Some preliminary thoughts on abnormal phenomena of condensed matters loaded with D/H

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Outline

1. Threshold of entering this field
2. How to get good reproducibility

- the role of positive or negative ‘impurity’
- sample preparation, pretreatment, loading and characterization

3. How to trigger synergistically

- new coupling in non-equilibrium state
- subsurface, nanostructures
- a possible combination of CMNS with ICF

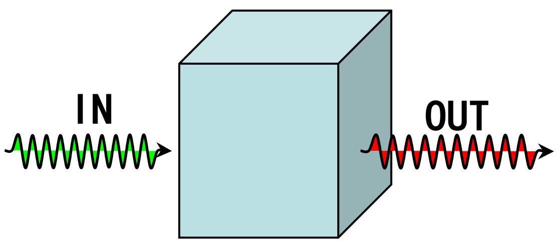
The threshold of condensed matter nuclear science (CMNC) is very high

Originally scientists studied condense matters by preparing and characterizing the structurally well-defined and ordered crystals (bulk phase), then the subject was expanded into structurally well-defined surfaces and the top few layers of metal and oxide crystals. It is hard to prepare and characterize the various surface facets.

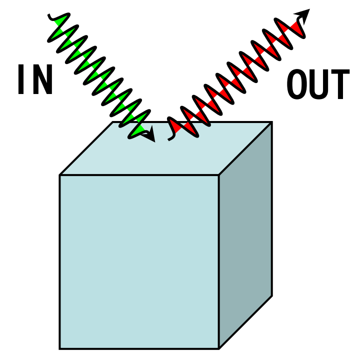
For catalysis and electrochemical industries, the people have to move forward to prepare good catalysts and electrode materials. it’s necessary to get the deep insight of surface reaction mechanisms. As a consequence, much more complex surfaces were prepared to rationally design and create various active sites of adsorption/reaction of heterogeneous surfaces.

Nowadays the people can study the single active sites, single atom(s) supported by metal/semiconductor/oxide/carbon—single atom catalysis (SAC) by tools with very high spatial resolution (angstrom) experimentally and theoretically.

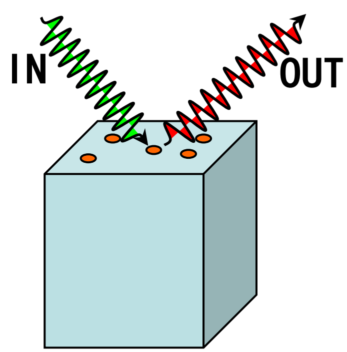
Condensed matter nuclear science may belong to the future of science



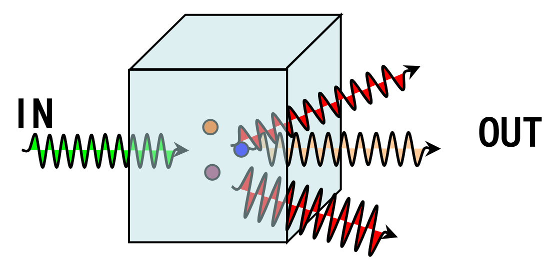
Ordered Bulk Phase



Structurally well-defined surface



Surface active sites



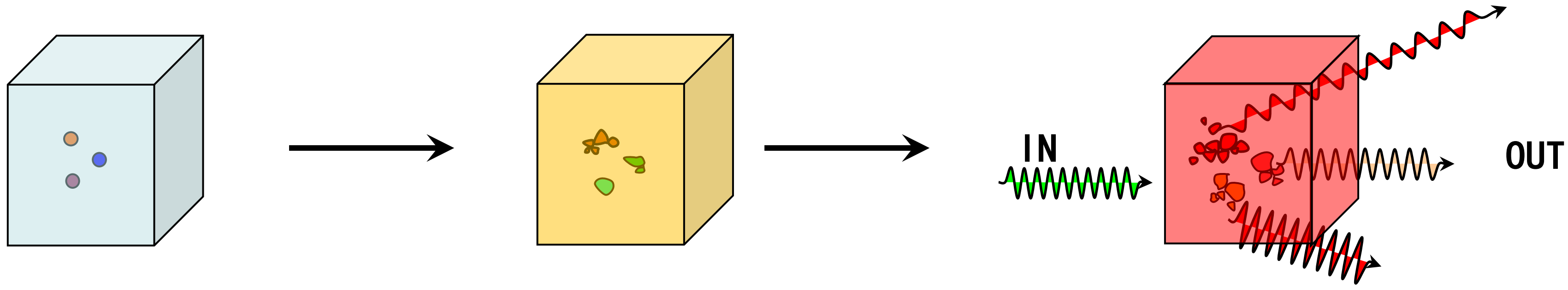
Bulk active sites
Belong to Future?

