【Grant-in-Aid for Transformative Research Areas（A）】

1000-Tesla Chemical Catastrophe : Science of Chemical Bonding under Non-perturbative Magnetic Fields

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Research Area Information	Number of Research Area : 23A201 Project Period (FY) : 2023-2027 Keywords : strong magnetic field, chemical bonding, catastrophe	

Purpose and Background of the Research

●Outline of the Research

It is generally difficult to produce effects that greatly change the properties of matter by applying a magnetic field. However, when we leave the earth and expand the range to the universe, white dwarfs and neutron stars generate giant magnetic fields, where atoms can no longer form chemical bonds and remain in the atomic or plasma state. Therefore, magnetic fields are expected to play an important role in the formation of the natural world, including the universe. It is expected that the hidden properties of nature will appear in extremely strong magnetic fields, and thus technological challenges to extend the upper limits of strong magnetic field generation have been continuing worldwide for more than half a century.

In 2018, ISSP, UTokyo succeeded in generating the world's strongest indoor artificial magnetic field of 1200 Tesla. This is about 24 million times stronger than the earth's magnetic field. The purpose of this research is to search for undiscovered ultra-strong magnetic field effects that mimic the giant magnetic field effects in outer space using the 1000 Tesla class fields. Chemical catastrophe is a phenomenon in which molecular destruction occurs due to the effect of a strong magnetic field, and is a typical example of a non-perturbative magnetic field effect.

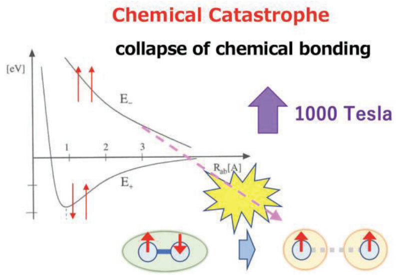

Figure 1. An image of the chemical catastrophe.

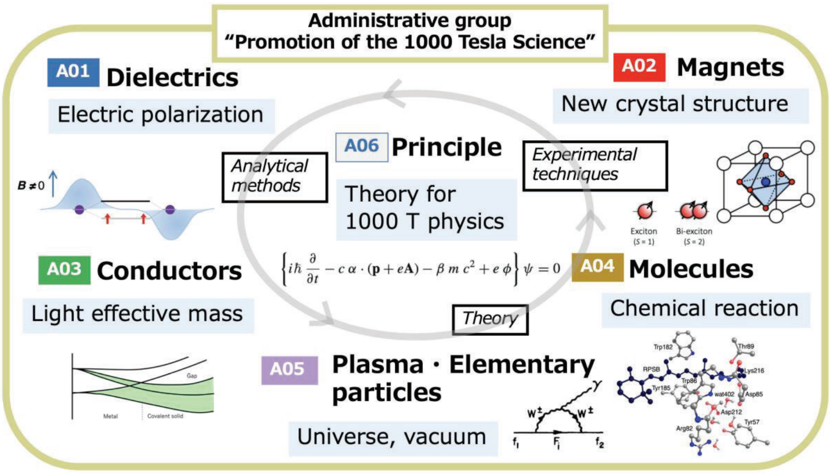

Figure 2. A schematic diagram of the research structure of the 1000 Tesla Science.

●1000-Tesla Magnetic Fields

The 1000 tesla ultra-high magnetic field used in the research is generated by a destructive method called the electromagnetic flux compression. The coil and metal cylinder used to generate the magnetic field are destroyed with the sample to be measured in a single magnetic field generation.

The duration of the magnetic field generation is about 1/100,000 of a second, which means that an advanced single-shot measurement is required. Various kinds of measurement techniques possible in ultra-high magnetic fields have been rapidly developed in recent years. In this study, we will search for non-perturbative magnetic field effects by means of various high-speed single-shot measurements.

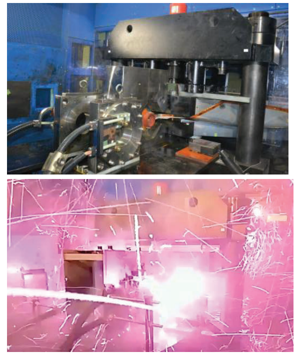

Figure 3. Photos of the 1000 T generator (top) before and (bottom) in the field generation.

Expected Research Achievements

●Chemical Catastrophe in Condensed Matter

In a material, many atoms are bound together, and the competition of various interaction energies induces a variety of properties, so if the energy balance can be changed using a magnetic field, a solid-state version of the chemical catastrophe can be realized. For example, some substances have been discovered in which molecule-like atomic groups are formed. It has been found that it is possible to break up these molecules in solids with a strong magnetic field. (Figure 4) Furthermore, although the magnetic field effect on typical dielectric materials that do not contain magnetic ions has received little attention so far, from the perspective of the magnetic field effect on chemical bonds, catastrophe phenomena can also be seen in the dielectric properties. Furthermore, conduction electrons are strongly influenced by magnetic fields and have the potential to change the crystal structure, which we will explore.

●Academic Fusion Research based on 1000 Tesla

We will also clarify non-perturbative magnetic field effects on chemical reactions and new magnetic field-induced phenomena targeting elementary particles and cosmic plasma. The purpose of this research is to comprehensively understand the phenomena induced by ultra-strong magnetic fields, using solids, proteins, molecules, plasma, and elementary particles as experimental objects. By doing so, we will create a new academic fusion research based on the 1000 Tesla ultra-strong magnetic field. (Figure 5) We expect that various challenging research topics will emerge, and we believe that we can create opportunities for young researchers to flourish.

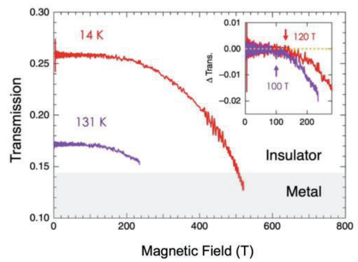

Figure 4. Insulator-metal transition in a vanadium oxide, indicating the collapse of molecules in the solid.

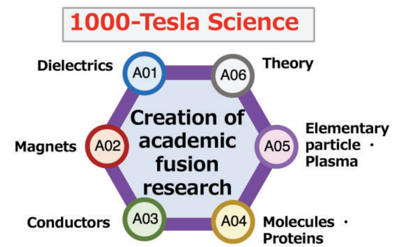

Figure 5. Image of the academic fusion research based on 1000 T magnetic fields.

Homepage Address, etc.	https://1000tesla.issp.u-tokyo.ac.jp/