IH Ref: IH-Fox-012-Prov

Methods and Apparatus for Triggering and Controlling Heat Generation Reactions

TECHNICAL AREA:

Metal alloy composite particles that are "triggered" to produce excess heat, via pressurization and magnetic flux. By varying the pressurization and magnetic flux parameters after "triggering," a method for control can be established.

BACKGROUND:

Previous work has focused on the development of various interstitial vacancies (within metallic alloys and metal-nonmetal materials) including defects and dislocations to form dense clusters of hydrogen and/or its isotope atoms. These alloys and material are combined and produced in the form of nanoparticles. In a dense cluster state, an additional kinetic energy impulse can lead to a reaction of the hydrogen (or its isotope) atoms within the lattice substructure of the nanoparticles. This energy impulse can be provided by a multitude of sources. By combining a reactor containing dense clusters and appropriately "triggering" the reaction, a heat generator capable of providing excess heat based on an intentional input is possible. In order to control the amount of heat output by the reaction, it is necessary to control the amount of hydrogen (and/or its isotopes) available for the reaction. By varying the frequency and direction of pressurization and magnetic flux to drive hydrogen (and/or its isotopes) into and out (herein referred as loading and unloading, respectively) of the lattice substructure to repeatedly start or stop the "triggering", a method for controlling the output heat is described.

EXISTING TECHNOLOGIES:

The existence of high density hydrogen (and/or its isotopes) clusters has been demonstrated in metallic materials (and combinations of metallic/non-metallic materials). Depending on the material and the structure of the materials (film or nanoparticles), various other methods of triggering have been proposed. These include electrolytic "triggering" whereby an electric current is passed through the material in order to cause

the hydrogen atoms (and/or its isotopes) to react and generate heat. Other methods include heating the particles to high temperatures (1000C+) followed by a low/modest pressure pressurization with hydrogen (and/or its isotopes). In electrolytic systems, loading and unloading occurs through polarity reversal. In high temperature systems, loading and unloading occurs through pressure reversal. However, at elevated temperatures, the required pressures (or vacuum level) for loading and unloading may not be attainable due to equipment limitations.

PROBLEMS WITH EXISTING TECHNOLOGIES:

In order to create an efficient "triggering" mechanism, the output energy (heat) needs to be significantly higher than the input energy. However, using electrolytic or high temperature pressurization methods required a significant amount of energy and thereby reducing the efficiency of the "triggering". The electrolytic methods almost exclusively requires the use of films to achieve high enough current densities. Using the electrolytic method is difficult in nanoparticles due to the porosity and resulting reduced contact area between particles. In high temperature nanoparticle environments, maintaining a high temperature requires significant energy. Any "triggered" reactions usually provide a low efficiency or Coefficient of Performance (COP).

SUMMARY OF THE PROPOSED SOLUTION AND THE ADVANTAGES THE PROPOSED SOLUTION PROVIDES:

The proposed solution described the use of two methods (1) Low Temperature (<300C) Pressurization and (2) Magnetic Flux, to "trigger" reactions within composite alloys described in previous work. Two method of triggering using magnetic flux are proposed (2a) Bulk momentum transfer and (2b) High Density Cluster momentum transfer. The bulk transfer relates to the momentum transferred by the charged hydrogen (and/or its isotopes) into existing particles high density hydrogen clusters. The high density cluster momentum transfer approach deals with the magnetic permeability of palladium. By achieving a resonant frequency for the dislocations, existing hydrogen (and/or its isotopes) within the hydrogen clusters will experience momentum transfer and result in increased velocity of charged particles. The advantage of the proposed solution

is that it requires relatively low energy input compared to other methods of "triggering". Furthermore, the implementation of the proposed solution can be conducted using off the shelf equipment and can be implemented in various reactor setups. Varying parameters for both the pressure and magnetic flux based methods allows for easily reversible of hydrogen (and/or its isotopes) flow in and out of the nanoparticle alloys to allow for easy loading and deloading.

Note* - The detailed description describes both setup and procedures for the two methods of momentum transfer. The procedural claims are not specific to this setup. The setup is notional and the proposed procedure can be used in a variety of reactor setups.