The threshold of condensed matter nuclear science (CMNS) is very high

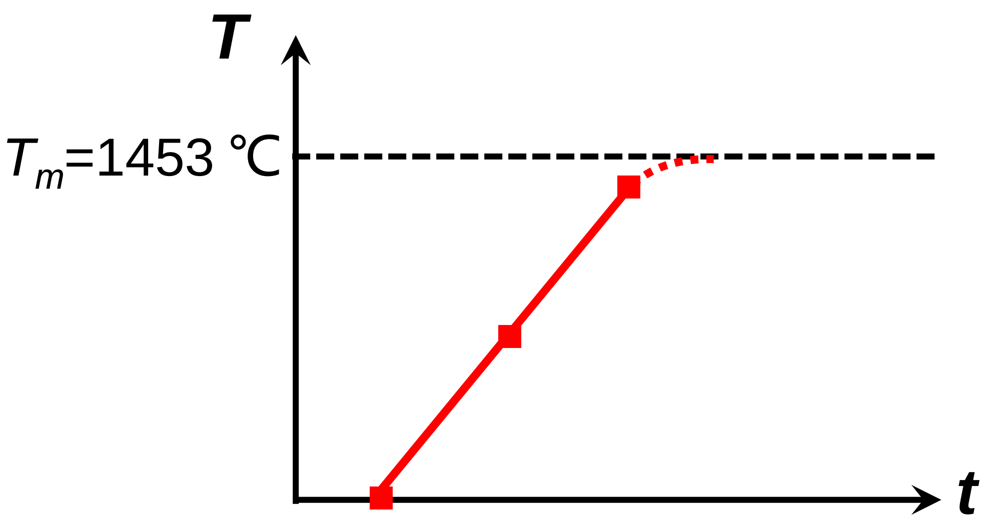
More importantly, operando spectroscopic techniques have been developed to investigate the detailed structure and dynamics of active sites under the real reaction condition.

There have been some strong demands to go back to bulk phase as the spiral development, i.e., how to prepare thus characterize the structure and dynamics of active sites inside the bulk phase (under non-equilibrium condition), especially related to energy and life sciences. This is a huge challenge at the present stage because so far no body has been able to controllably create and characterize these active sites inside the condense matters and to replicate the phenomenon (this inevitably causes the severe problem of irreproducibility of experiments). Therefore, the condensed matter nuclear science could belong to the future of science.

The triggering causes irreversible change



Triger active sites inside the bulk ? ? ?



How to get reproducibility (reliability)

The positive or negative role played by trace ‘impurity

1. **Cathode (bulk, surface defects...)**
2. **Anode dissolution**
3. **Solution**
4. **Gas**
5. **Cell wall**

Detailed diagnostics are important to well understand ‘impurity’!

How to get reproducibility (reliability)

1. Sample preparation
2. Sample cleaning
3. Sample pretreatment
4. Sample loading

before the sample triggering

For any experiment having the positive result the localized structure of sample must be changed irreversibly. It's necessary to go back to the origin structure (especially sample).

Nanostructure systems are easily to regenerated

The poor reproducibility in the current researches is at least partially due to the irreversibly change of materials after the D/H loading and especially triggering procedures. The defined structure cannot be recovered completely for the next experiment because of distortion of metal lattice, phase transition or cracking happened.

A very important advantage of using nanostructures is that after the experiment, these nanostructures can be easily dissolved by chemical way then re-synthesized to fresh nanoparticles for the next experiment. Moreover, various core-shell and core-shell-island nanoparticles can be rationally synthesized to implement the desired composition (e.g., Pd, Ni, Li) and their quantity ratio.

