Anomalous Heat Generation Experiments Using Metal Nanocomposites and Hydrogen Isotope Gas

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3. Experimental Results at Tohoku Univ.
   (PNZ4s, CNZ5s, PSn1, CNS3s, CNZ6s)

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1. Background
Collaborative Research Project (2015.10-2017.10)

Objectives

To clarify the existence of the anomalous heat generation phenomenon.

Setup of a new national project by obtaining guiding principles on how to control the anomalous heat generation phenomenon.

Organization

Collaborative Research Project

- Technova Inc.
- Nissan Motor Co., Ltd.
- Kyushu University
- Tohoku University

Nagoya University

Kobe University
## Summary of Experimental Results at Tohoku Univ.

<table>
<thead>
<tr>
<th>samples</th>
<th>Gas</th>
<th>Temp.</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNZ4s</td>
<td>D</td>
<td>160-300°C</td>
<td>1) Excess Heat 4-5W, Integrated $H &gt; 15eV/D$ (1.4MJ/mol-D)</td>
</tr>
<tr>
<td>(PdNi&lt;sub&gt;7&lt;/sub&gt;/ZrO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNZ5s</td>
<td>H</td>
<td>160-250°C</td>
<td>1) Excess Heat 2-5W, Integrated $H &gt; 68eV/H$ (6.5MJ/mol-H)</td>
</tr>
<tr>
<td>(CuNi&lt;sub&gt;7&lt;/sub&gt;/ZrO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td>2) <strong>Coincident increase events</strong> of the pressure of the reaction chamber and gas temperature</td>
</tr>
<tr>
<td>PSn1</td>
<td>D</td>
<td>200-300°C</td>
<td><strong>No Excess Heat at elevated temp.</strong></td>
</tr>
<tr>
<td>(Pd/meso-Si)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS3s</td>
<td>H(D)</td>
<td>150-300°C</td>
<td>1) In the case of H, Excess heat 2-4W, Integrated $H &gt; 110eV/H$ (10.7MJ/mol-H)</td>
</tr>
<tr>
<td>(CuNi&lt;sub&gt;10&lt;/sub&gt;/SiO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td>2) No excess Heat in the case of D</td>
</tr>
<tr>
<td>CNZ6s</td>
<td>H</td>
<td>150-350°C</td>
<td><strong>Coincident increase events</strong> of the pressure of the reaction chamber and gas temperature were replicated</td>
</tr>
</tbody>
</table>
2. Experimental
Experimental Setup

Oil Flow-Calorimetry at High Temperature

A lot of Measurement Points

Resistant to Outer-Temperature Fluctuation
Appearance of Experimental Setup

Thermostatic chamber

Main experimental setup
Sample Preparation ($\text{ZrO}_2$)

- **Melt Spinning**
  - Amorphous Mixture of Metal Elements prepared by Melt Spinning method

- **Formation of Nano Particles by Oxidization**
  - 723K for 60 hr; Preferential oxidation of Zr to $\text{ZrO}_2$

- **Experiment at Kobe Univ.**
  - PNZ4

- **Experiment at Tohoku Univ.**
  - PNZ4s

Two samples subjected to the same process

- **Materials**
  - $\text{Pd}_{0.04}\text{Ni}_{0.31}\text{Zr}_{0.65}$ or $\text{Cu}_{0.04}\text{Ni}_{0.31}\text{Zr}_{0.65}$
Excess Power Evaluation

$$\eta Q = F_R \cdot \rho(T_{ave}) \cdot C(T_{ave}) \cdot (T_{out} - T_{in})$$

Flow rate  Density  Specific heat  Delta T

$$Q = W_1 + W_2 + H_{EX}$$

Outer Heater  Inner Heater  Excess Heat

$\eta$ (recovery rate) is estimated based on blank run data. Then, $H_{EX}$ (Excess Heat) is calculated by the above equations.
Error Estimation

\[EXH = \frac{mC\Delta T}{\eta} - W\]

\[\delta(EXH) \approx |\delta(m)| \frac{C\Delta T}{\eta} + |\delta(\Delta T)| \frac{mC}{\eta} + |\delta(w)|\]

| Input [W] | \(\delta\) (W) | DeltaT [K] | \(\delta\) (DeltaT) | C[J/gK] | \(\rho\) [g/cm3] | FL[ml/min] | \(\delta\) (FL) | \(\eta\) | \(\frac{|\delta(m)| C\Delta T}{\eta}\) | \(\frac{|\delta(\Delta T)| mC}{\eta}\) | \(\delta\) (EXH) |
|-----------|----------------|------------|---------------------|--------|----------------|-----------|------------|------|----------------|----------------|------------|
| 79.61     | 0.031          | 128.05     | 0.261               | 1.817645 | 0.994537 | 14.28     | 0.012      | 0.692 | 0.067          | 0.162          | 0.260      |
| 134.01    | 0.076          | 191.5      | 0.390               | 1.92143 | 0.973475 | 14.4      | 0.04       | 0.641 | 0.372          | 0.273          | 0.721      |

