the higher (160 W) conditions, with H/Ni loading patterns.



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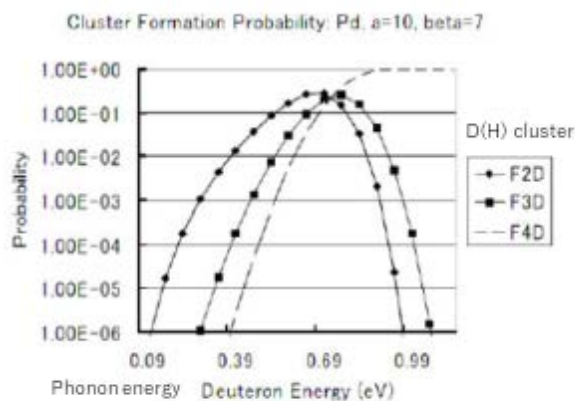


Fig. 9: Competition of H-cluster formation probabilities under the FCC lattice proton phonon excitation energy [22].

In Fig.8, we show the heat vs. H/Ni correlation patterns are reproducible for changing samples and heating conditions. Total heat energy by excess thermal power plateau by this 160 W run is 12.6 MJ/mol-H, which is equivalent to the specific reaction energy of 131 eV/H-atom-absorbed, for 70h duration. We know that H-absorption to CNZ sample at elevated temperature is endothermic. However, even if we assume that H-absorption is exothermic reaction, 131 eV/H-atom-absorbed is too large in 2-3 orders of magnitude to be chemical reaction, and we must conclude it by nuclear reaction origin. It is very important physics issue that light hydrogen may generate fusion-like nuclear energy in an experimental system of laboratory. By assuming 4H/TSC WS fusion, 68 ppm H atoms would be consumed by the nuclear reaction for MHE excess heat generation in this case.

However, why have we observed larger and longer “high-power plateau” with higher H/Ni saturated value by the 160 W heating case than the 100 W case?

For  $H/Ni > 1.0$  condition, phonon-excited movement of protons (Hs) from 4 O-sites to a T-site becomes highest probability for one H, and lower probabilities for 2H, 3H and 4H in relative order, when Ni-core temperature is lower. T-sites occupation of Hs is most enhanced for lower temperature condition. See Fig.9 for enhancement of H-cluster formation probability by the phonon excitation level. Namely, 4H/TSC WS fusion rate at T-sites becomes the more enhanced the higher temperature for O-site phonon excitation, for  $H/Ni > 1.0$  condition. T-sites will remain empty after 4H/TSC WS fusion events. Therefore, it takes the condition that the more time of full T-sites occupation with Hs needs when the 4H/TSC WS fusion rate is higher. As consequence, integrated excess heat by MHE reactions can be enhanced by higher W2 heater condition. However, how large W2 watts can be supplied is the actual problem. However, we observed that duration of “high Wex plateau” changed by changing samples (by changing Cu/Ni atomic ratio and frequency of re-calcination) [21].

### **3. Triggering Mechanism of MHE Power Re-Activation**

We have found the MHE re-activation method by the RCV-close-to-open method [9, 10]. Before the saturation of H/Ni value (close to 2.0 in real runs), we may close the RC gas valve and wait for several hours.