Some Key Factors and Issues

Preparation

Sampling
Ni, Pd, Li alloys…
powders, nano-structures
D_2, H_2, D_2O, H_2O
LiOD…

Loading
Solid—gas
solid—liquid
Hydrogen (deuterium) storage systems…

Triggering
Current, laser, pressure, temperature, microwave, particle beams, mechanic, CIF …

REPRODUCIBILITY

Characterization
Temperature calorimetry
resistance, EC
spectroscopy
diffraction,
SEM TEM, STM,
nuclear product analysis,
…

Theory
Selective resonant tunneling model, Role of coherently excited localize anharmonic vibrations, …

Some issues

Impurities, surfactants, surface treatment, heterogeneous distribution

Some issues

Energy, spatial and time resolutions, in-situ & operando measurements

The subsurface of condensed matter science

At the present stage the best way could be to design sub-surface systems (several to several ten atomic layers below surface) of condense matter, which has some similarity as bulk phase but can be designed and characterized at least to some extent. This infers that nanostructures (particles, plates, rods, flowers etc.) as well as small tubes with ultrathin wall and ultrathin wires of metal/metal hydride could be the best systems to be studied. Most nanostructures such as small nanoparticles (<10 nm), relatively larger nanostructures coated with ultrathin metal layer (ca. 1-5 nm) can be chemically synthesized easily. To avoid aggregation of nanoparticles, especially for the small nanoparticles, the surfactant to protect the particle surface must be used. .

Triggering process seems to be underestimated

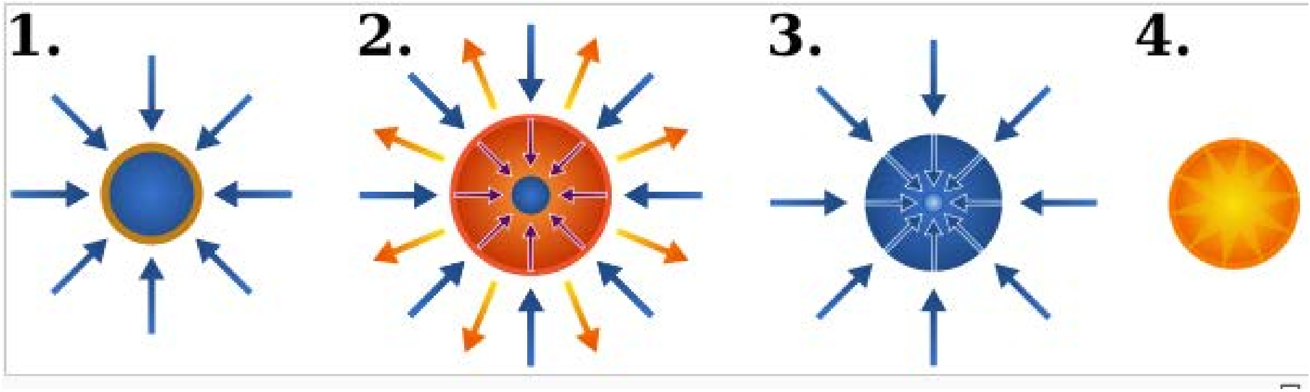
Among three key factors (loading, triggering, measurement) in the experiments, the second factor seems to be underestimated. In fact, a non-equilibrium state has been triggered unintentionally in some cases. The highly deuterized or hydrided metals, as pseudo-steady/non-equilibrium systems, are easily trigged by either internal or external effects. For example, the ‘heat after death’ phenomenon may be due to the fact that after a long electrolysis, both macro- and micro-structures in the bulk material could be changed abruptly by distortion of metal lattice, phase transition, or cracking (happened to get more active sites). The behavior of deuterium or hydrogen could be much different especially under the non-equilibrium state.

Triggering process seems to be underestimated

Raising the temperature close to the melting point could be a way to create a unique non-equilibrium state that may promote the reaction effectively. However, the concentration of absorbed D/H in metal is extremely low, significantly lower than that at the room temperature. Therefore it could be necessary to apply high pressure of D_2 or H_2 to force the loading of D/H at high temperature, which may take place only in the region of subsurface of metals. To avoid the conflict of the mutual requirement of heavy loading and high temperature condition, the sharp increase of temperature by the laser, current, or electro-magnetic pulses are obviously helpful because the absorbed D/H cannot escape from the bulk phase of metal in a very short period of time.

