In Honor of Yoshiaki Arata

Talbot A. Chubb
Physicist Consultant, 5023 N. 38th St., Arlington VA 22207, USA, tchubb@aol.com

Abstract

This paper seeks to make readers aware that Arata and Zhang (A&Z) in 2007/8 demonstrated operation of an autonomous fusion "heater". The heater generated a steady outflow flow of heat at slightly above room temperature throughout a run lasting hundreds of hours. The steady nuclear heat occurred after a brief burst of chemical heat during D_2 absorption. No other energy input was present.

The paper also seeks to make readers aware that in 2005 A&Z demonstrated continuous fusion heat at 191°C in a gas loaded reactor which was initially maintained at 141°C by an electrical heater. It is estimated that 25% of the heat delivered to the room was fusion energy and 75% was electrical heater energy. The catalyst temperature was high enough for practical generation of electrical power.

Introduction

The paper introduced a session on catalytic fusion in honor of Professor Arata and the pioneering work which he has carried out in conjunction with Yue-Chang Zhang (A&Z). The A&Z team has pioneered and defined what is meant by nano-Pd fusion. They proved that nuclear reactions can be made to take place in nanometer solid material. Their work opens the road to development of commercial fusion heaters.

Dr. Arata is Professor Emeritus at Osaka University. Born in 1923, he graduated from Osaka U. with a Bachelors in Engineering in 1949, received a Doctorate in 1957, and became Professor. in 1964 . He started Japan's plasma fusion program. Since there was no D_2 gas available for his arc plasma studies, he made his own deuterium gas by plating D_2O electrolyte onto a Pd cylinder, collecting the gas that permeated the cylindrical tube. In 1958 he achieved the world's record for arc discharge current density. He was a pioneer in electron beam and laser beam welding and became Director General of the Osaka U. Welding Institute in 1977. Arata was elected Member of the Japan Academy in 1988, received the Arthur Schawlow Prize in 1992 from the American Society of Metals, and was honored by the Emperor of Japan in both 1995 and 2006. He has received many other awards.

Arata and Zhang began their cold fusion studies in 1989. Arata applied his engineering science background to the goal of proving or disproving cold fusion reality. He was initially a skeptic.

A&Z published their first nano-Pd work excess heat studies using a "DS-Cathode" in 1994, presenting strong evidence that fusion heat release had occurred.

A&Z introduced new terms to describe the new hardware and concepts that were unique to their investigations. One of these is “DS-cathode”, which means “double structure” cathode, i.e., an outer Pd metal cylinder with stainless steel (ss) welded end pieces and an inner reactive filling of nano-Pd powder. D^+ ions are deposited onto the Pd cylinder, and the cylinder is filled with contacting nano-Pd grains. The A&Z cathode contrasts with the pieces of wire, sheet, or metal rod used by other experimenters in 1989. Another A&Z term is “spillover effect”, taken from catalyst chemistry, where it means that effective catalytic area exceeds area measured by a standardized N_2 adsorption protocol. As used here it means that the evacuated nano-Pd catalyst bed absorbs and redistributes by grain-grain contact the deuterium permeating a DS cathode’s Pd wall, creating an almost uniform D/Pd ratio throughout the catalyst bed. The high surface mobility largely avoids the deuterium density gradients existing in electrolysis-loaded bulk Pd cathodes. The chemical pumpimg caused by high surface mobility and high absorbtivity at low pressure can be called “spillover effect” pumping.

Figure 1. The experimental setup used in 1996.