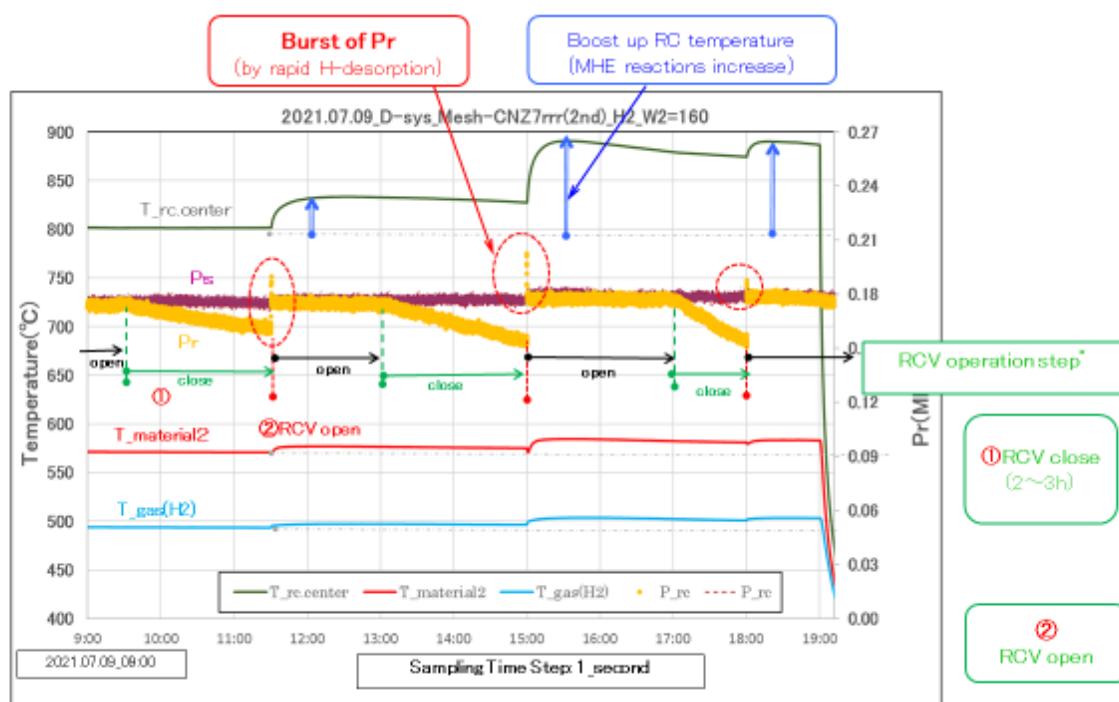


Fig. 10: Re-activation data of MHE power by the RCV-close-to-open method [9, 10, 21]

We observe H-gas pressure decrease (brown-color data in Fig.10) during the closure of RCV (reaction chamber valve), showing slow H-absorption by CNZ sample. When we opened RCV, there happened a burst of Pr (H-pressure of RC) and boost-up of RC temperatures were recorded to show increase of MHE power, namely re-activation. After the triggering of RCV-opening, boosted-up excess power (15-10 watts in the run) have continued for many hours. By repeating the RCV-close-to-open treatments, we observed boost-up of excess power level repeatedly. What is the mechanism of this triggering/activation phenomenon?