DETAILED DESCRIPTIONS OF THE PROPOSED SOLUTION AND FIGURES:

1. Low Temperature Pressurization

A. Setup

The proposed setup described in Figure 1 provides a method for pressurizing (with hydrogen and/or its isotopes) nanoparticle alloys which already have high density hydrogen (and/or its isotopes) clusters within the lattice substructure. Fundamentally, the main components of the system include (1) a reactor containing the nanoparticle alloy, (2) an inlet for hydrogen (and/or its isotopes) (3) an outlet through which a vacuum is applied (4) an external heater to raise the temperature of the reactor (5) a thermocouple to monitor the temperature of the nanoparticles and (6) a heat transfer medium that encapsulates the reactor in order to use the heat generated from the "triggered" reaction (in this case an outer reactor is shown). Other required miscellaneous items (not shown) include a (7) a source of hydrogen (and/or its isotopes), a pressurized tank is most common (8) a roughing and turbo-molecular pump to achieve a sufficient vacuum within the reactor (9) a source of power for the heater (10) other Monitoring and Control (M&C) hardware such as temperature controllers, relays, and flow control equipment.

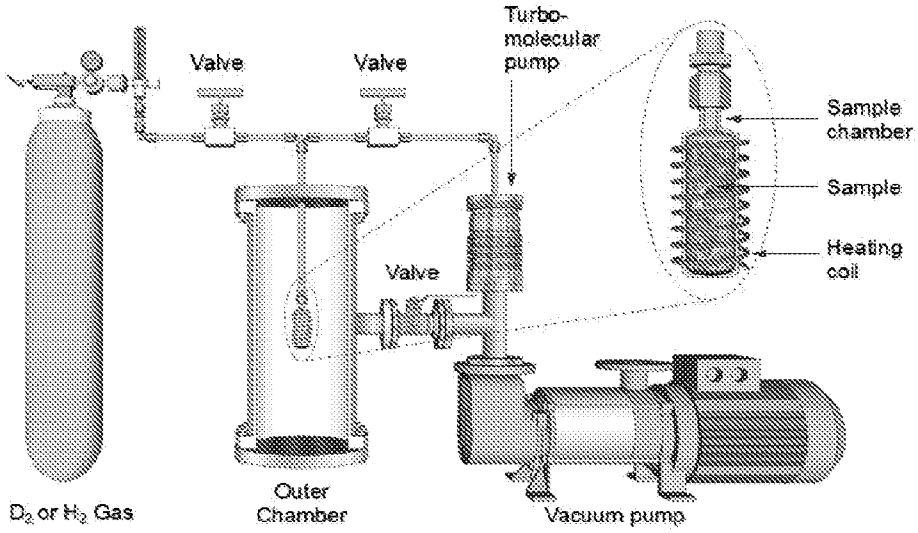

Figure 1: Setup of Pressurization/Depressurization

Control of the heat output requires two reactors, setup in a manner described above and shown below in Figure 2. The only difference is that the hydrogen and vacuum occurs simultaneously (and opposite) between the two reactors. In case 1, the concept from Figure 1 is shown with two reactors. Instead of the outer chamber, a water cooling chamber/jacket is shown for practical applications. In both cases, a compressor drives the hydrogen (and/or its isotopes) from one reactor to the other. In case 1, reactor 1 is being loaded while reactor 2 is under vacuum (unloaded). In case 2, reactor 2 is being loaded while reactor 1 is under vacuum (unloaded).