In the case of CNZ5s, \(\sigma = 0.3W\) for 80W Input, \(\sigma = 0.75W\) for 134W Input.
If we take \(3\sigma\) for error range, we get 0.9W for 80W and 2.3W for 134W.
3-1 PNZ4s (Pd$_{0.04}$Ni$_{0.31}$Zr$_{0.65}$) with D$_2$ Gas
Heat Release at Room Temp.

\[ E = \int P \, dt \, = \, 24.22 \times 3600 \, = \, 87.2\,[kJ] \]

PNZ4S; Tohoku

Absorbed D: 1.59 mol

54.8 kJ/D-mol

0.57 [eV/D]

PNZ4; Kobe

54 kJ/D-mol

0.56 [eV/D]

agree
Excess Heat Generation: PNZ4s with D$_2$

Integrated EXH: 2.47 MJ

Absorbed D: 1.73 mol

At Least 1,430 kJ/D-mol

14.9 eV/D

Cannot Explain by Chemical Reactions
3-2 CNZ5s (Cu$_{0.04}$Ni$_{0.31}$Zr$_{0.65}$) with H$_2$ Gas
Overview of CNZ5s Experiment

Temperatures monitored by RTDs and E1

Blank  Baking  CNZ5s Experiment
Comparison between RTDs and E1

Temperatures of E1 and RTD4 are higher than those of Blank Run.
Fluctuations of Pressure of Reaction Chamber (Pr) and E2 Gas Temp. (E2) during CNZ5s Experiment
Coincident Increase of Pressure of Reaction Chamber (Pr) and E2 Gas Temp. (E2)
Coincident Increase of Pr and E2: Zooming Generation of High Temperature Gas?
Excess Heat Generation; CNZ5S with H$_2$

Error factors
① Fluctuation of Oil Flow
② Fluctuation of Temperature measurement
③ Fluctuation of power input

Int. Released Energy: 1.8MJ
Absorbed Hydrogen: 0.29mol

Released Energy per H: 6.5 MJ/mol-H
: 67.8eV/H

Not Explained by Known Chemical Reactions

- H absorption heat: 42kJ/mol-H (NiZr$_2$)
- H combustion heat: 121kJ/mol-H

Reaction between Fe$_2$O$_3$ and Ni with H$_2$: 137kJ/mol-H

All NiO and Zr reaction: 121kJ
Broken ZrO2 beads after excess heat release

The sample was sieved out to separate from ZrO2 beads (1mmϕ). But we found that some broken parts of ZrO2 beads were mixed with the metal nano-composite sample.

Suggests that very large local heat stress was loaded on ZrO2 beads.
3-3 \textbf{PSn1;Pd/TMPS-4R} with \textbf{D}_2 \textbf{Gas}
Nano-Pd embedded in Mesoporous Silica with 4nm hole prepared by Nagoya Univ. (PSn1;Pd/TMPS-4R)

PSn1; 112.4 g
-No filler-
Pd; 7.52 g
PdO; 8.65 g

http://www.taiyointernational.com/products/mesoporous-silica/)
No excess heat observation in the case of Pd only samples.
3-4 CNS3s; with H₂/D₂ Gas
It seems that higher temperature in the reaction chamber is an important factor for anomalous heat generation.

When we changed H$_2$ to D$_2$ gas, we observe no excess heat.

Generated Energy

10.7 MJ/mol-H
110 eV/H
3-5 CNZ6s; with H$_2$Gas
Coincident increase events of E2 and Pr Burst-like Coincident increase events similar to CNZ5s were observed.
Replication of Coincidence Events at (1)

Coincident increase events of the pressure of reaction chamber and gas temperature were replicated.

$W_1, W_2 = (134, 0)$
Concluding Remarks

- **Anomalous excess heat generations** were observed for all the samples at elevated temperature (150°C-350°C), except for the Pd nanoparticles embedded in mesoporous SiO₂.

- Integrated excess heat reached more than several MJ/mol-H(D) which could NOT be explained by any known chemical process.

- **Coincident burst-like increase events** of the pressure of reaction chamber and gas temperature, which suggested sudden energy releases in the reaction chamber, were observed many times for an experiment using the $\text{Cu}_{0.044}\text{Ni}_{0.31}\text{Zr}_{0.65}$ (CNZ5s) sample. These burst-like events were replicated during the experiment using the same composition sample; $\text{Cu}_{0.044}\text{Ni}_{0.31}\text{Zr}_{0.65}$ (CNZ6s).

- **Qualitative reproducibility between Kobe and Tohoku experiments** was good.
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