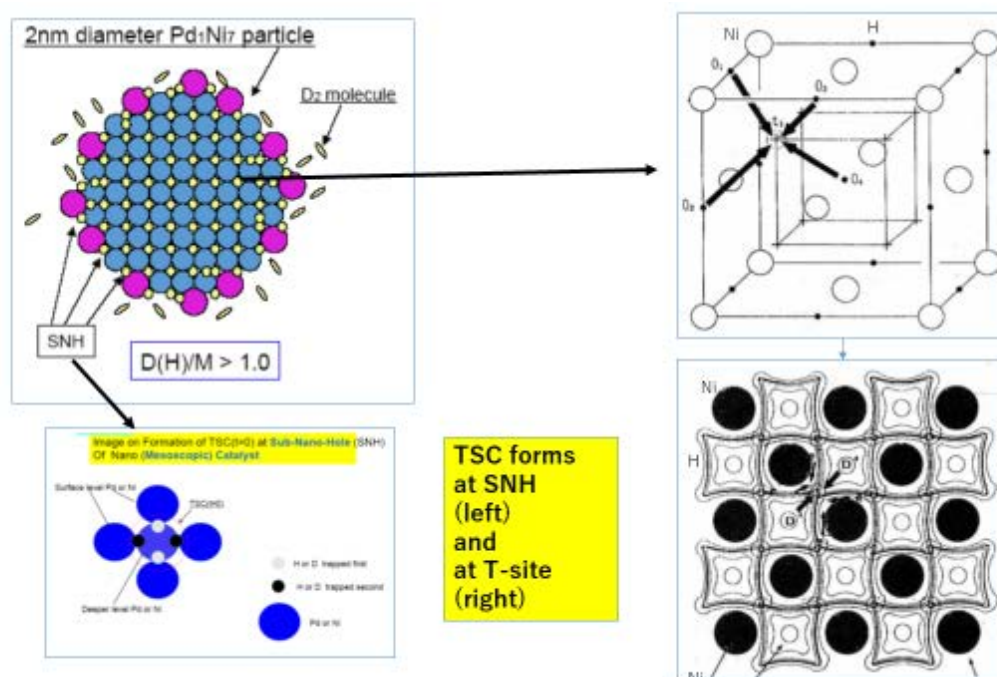


Fig.11: 4H/TSC WS fusion events can take place at surface SNHs (lower left figure) and also at T-sites of Ni-nano-core FCC lattice sites (right figure)

During RCV-closed, H<sub>2</sub>-accumulated on SNHs, moving from Ni-core inside. When RCV is opened, incoming H<sub>2</sub> meets accumulated H<sub>2</sub> to generate 4H/TSC to WS fusion, which makes heat burst and H-desorption burst is induced. (see left of Fig.11) After H/Ni exceeds 1.0, absorbed Hs slowly fill T-sites by H-moving from surrounding 4 O-sites under phonon excitation (see figure, right lower). 4H/TSC WS fusion rate will be enhanced at T-sites under this process. When all T-sites will be filled with Hs, 4H/TSC formation rates will drop. By RCV-C/O trigger with H-desorption burst, empty T-sites will be generated, and process of the slow phase H-loading at T-sites restarts to generate 4H/TSC WS fusion events.

#### 4. Concluding Remarks

- 1) After starting initial heating by W2 (100 -160W) heater, excess thermal power by MHE is steeply generated from around 300 degree C of CNZ-sample powder outer region temperature.

- 2) Excess power suddenly starts to increase when H/Ni loading ratio reached at around 1.0. This timing is considered to be the time that H-loading at O-sites of Ni core becomes full to attain H/Ni =1.0 in about 20-60 minutes in our runs (Fast Loading process).
- 3) After that turning point, relatively high excess power generation continues (for 1- 4 days)\_until the elapsed time region where H/Ni loading ratio saturates to be far greater than 1.0; H/Ni =2.2 was the saturated value in some run. This is the second phase H-loading by T-sites loading in Ni core: (Slow Loading process).
- 4) MHE power generation can be explained by the nuclear energy release of 4H/TSC WS fusion events at T-sites by dynamic 4H cluster formation of 4 protons moved from O-sites under phonon excitations in GMPW (global mesoscopic potential well) of Ni-nano-islands. This is the major process of power\_(about 20W in our experimental runs). In addition minor excess power (about 4 W or less) is considered to be continuously released by 4H/TSC WS fusion events at SNHs (sub-nano-holes) on surface of Ni-cores. This minor process remains after H/Ni ratio is saturated.
- 5) We found a method of MHE power re-activation by the RCV (reaction chamber valve) close-to-open method after H/Ni loading ratio becomes nearer to saturation. When RCV is opened, pulse thermal power generation happens by 4H/TSC WS fusions at SNHs, which induces H-gas desorption-burst from T-sites of Ni-cores. This trigger event produces empty T-sites in Ni-cores\_and the slow H-loading to T-sites restarts with relatively large generation of 4H/TSC WS fusion power (10-15 W) for considerably long time (about one day in present trigger-trial runs). This re-activation/trigger process can be repeated.
- 6) Prediction by the TSC theory seems working very well.

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