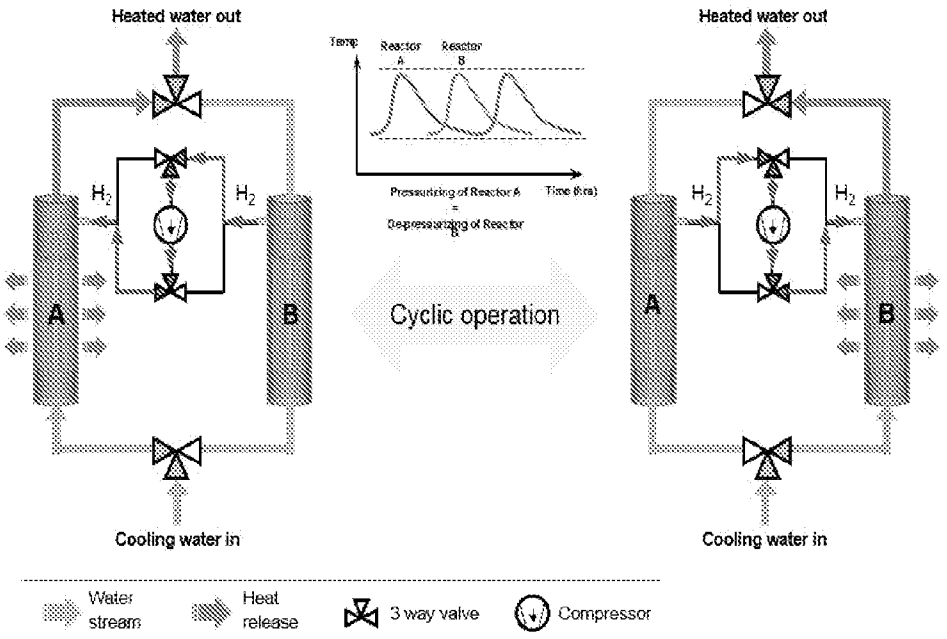

Figure 2: Case 1 (left) and Case 2 (right) showing 2 reactor simultaneous loading/unloading

B. Procedure

The procedure for "triggering" the nanoparticle alloy comprises the following steps: (1) Load the required amount of nanoparticles into the reactor (2) Expose the reactor to a vacuum using both the roughing and turbo-molecular pump. The pressure at the nanoparticles should reach 100 mTorr or below. (3) Apply heating (up to 100C) to remove any contaminants on the surface of the particles while maintaining the relevant lattice substructure formation and associated density of hydrogen (and/or its isotopes). The first instance of vacuum for the particles should occur over 24 hours. Following the first vacuum, any subsequent vacuum time should be at least 15 seconds. If the reactor is not re-exposed to atmospheric air, this time is sufficient. Heating is only required during the first vacuum instance after exposure to atmospheric air. (4) Pressurize the reactor quickly (within 1 second, with hydrogen and/or its isotopes) to at least 150 PSIG. This high level of pressurization delivers enough momentum to the high density clusters to "trigger" the reaction. The "triggering" effect is seen by the high initial temperature peak obtained by the particles, shown in Figure 3.

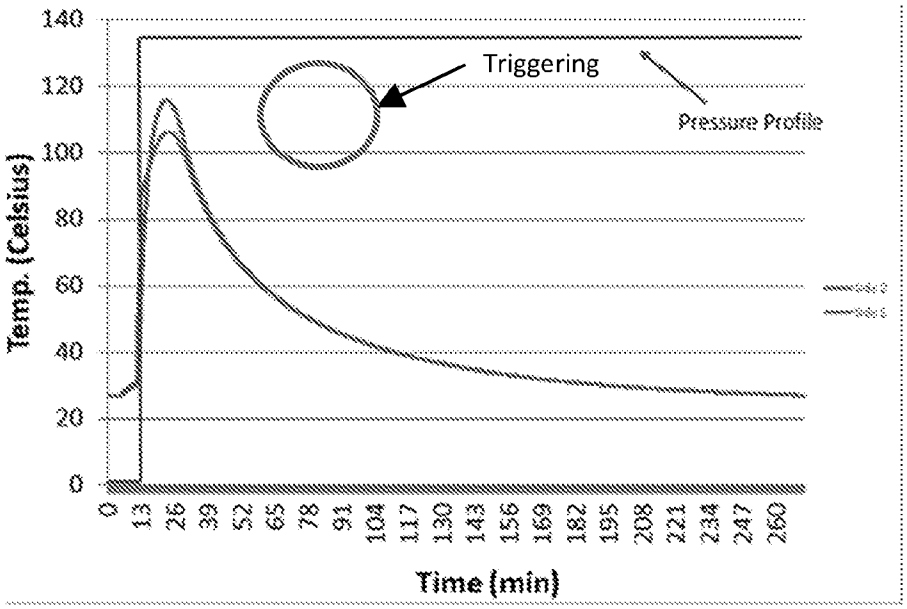

Figure 3: Required pressure profile and temperature peak indicating "triggering"

The decrease in temperature after the peak is not desirable for continual heat production. Previous results have shown that unloading the particles followed by reloading results in heat generation. Therefore, by repeatedly loading and unloading, a repeating peak can be established.

To control the reaction and produce a consistent heat output, a procedure of the control of a two reactor operation (shown above in Figure 2) is described. In order to obtain the maximum benefits of the proposed operation, the particles must first undergo steps (1)-(4) described above. After applying vacuum ($<10^{-3}$ torr), transfer the particles in a non-oxidizing environment (vacuum or inert gas) to the two reactor system. The particles should be divided evenly in both reactors.