Figure 1 shows the experimental setup used in 1996. The cabinet on the left maintains a reservoir of constant temperature water that serves as the water supply for 2 constant displacement pumps sitting on the desk. The pumps feed water to 2 independent test cells inside dewars in the styrafoam box on the right. The styrafoam box is covered by a lid during normal operation. Electronics in the cabinet to the far right digitizes input voltage and current which are used to calculate input electrolysis power. Inflow and outflow temperature for the 2 cells is measured by thermocouples. The stability of the water flow calorimetry is verified by the equality of input and output powers during an incubation period within which no fusion power is liberated, as shown in the first part of Figure 3.[1]

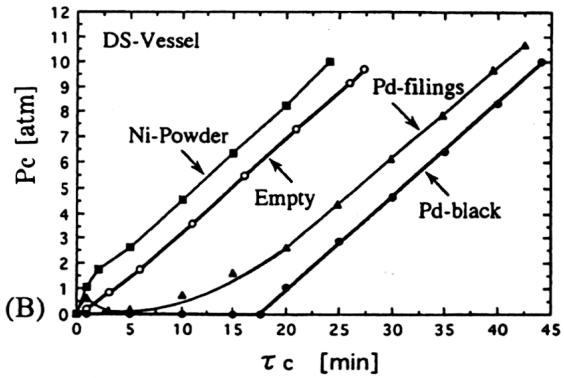

Figure 2. Illustration demonstrating spillover effect pumping

Figure 2 shows how A&Z quantify the hydrogen absorption behavior of Pd-black by measuring its ability to absorb inflowing H_2 at low pressure. In a standard test a constant cc-atm/min of H_2 gas flows into a vessel of known volume. The pressure-rise time history of powder samples is compared with the pressure rise of the empty test vessel. When the test sample is Ni powder, the pressure rise is faster than for the empty vessel, partially due to inertly occupied volume. When the sample is Pd-filings, there is a small lag in the pressure rise due to the Pd absorption of H_2. When the test sample is Pd-black, there is initially no measured rise in pressure, presumably due to immediate transfer of adsorbed H throughout the catalyst bed, accompanied by its rapid absorption within the individual nanometal grains. The duration of the spillover effect period has been used by A&Z to identify good catalyst for fusion promotion.

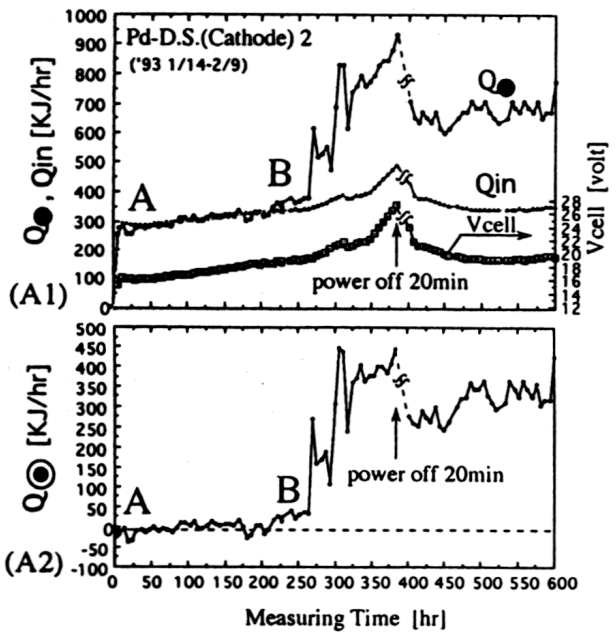

Figure 3. A&Z excess heat run published in 1994

The top portion of Fig. 3 shows plots of output power, input power, and cell voltage vs. run time. Fig. 2 bottom shows excess power = output minus input power vs. run time. The period of zero excess power between times A and B is called the incubation period.