An approach of metal nanoparticle--ICF

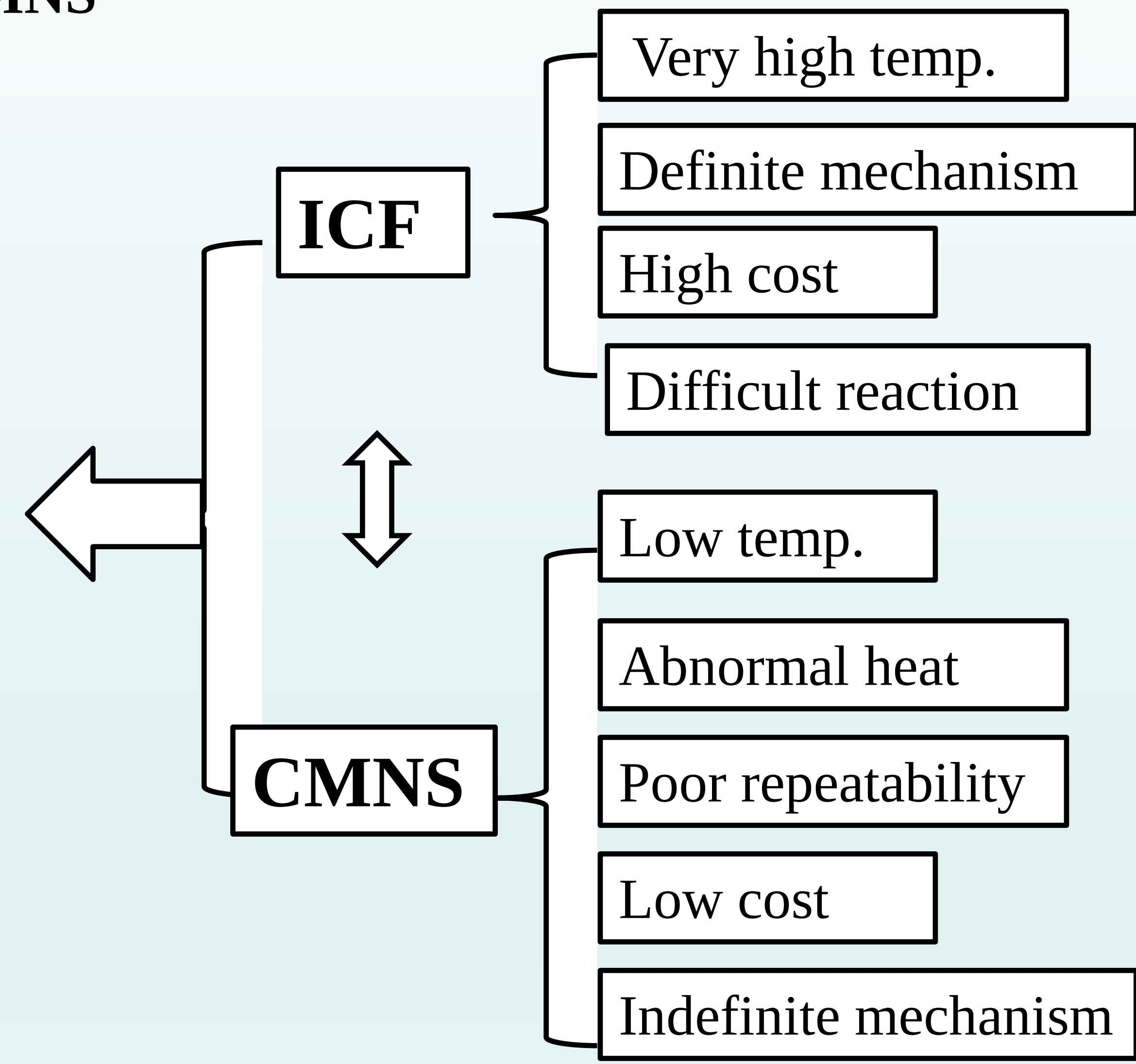
One of the extreme trigger methods could be the utilization of inertial confinement fusion (ICF) facility. The highly D/H loaded metal nanoparticles are filled in the target ball then it is compressed to extremely high densities and temperatures by the initiating laser beams. The sufficiently high density and temperature are achieved before the target disassembles. The combination of hot and cold fusion may reduce the threshold of technical parameters for ICF and promote the reaction effectively.