Once the particles have been transferred into the reactors, the following steps are proposed:

(1) Turn on compressor and adjust 3 way valve (electronically) to allow transfer of hydrogen (and/or its isotopes) from reactor B to reactor A. The increased pressure in

reactor A (150PSI max) will cause the "triggering" of reactor A particles and a vacuum (10^{-3} torr) in reactor B.

(2) Once the peak temperature has been reached (typically 10 seconds to 5 minutes max, depending on the amount of particles), reverse the process described in step (1) to allow transfer of hydrogen (and/or its isotopes) from reactor A to reactor B. This will results in "triggering" of reactor B particles and a vacuum (unloading) in reactor A.

By repeating steps (1) and (2) a more consistent heat output can be achieved. Figure 4 below shows the heat output from the described 2 reactor configuration and operations. The pressure profile is also shown. In this case, when the reactor is pressurized, the temperature increases. Sometime after the temperature peaks, a vacuum is pulled in the reactor. The dashed red and green lines represent the times for pressure and vacuum for each reactor, respectively.

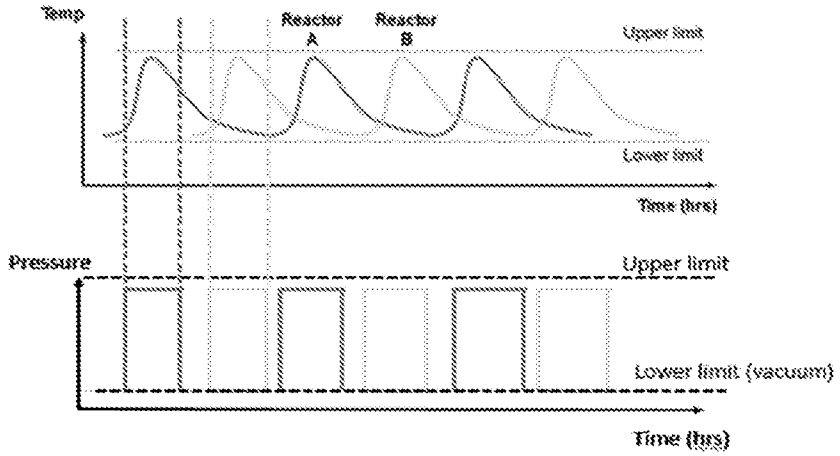

Figure 4: 2 reactor heat output and pressure profile

A process diagram is shown below in Figure 5.