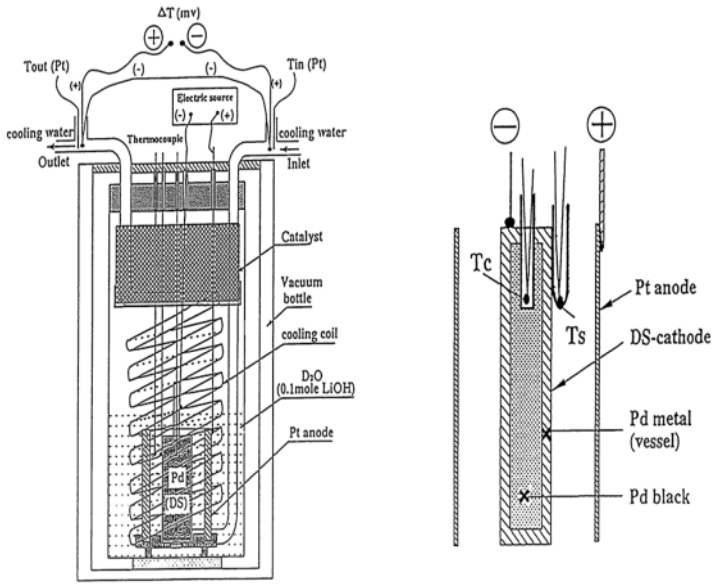

Figure 4. Electrolysis cell and DS-cathode used in 1995. DS-cathode shown on right.

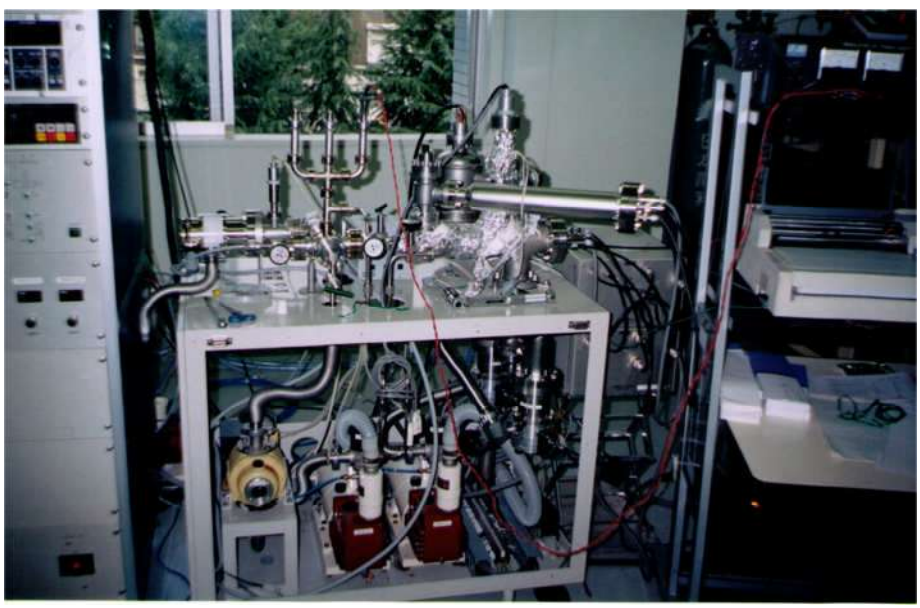

Figure 5. Stainless steel (ss) manifold system used in analysis of desorbed gases

By 1996 A&Z had designed a mass spectrometer system to look for ^{4}He and ^{3}He in their post-run powder. They constructed a turbo-pumped welded ss manifold with separate quadrupole spectrometers which were programmed to repeatedly scan the mass-4 and the mass 3 peaks. They included a small oven to outgas strongly absorbed D_2, HD, and He molecules in post-run catalyst powder, and later added a titanium sputter pump to selectively absorb D_2 and DH in isolated samples of desorbed gas, as shown below, further verifying the identity of the ^{4}He peak. As-received Pd-black shows no ^{4}He.

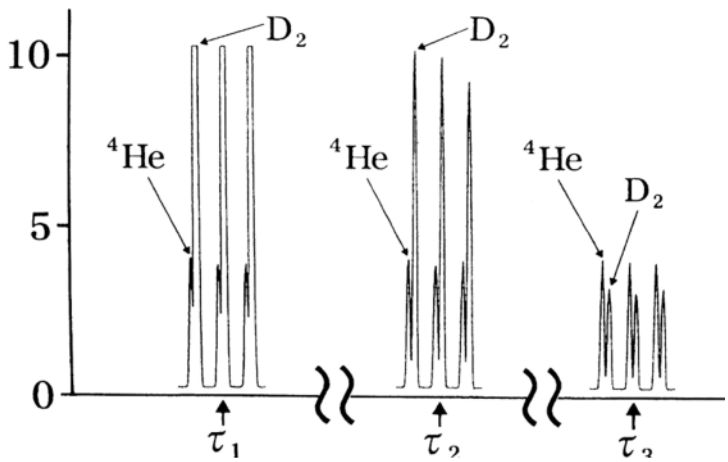

Figure 6. Spectra of sample of desorbed gas

The clearly resolved ^{4}He and D_2 peaks shown in Fig. 6 demonstrate what can be accomplished by a skilled experimenter using a high quality quadrupole mass spectrometer. In one run A&Z actually resolved the ^{3}He peak from the DH peak, which is much more difficult.

