Ultrahigh-flux concerting materials unit

Organized Session: Nov. 9th, 9:00am - 12:00am (JST)

Materials for fusion and other nuclear reactors, aerospace crafts, chemical plants etc. are used under extreme conditions of localized stress and steep gradient of temperature and composition. In addition, radiation damage is also overlapping under neutron and other irradiation conditions, leading to ultrahigh flux of energy and various particles in materials. Such non-equilibrium conditions induce amorphous and metastable compounds (metastable phase), and self-organization of constituent atoms including crystal lattice defects. As the hydrodynamic vortex in fluid and skin color patterns of animals, such as giraffe and zebra, metastable cyclic pattern structures are produced in mesoscale larger than the water molecule and plasmas in the former case, and biological cell and coloring agent in the latter case. Self-organization patterns with an interval of several 10 nanometers to microns have been identified many times even in solid matters with strong atomic bonding for hard enough self-standing crystal, under heavy-cycle deformation, and neutron and ion irradiation conditions.

Even though formation of the metastable phase and mesoscale patterns has been analyzed and well simulated by experiments and calculations, their physics are still incomplete, novel and very interesting to reveal how the self-organization phase and patterns induce the macroscopic properties. Based on the physics, the non-equilibrium self-organization structure can be correlated with the material properties, and enables us for materials design to accelerate the adaptive structures to the extreme conditions. One of the purposes of this research unit is a paradigm shift from resistant and stable materials to adaptive and metastable materials, leading to creation of novel materials. On the other hand, perfect adaptation is absolutely unrealistic, because materials degradation is unavoidable if the adaptive self-organization is less enough for perturbation of the extreme conditions, accumulation and intrinsic mutation of materials damage structure. This research unit focuses on also the unavoidable materials damage based on the understanding of reversibility and irreversibility of materials structure and properties, and seeks long life materials and precision estimation of their life to develop engineering systems using the minimum materials for compatibility with economical and safety requirements.

This research unit investigates structural and functional materials. The structural materials for investigations consist of metals and ceramics, however their boundary is not necessarily clear. The metallic materials investigated are (1) refractory metals, where covalent bond is relatively larger than the other metals, and therefore good high-temperature strength is expected as ceramics, and (2) non-refractory metals strengthened by dispersion of refractory ceramic nano-particles. On the other hand, ceramic materials investigated are to be modified for metallic pseudo-ductility etc. by extrafine fibrillization, joining and composite assembly with metallic materials. Besides, the ceramic functional materials are to be improved by metallic dispersion and introduction of supersaturated non-metallic ion vacancy defects and accompanied metallic bonding, in order for novel and accelerated functional characteristics. In other words, meta-states, such as ceramic metals and metallic ceramics, are expected to create novel materials. The fabrication for the meta-state materials is generally composed of microstructural control by non-equilibrium hybrid processes. From a viewpoint of condensed matter physics, control of collective atoms dynamics including crystal lattice defects in materials is indivisible and continuum through the engineering stages for the production and use of materials, thus the research unit seeks their comprehensive understanding and systematization.

In the functional hydrogen materials field, investigations and discussion for mechanisms and applications of ultrahigh flux of hydrogen atoms much greater than equilibrium, using injection of accelerated hydrogen ions into high hydrogen solubility materials with a less solubility coating on the injection surface, are ongoing. Challenging goals are, for examples of various applications, (1) creation of extremely greater hydrogen storage than intrinsic solubility limit in materials, using the supersaturated-hydrogen-induced metastable phase as the trapping site, and (2) high efficiency tritium decontamination by isotope exchange under high-flux hydrogen in the clearance of expecting materials after the use in nuclear reactors.