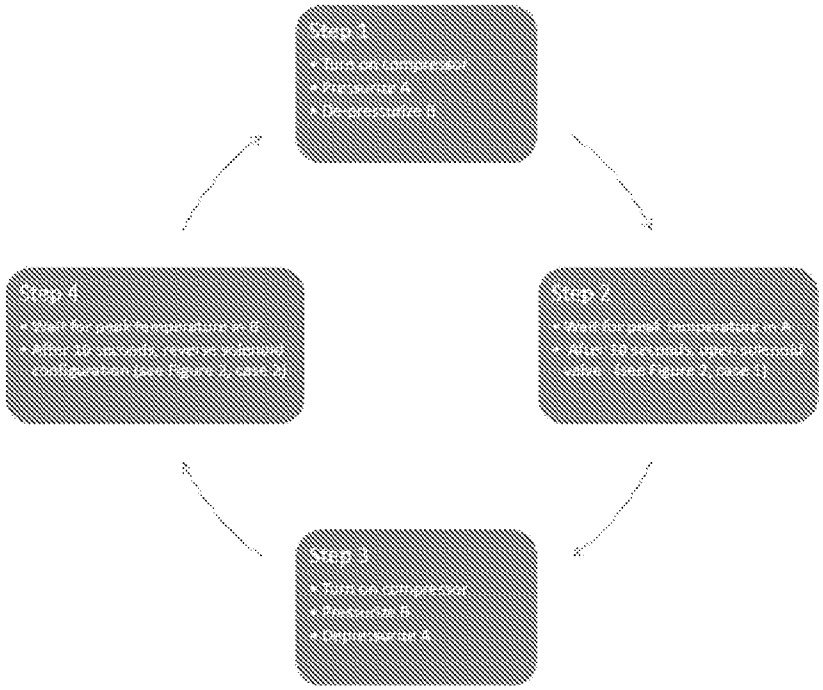

Figure 5: Process diagram for pressurization method

2. Magnetic Flux

A. Setup

i. Bulk Momentum Transfer

In the proposed magnetic flux setup, an electro-magnet is used to pulse the reactor in order to load and unload the hydrogen (and/or its isotopes) from the nanoparticles. A reversible Radio Frequency (RF) power supply is used to generate the required frequency. In the absence of an electric field, the use of a magnetic field on a charged particle results in a Lorentz Force which can be described by $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$, where the **v** is the velocity vector of the particle, and **B** is the magnetic field vector, and q is the charge of particle. The equation above means that the force vector on the particle is changing as its path changes. Effectively, for a constant charge and a constant magnetic field vector, the particle will travel in a circular motion. In order to ensure the charged particles impact the nanoparticles with the highest possible momentum, the nanoparticles must be placed in the same circular path. In other words, a linear tubing setup, as shown in Figure 1

would not be adequate. The radius in the tubing will cause the hydrogen (and/or its isotopes) atoms to impact the tubing walls and cause a significant reduction in particle velocity and momentum, thereby reducing the effectiveness of the momentum transfer.

To maximize the ion momentum into the bulk particles, a combination of an electric field and magnetic field is necessary to guide the charged particles into the bulk nanoparticles. This ion momentum can be achieved by existing electrostatic accelerators and/or ion beam generators. By using an electrostatic accelerator, which both accelerates and focuses ion beams, followed by a constant magnetic field, the particles can be guided around a circular path. The electrostatic accelerator (as shown in Figure 6, below) could consist of a gas travelling through a plasma which ionizes the gas. The liquid cooled baffles lower the ionized gas temperature. The charge exchanger removes unwanted ions. The desired ions (He- in the figure below, but H+ in the proposed setup) are then accelerated and focused. A magnetic field (generated by Helmholtz coils) is used to guide the particles into the reactor. The coupling of an electrostatic accelerator in the presence and a magnetic field to impart kinetic energy into the reactors is innovative.

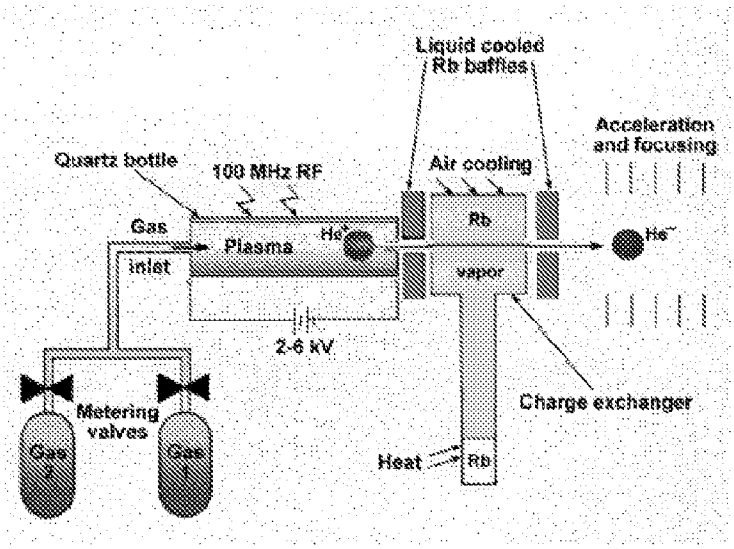

Figure 6: Example of electrostatic accelerator, source: http://www.pelletron.com/rfch72a.gif

The proposed schematic below (Figure 7) describes method (2a) Bulk momentum Transfer. An electrostatic accelerator on each end is used to accelerate the protons in and out of the bulk nanoparticles. They are alternatively cycled. This same setup is implemented in a second reactor. The overall heat output from 2 reactors is similar to Figure 4. The only difference is the method of momentum transfer. A good vacuum needs to be maintained in the entire system to minimize recombination of free protons in the system with electrons from metal in the system.

Note* - This method of bulk momentum transfer can also be used for loading hydrogen (and/or its isotopes) into the particles.