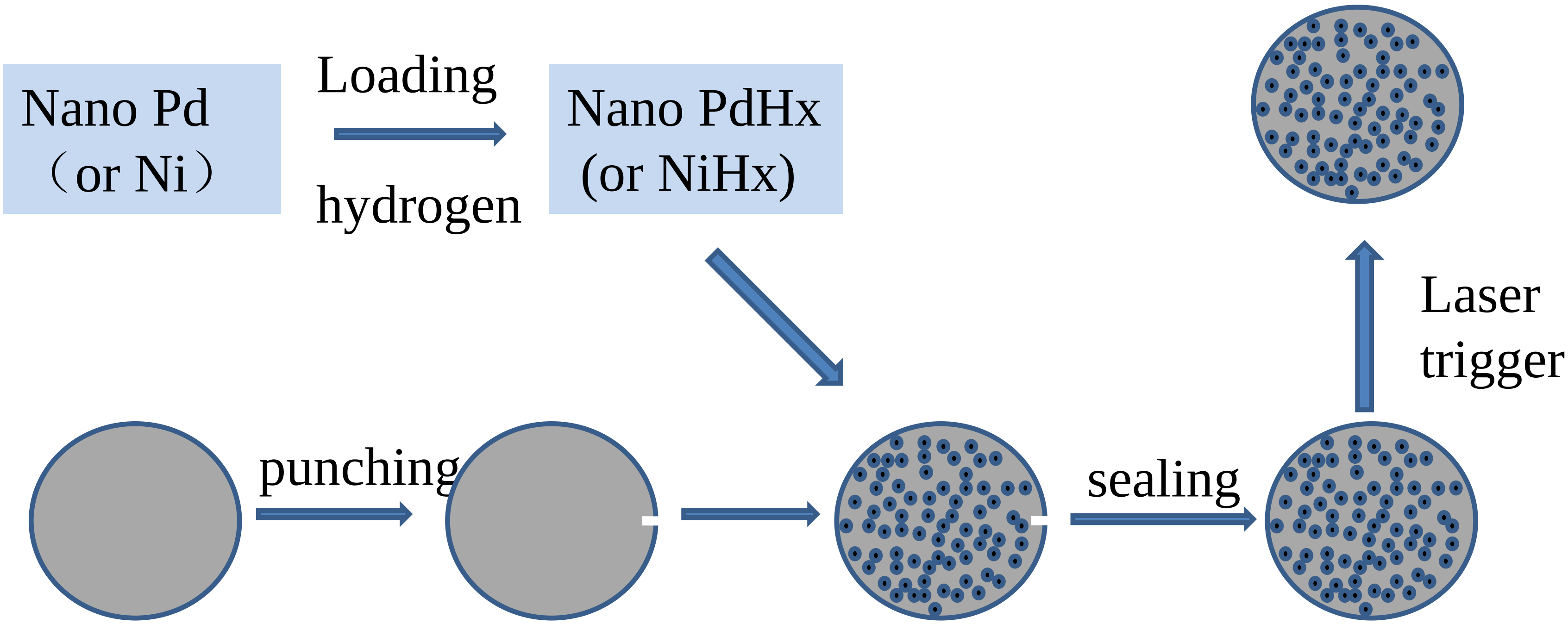
Metal nanoparticle-loaded hydrogen—ICF

The combination of CMNS and ICF

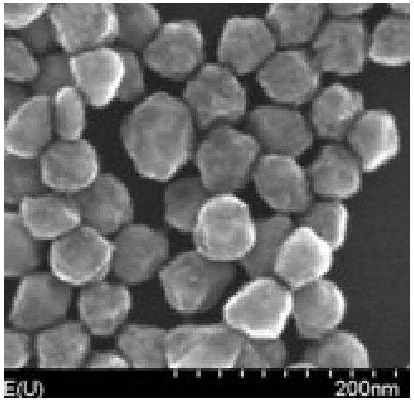
Considering the possibility for condensed phase assisted nuclear reaction, by borrowing the technology of ICF, using highly active hydrogen-loaded alloy nanoparticles replace the solid deuterium to in target sphere, in order to explore the possibility for achieving controllable nuclear fusion at mild conditions compared with thermonuclear fusion.