During the period 1992-2001 A&Z convinced themselves that cold fusion was real. They published 10 excess heat runs, showed excess heat when D_2O electrolysis was used and not when H_2O was used, and when Pd-black was used and not when Pd filings were used. They observed ^{4}He and sometimes ^{3}He in post-run powder, and not in as-received powder, and they successfully exported their DS-cathode experiment to the McKubre's SRI lab. In 2002 they made a major advance, producing fusion in ZrO2+nano Pd catalyst.[1]

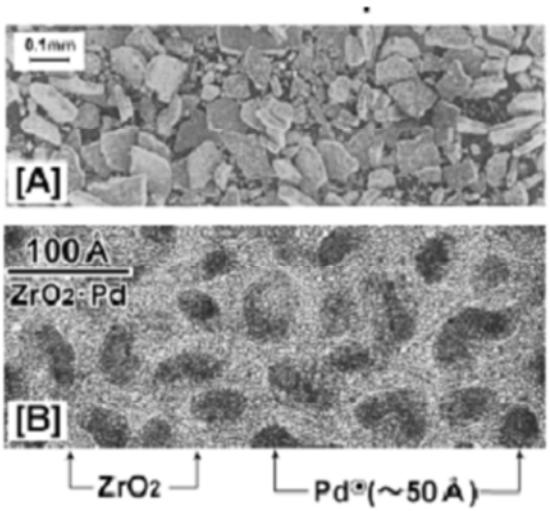

Figure 7. New catalyst shows nano-Pd embedded in ZrO_2

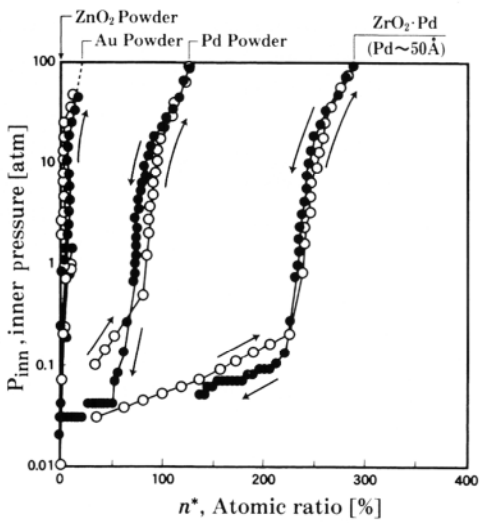

Figure 8. H/Pd = 2.9 at 100 atm

The invention of ZrO_2,nano-Pd catalyst by the Institute of Materials Research at Tohoku U. permitted gas loading to replace electrolysis. Their catalyst is produced by a well defined protocol.[2] In 2005 A&Z demonstrated fusion heat at 141°C starting temperature. D_2 pressurization of new catalyst raised catalyst temperature to 191°C. Catalytic fusion power = ~0.33 × the heater power that had maintained reactor wall at 141°C.[1]

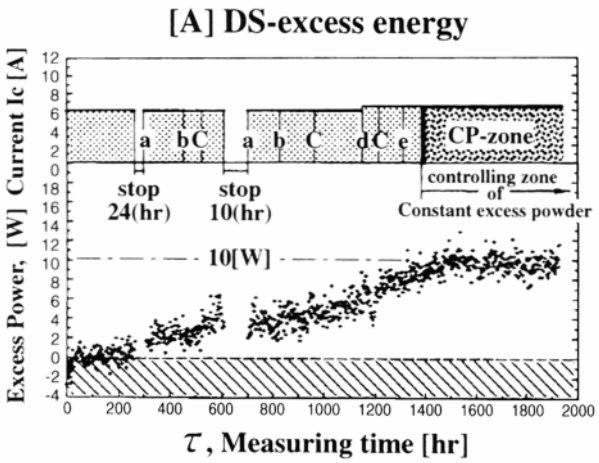

Figure 9. Deuterium deposited by D_2O electrolysis onto DS-cathode containing ZrO_2, nano-Pd catalyst produced 3 weeks of stable excess heat at 10 W. Integrated heat ≈ best hot fusion result.