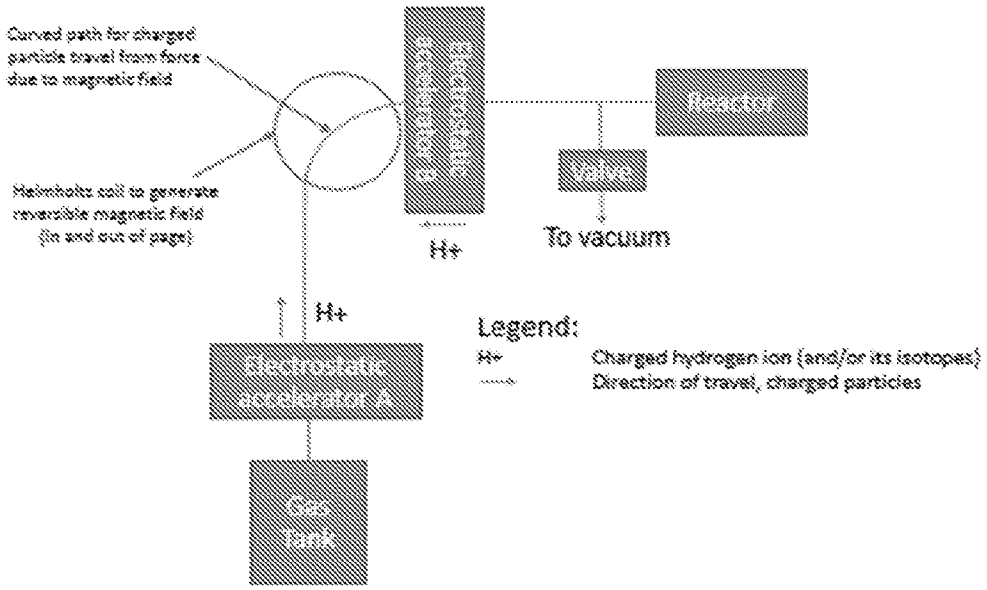

Figure 7: Bulk Momentum Transfer Schematic

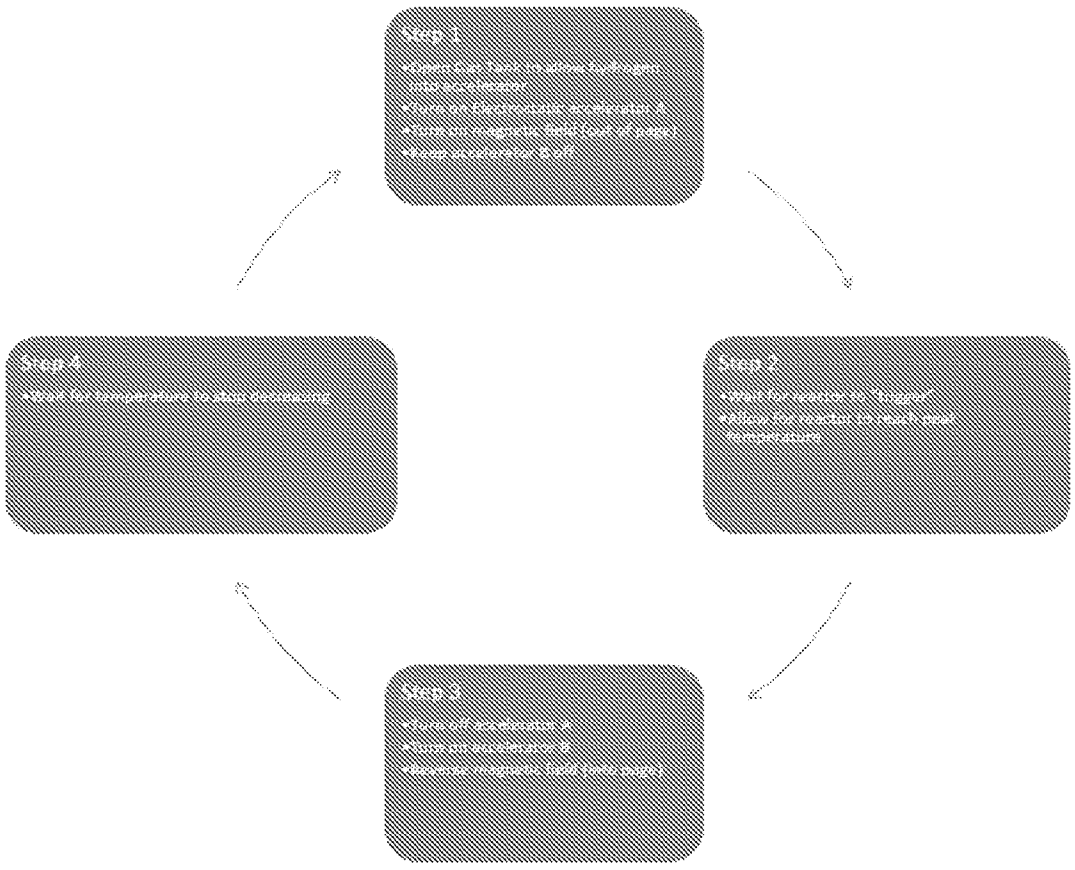

Figure 8: Process diagram for bulk momentum transfer

ii. High Density Cluster Momentum Transfer

The setup for method (2b) High Density Cluster momentum transfer can use most of the existing reactor setup. There may be a need to reduce the reactor thickness depending on the penetration of the magnetic field. In this case, using high frequency RF coils (MHz range) wrapped around the reactor and tuning to the correct resonant frequency, causes "rapid vibrations" within the high density clusters to "trigger" the reaction. The small length scales of defects require an acoustic frequency in the low THz. Longer dislocations require frequencies in the MHz range. There are two proposed configurations for the electromagnetic coils: (1) Helmholtz Coils and (2) Solenoid and are shown in Figures 5 and 6, respectively.

1. Helmholtz Coil Configuration

In this configuration (Figure 9), 2 sets of 2 Helmholtz coils (4 total) are placed around the reactor. The two sets of coils ensure that a magnetic field is generated in both the x and y plane. Depending on the strength of the each set, a net field will be generated. Oscillating both fields at the required frequency, while exposing the nanoparticles to hydrogen (and/or its isotopes), is used to both "trigger" (when hydrogen charge enters the reactor) and control (when hydrogen charge leaves the reactor) the reaction.

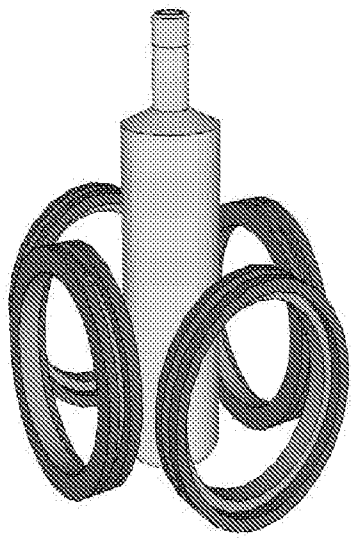

Figure 9: Reactor with Helmholtz coils

2. Solenoid Configuration

In this configuration (Figure 10), a solenoid is placed axially around the reactor. This results in an oscillating magnetic field in the axial direction. Similar to above, oscillating both fields at the required frequency while exposing the nanoparticles to hydrogen (and/or its isotopes), is used to "trigger" the (when hydrogen charge enters the reactor) and control (when hydrogen charge leaves the reactor) the reaction.