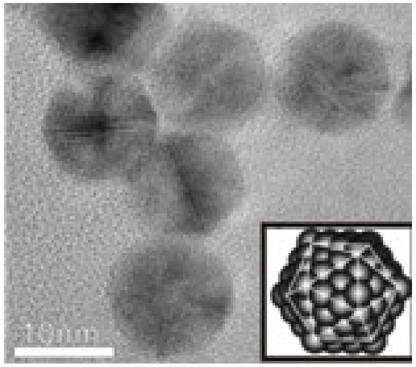


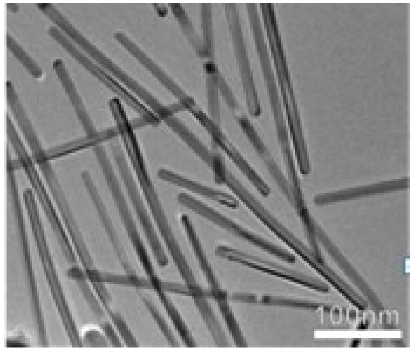
An approach of metal nanoparticle--ICF



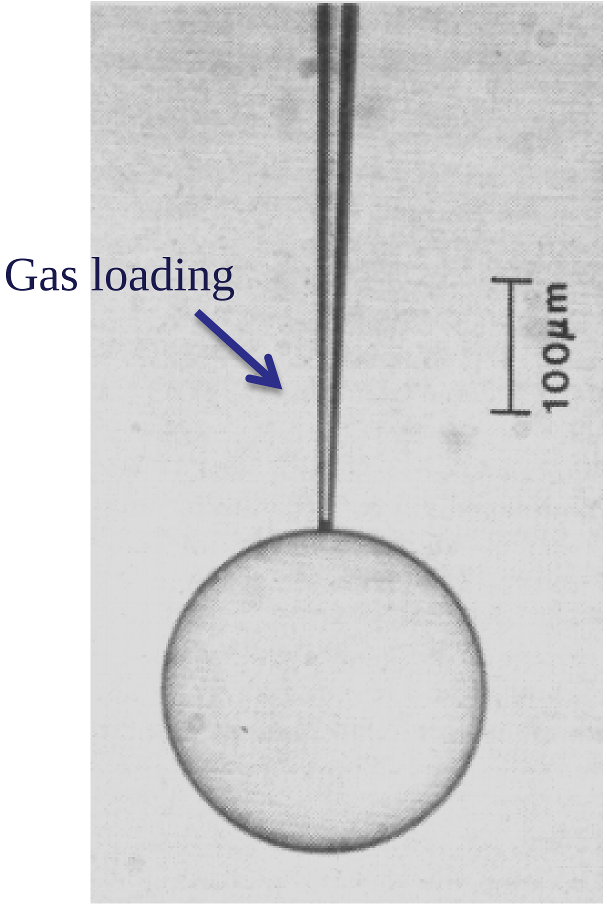
Schematic diagram

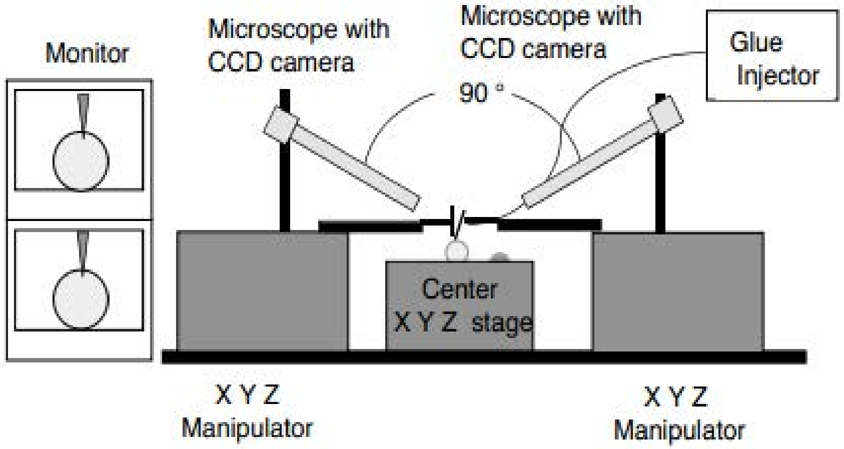


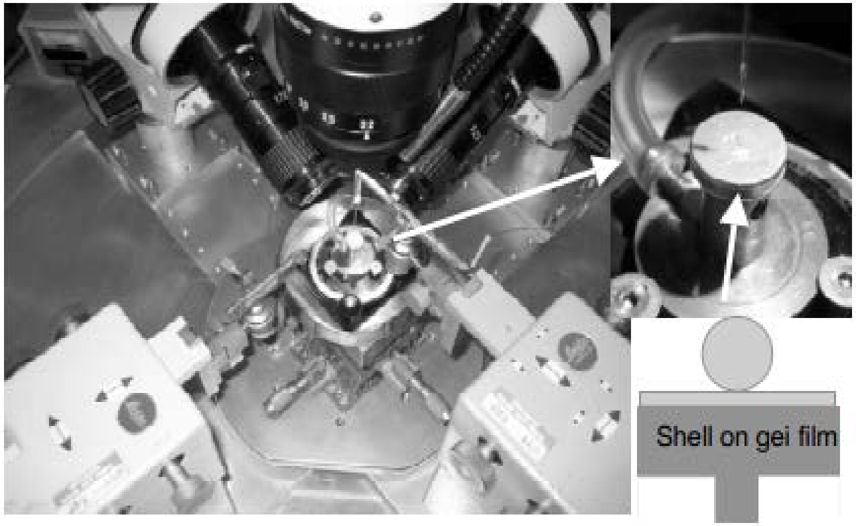




An approach of metal nanoparticle--ICF







Operating deck

Summary and Questions

1. Threshold of entering this field of CMNS is very high as it may belong to the future of science
2. How all experimental factors can be well controlled for being replicated by others
3. How the work can be collaborated internally and externally
4. How to develop new experimental and theoretical methods with recent progresses of science
5. How the community can be adopted and supported by the whole science community

Some thoughts on CMNS

- CMNS may result from some nonequilibrium processes in highly D/H loaded metals; e.g., a rapid change in the configuration of host metal atoms could create unique "CMNS active sites".
- To avoid the conflict of the loading and triggering targets, the sharp increase of temperature by the laser, current, or electro-magnetic pulses are obviously helpful because the absorbed D/H has no time to escape from the bulk phase of metal.
- Raising the temperature close to the melting point could be a way to create a special non-equilibrium state that may promote the reaction effectively.
- The small tubes with ultrathin wall, ultrathin wires or nanoarticles of metal/metal hydride are the best for these high temperature/pressure studies. For the small nanoparticles, the surfactant to protect the particle surface must be used.

Some thoughts on CMNS