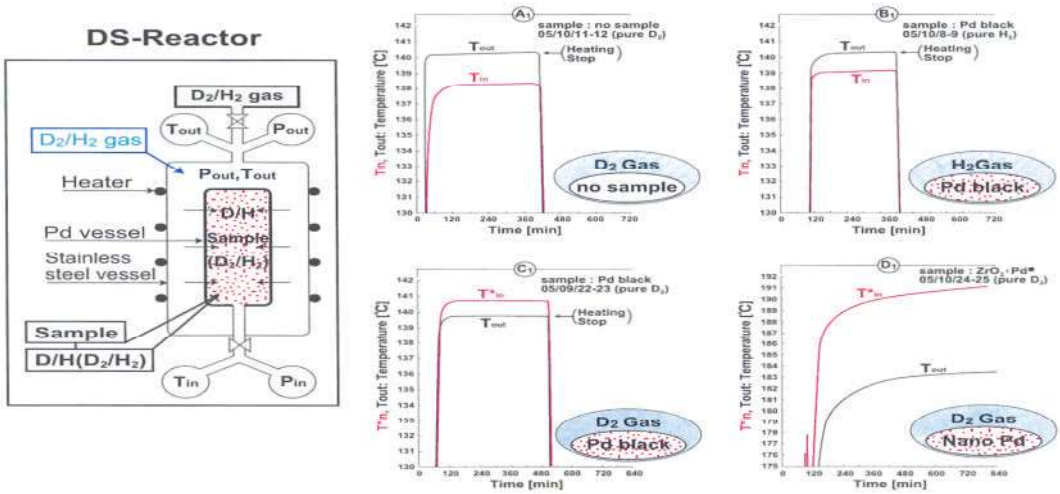

Figure 10. Gas loading tests at elevated temperature

The DS-Cathode is called the inner–vessel of a double cylinder reactor. Four tests were carried out using a reactor pre-heated to 141°C:

(1) D_2 flows into volume between outer and inner vessels, no catalyst
(2) H_2 flows into volume between outer and inner vessels, uses Pd–black: $T_{out} > T_{in}$
(3) D_2 flows into volume between outer and inner vessels, uses Pd–black: $T_{in} > T_{out}$
(4) D_2 flows into volume between outer and inner vessels, uses ZrO2,nano-Pd catalyst: $T_{in} > T_{out}$ and T_{in} rose from 141°C to 191°C

Test 2 shows that no heat is generated when the catalyst is Pd-black and the pressurizing gas is H_2. Test 3 on lower left shows reversed heat flow from Pd-black catalyst. Heat is flowing from the inner vessel that holds the catalyst towards the outer vessel wall where the electrical heater is located. Test 4 shows that when ZrO_2,nano-Pd catalyst is used the heat flow from

catalyst to outer vessel wall is 7 times greater than when Pd-black is used. The study indicates that a larger system of the same design would generate enough catalytic fusion heat to permit the heater to be turned off. This means that ZrO_2,nano-Pd catalytic heaters can be used to provide fusion heat at 191°C.