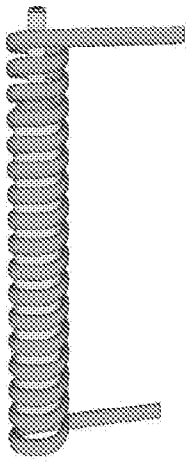

Figure 10: Reactor with Solenoid

B. Procedure

i. Bulk Momentum Transfer

In the case of Bulk Momentum transfer, after preparing the particles as discussed in steps (1)-(4) in section 1B, they should be placed into the reactor. (1) After turning on the hydrogen (and/or its isotopes) gas, the electrostatic accelerator is used to focus the charged protons from the electrons. Once the particles enter the magnetic field, they will be guided into the reactor. The radius and strength of the magnetic field is designed depending on the velocity of the particles exiting the electrostatic accelerator. (2) Once the charged protons impact the bulk nanoparticles, the reaction is "triggered" and the temperature increases. (3) When the temperature peaks, the 1st electro static accelerator is turned off and the 2nd is turned on. (4) Additionally the magnetic field is reversed. While the magnetic field is reversed, any protons travelling from reactor A will be directed towards reactor B. (5) The reactor B electrostatic accelerator is turned on (along with magnetic field) to load the particles in reactor B. The cycling of magnetic fields and electrostatic accelerators will cause the cycling of protons from one reactor to the other. Periodic injection of protons will be required to compensate for any recombination that occurs during system operation.

ii. Dense Cluster Momentum Transfer

In the case of Dense Cluster Momentum transfer, after preparing the particles as discussed in steps (1)-(4) in section 1B, they should be placed into the reactor. (1) After pressurizing the reactor with hydrogen, (2) Turn on the magnetic coils at the required frequency.

Due to the reaction mechanism, long term heat output is expected. If the heat output does diminish, it is also possible to combine the methods described in the bulk momentum transfer section above. This would result in bulk momentum transfer as well as momentum transfer in the lattice substructure possibly increasing the overall number of reactions.

