Material Science Research Laboratory

Brief Overview

The Materials Science Research Laboratory conducts R & D to provide engineering solutions from the viewpoint of materials to enable the highly efficient operation of energy equipment together with the creation of materials which can bring about technological innovation in the energy industry.

Achievements by Research Theme

Hydrogen basic technology

[Objectives]

To clarify the approaches of electricity businesses to new technologies relating to the production, transportation, storage and use of hydrogen when a hydrogen-based society is realised

[Principal Results]

- GTL gas oil was revealed as the leading candidate for alternative fuel at present from three viewpoints of technologies for fuel manufacture, fuel supply and car. A manufacturing method for GTL gas oil based on hydrogen (non-fossil fuel) and CO_2 recovered from thermal power generation was examined and the technical problems were identified.
- With a small SOFC (ceramic reactor) which operates between 500℃ and 600℃, it was found that the power generating performance of the module could be improved by some 30% with pressure of approximately 0.3 MPa. In addition, the relationship between the water vapour volume and the amount of generated hydrogen during water vapour electrolysis was clarified. Furthermore, it was found to be possible to improve the separation efficiency of hydrogen and oxygen as a result of the selection of an adequate supply of gas to the anode.

Structural materials elvaluation

[Objectives]

To understand the strength characteristics and develop a life assessment method and a corrosion reduction technology to contribute to the solving of various problems of materials used for thermal and nuclear power generation from the aspect of structural material assessment

[Principal Results]

- To understand the high temperature strength characteristics of gas turbine blade materials, the constitutive equation for uni-directionally solidified super-alloys was extended to take the temperature dependency into consideration. In addition, the characteristics of fatigue crack propagation along the direction of crystal growth under the transversal load condition were clarified.
- For the development of an integrity assessment method for new types of nuclear reactors, high temperature strength test data for high chrome steel was obtained and the functions of the structural integrity assessment system were improved.

Water chemistry management

[Objectives]

To reduce radiation exposure in light water reactors, improvement and standardization of water chemistry will be done. Moreover, to improve reactor safety, mitigation of SCC will be also carried out.

[Principal Results]

- The primary water stress corrosion cracking (PWSCC) test and surface film analysis were conducted for Inconel materials under 50 ppb zinc injection condition. Test results revealed that the film affected initiation of SCC.
- Dissolution of corrosion products under simulated condition of PWR plant shutdown maneuver was experimentally investigated. Lower solubility of iron and nickel was observed under oxidizing condition than reducing condition.

Coating evaluation

[Objectives]

To develop evaluation technologies for the resistance to thermal cycling and corrosion of the coating for gas turbines in order to achieve the cost reduction and to ensure the reliability.

[Principal Results]

- Thermal cycling tests on the thermal barrier coating (TBC) revealed that the damage behavior subjected to thermal cycles under a temperature gradient corresponding to an in-service gas turbine was different from that subjected to thermal cycles without thermal gradient.
- The corrosion tests were conducted on various heat-resistant alloys in the gas atmosphere containing a corrosive impurity (SO_2 gas) under the atmospheric and high pressures, and the corrosive behavior of the alloys was clarified.

Energy conversion and storage materials technology

[Objectives]

To establish a safe and maintenance-free energy storage technology which contributes the time difference between the generation and consumption of electric energy and to achieve a higher efficiency of dye-sensitised solar cells as the launch pad for the practical use of solar cells as these cells can make the low cost introduction of solar cells possible

[Principal Results]

- The application of conventionally used carbon anode was established in all solid state lithium polymer battery.
- In connection with durability which is important for solar cells, the changes of various properties in time during the storage of dye-sensitised solar cells were investigated and the temporal change mechanism was suggested.

Micro/nano science of advanced materials

[Objectives]

To develop micro-technologies of refining and integrating functional oxides on a microscopic scale for the development of innovative materials.

[Principal Results]

- Successful establishment of the technology to tune the ground state of high-T_c cuprates from superconductor to insulator by applying a newly developed fine and continuous tuning technique of the lattice parameters with an aid of epitaxial growth, and extraction of one of the necessity conditions for the occurrence of superconductivity.
- Successful realization of high-mobility, low-power, and high-speed switching operation in organic single crystal field-effect transistors using an ionic liquid as a gate electrolyte.
- Discovery of a new thermodynamic phase showing an anomalous temperature dependence in the heat capacity on the way to doping carrier to 3D copper oxide $CaCu_3Ti_4O_{12}$, which is a candidate for a thermoelectric material.

Analysis of the mechanism of functional oxides

[Objectives]

To make progress in an understanding of 3d transition metal oxides that shows useful functions, and to create new functional oxides based on such an understanding.

[Principal Results]

- Discovery of the giant modulation of the low-temperature thermal conductivity in layered cobalt oxide $GdBaCo_2O_{5.5}$ by magnetic fields, and clarification how spins are coupled with transport properties.
- Discovery of the diamagnetic state associated with the emergence of ferrimagnetic order in the magnetization process of layered manganese oxide $GdBaMn_2O_5$, and clarification the microscopic feature of the complicated correlation between three different spins accompanying the emergence of charge ordering.