- The surface contamination must be avoided and many characterization methods and tools under high vacuum condition must be developed to extract the week signal contributed from the surface.
- Not only normal condense matter but also abnormal (‘soft’) condensed matters may support nuclear reaction, which may need to have stimulated surface phonon emission or coherent shaking of surface and/or sub-surface atoms periodically. The localized anharmonic vibrations might be one of the possible ways to realize the localized excited surface phonon, which could be triggered by thermal heating, THz pumping, gas pumping or inflating, etc. The abnormal phenomena may be more distinct when the condense matter is getting ‘soft’ in a non-equilibrium state when the condense matter is input with energy flux.
- The combination of hot and cold fusion may reduce the threshold of technical parameters especially the temperature for ICF

Brief Summary

- To avoid the conflict of the loading and triggering targets, the sharp increase of temperature by the laser, current, or electro-magnetic pulses are obviously helpful because the absorbed D/H has no time to escape from the bulk phase of metal.
- One of the extreme trigger methods could be the utilization of inertial confinement fusion (ICF) facility. The highly D/H loaded metal nanoparticles are filled in the target ball then it is compressed to extremely high densities and temperatures by the initiating laser beams. The sufficiently high density and temperature are achieved before the target disassembles. The combination of hot and cold fusion may reduce the threshold of technical parameters for ICF.

Thank you for your attention!

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