3. Probability of overcoming Coulomb barrier

The probability of fusion occurring between two particles can be estimated assuming quantum tunneling is the predominant mechanism for this type of reaction. In order for fusion to successfully occur, several factors must be considered. These include particle energy, coulomb barrier and elastic/inelastic collisions.

A. Particle Energy

Higher particle energies correspond to an increased probability of overcoming the coulomb barrier. In the two cases under consideration (pressure based triggering and magnetic (bulk momentum transfer) triggering), the velocities of individual particles can be calculations.

For the pressure case, a simple approximation, Bernoulli's principle can be used. The velocity of particles as a function of time will decrease due to the increase in reactor pressure. However the time dependency of velocity is outside the scope of this disclosure. Assuming a 150 PSI source, and vacuum in the reactor, the maximum velocity of hydrogen (and/or its isotopes) can be calculated as 1.52e5 m/s. In reality this velocity will be lower because it is difficult to maintain a perfect vacuum and collisions in the piping/reactor will slow down the particles.

For the magnetic case, the velocity of charged particles travelling through a magnetic field can be calculated as v = rqb/m, where v is the velocity, r is the radius of the path of curvature, q is the charge of the particle, b is the magnitude of the magnetic field, and m is the mass of the particle. Assuming a proton with m = 1.64e-27 kg, q = 1.60e-19, b = 4 Tesla, and r= 0.001 m, the velocity of a particle is 3.84e5 m/s.

The energy of these particles can be approximated using $E = ½ (mv^2)$. The particle energies are 5.66e-17 J, and 1.23e-16 J for the pressure and magnetic cases, respectively. A modest 4 Tesla magnetic field therefore, can provide an energy almost 3 times greater.

B. Coulomb barrier

In order for particles to be close enough for fusion, they must overcome the coulomb barrier. For the cases under consideration (proton/proton interactions), a coulomb barrier energy of 4.5e7K (Kelvin) or 3.45 KeV has to be overcome. The cases (pressure & magnetic) above correspond to an energy of 3.54e2 eV and 7.69e2 eV. In the above cases, a moving deuterium particle is assumed to interact with a stationary deuterium particle. Although it appears that these energies are close to the required coulomb barrier, these are the maximum energies. In other words, the average energy of the particles is much less. Assuming a Maxwell-Boltzmann distribution, this maximum energy makes up a very small percentage of the particles in the system.

The equivalent temperature of these particles is 4.1e6 K and 8.92e6 K, respectively. Using a Maxwell-Boltzmann distribution, the probability of finding particles with the energy mentioned above, is 2.7e-4 and 1.20e-5, respectively. In other words, the probability of finding particles at specific energies reduces as that energy increases. In fact, as shown the probability of finding particles at the maximum energy is extremely low.

In any case, the above energies are much lower than the required coulomb energy, 4.5e7 K. In a classical consideration, the particles will not overcome the required energy. However, if tunneling is assumed, the probability of the particles overcoming the Coulomb barrier can be estimated. Assuming a square coulomb barrier with height U = Uo (4.5e7 K) and width of L = 1 femtometer (range for the relevant interactions), the following equation can be used:

$$T \approx \frac{1}{1 + \left[\frac{U_0^2}{4E(U_0 - E)}\right] \sinh^2(\alpha L)}$$

E is the energy of the incident particles, and:

$$\alpha L = \sqrt{\frac{2m(U_0 - E)}{\hbar^2}} L$$

For the pressure case, the probability of the highest energy particles tunneling through the barrier are:

Pressure: 94.35%
Magnetic: 97.32%

However, the fraction of particles with the required energy is extremely small, as shown above. Including the weighted particle energies, the overall probability of overcoming the coulomb barrier is:
Pressure: (0.9435*2.7e-4) = 2.55e-4 = .03%
Magnetic: (0.9732*1.2e-5) = 1.17e-5 = .001%

Therefore, in order to increase the total probability of overcoming the coulomb barrier, the total **average** energy of the particles needs to be increased. To increase the probability to 1%, the proposed methods would need to be conducted in a very high energy environment. This could be achieved through a high ambient temperature (for the pressure based approach) or a high energy plasma (for the electro-magnetic approach) which is typically seen in traditional plasma based fusion type experiments.

*Note: overcoming the coulomb barrier does not necessarily indicate fusion will occur. Other aspects such as elastic/none-elastic collisions, cluster density effects, and particle interactions have not been considered here.