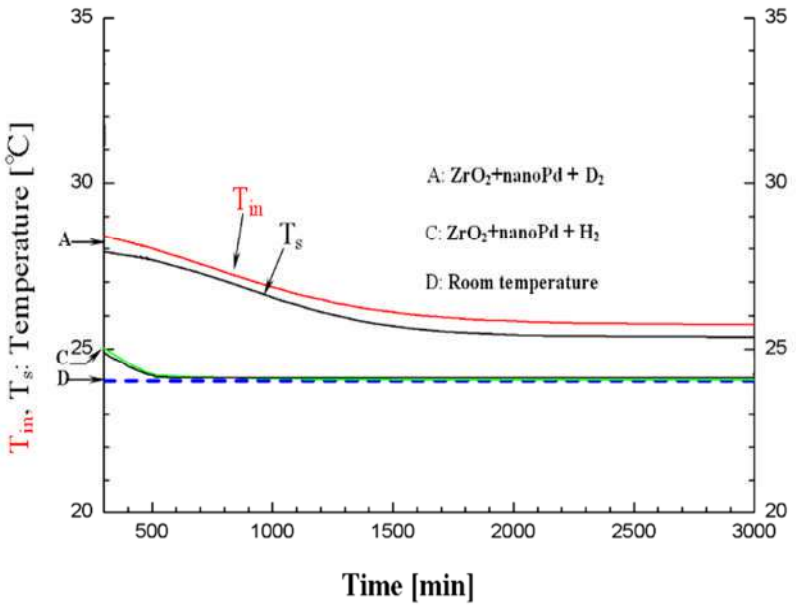

Figure 11. Autonomous heat with D_2; no nuclear heat with H_2

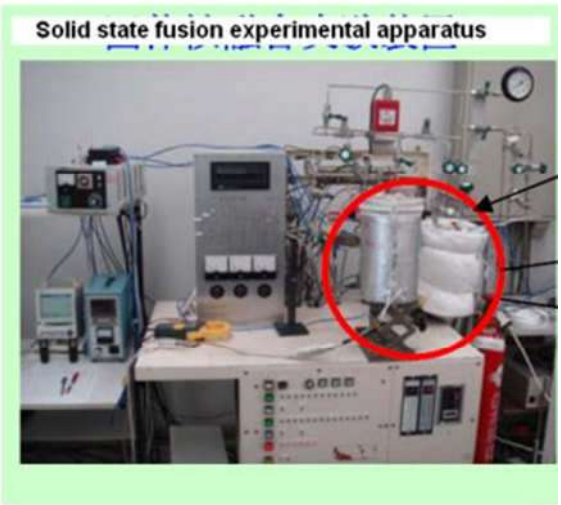

Figure 12. Test reactors

In their 2007/8 study A&Z replaced the double cylinder reactor used in 2005 with a simple single stainless steel cylinder sealed off at both ends and containing 7 grams of ZrO_2,nano-Pd catalyst. No internal Pd cylinder was used. The reactor was well insulated and operated at room

temperature. Zero electrolysis and zero heater power were used in the experiment. The catalyst bed was first evacuated. Then a Pd-filtered inflow of D_2 gas was applied so as to gradually raise the reactor vessel pressure towards 100 atm.[1] Fig. 12 shows 2 thermally insulated test reactors.

During the D_2 gas inflow period there was initial heat production due to the exothermic formation of palladium deuteride PdD_x. Reactor wall temperature rose from room temperature to about 34°C. The chemical heat flowed out of the system, so that by about 33 hours of run time all chemical heat had been lost to the room temperature environment. The assembly surface temperature returned gradually to 1.8°C above room temperature, and remained at 1.8°C above room temperature for hundreds of hours. A control run with H_2 gas inflow showed a comparable initial-transient wall temperature with a subsequent fall to room temperature by run time = 9 hr. The only plausible energy source for the sustained higher temperature produced by D_2 pressurization is the catalytic release of nuclear energy.

References

1. Yoshiaki. Arata and YueChang Zhang, Proc. Japan Acad. **70B**, 106 (1994); ibid. *Proc. Japan Acad*. **78B**, 57 (2002); ibid. Proc. ICCF12, 44 (2006); *ibid. J. High Temp. Soc., Jpn* **34**. 1 (2008).
2. S. Yamaura, K. Sasamori, H. Kimura. A. Inoue, Y. C. Zhang, Y. Arata, J. Mater. Res. 17, 1329 (2002).