Basic Technology Subjects

Materials Science Research Laboratory

Brief Overview

The aim of the Materials Science Research Laboratory is to contribute to reliable electric power supply and creation of a low-carbon society through fundamental materials researches for field applications to electric power plants, renewable energy utilization, and new materials development for energy conservation.

Achievements by Research Theme

Materials for Nuclear Power Plants

In order to decrease radiation exposure and maintain component integrity, we investigate water chemistry and environmental effects on corrosion in nuclear reactor components.

- Fuel crud deposition was investigated under a simulated water environment of domestic PWR core regions with no radiation exposure. The results suggested that the control of dissolved hydrogen concentration for the mitigation of primary water stress corrosion cracking can be effectively utilized with the zinc injection for dose rate reduction.
- The impact of seawater leakage on crevice corrosion initiation and propagation was evaluated through experiments using the stainless steels of condenser systems. We have succeeded in determining the threshold chloride concentration beyond which crevice corrosion occurs in stainless steels (Q12001).

Structural Materials

We will contribute to the reliable and stable operation of thermal and nuclear power plants through research activities such as fundamental data accumulation of high-temperature materials strength and corrosion behavior, development of lifetime evaluation methods for aged structural components and the development of non-destructive inspection technologies.

- Alloy740H, which has the highest creep strength among various Ni-based super alloys candidates for an Advanced-Ultra Super Critical (A-USC) thermal power plant aiming to operate at 700℃, has demonstrated superiority over other alloys in terms of fatigue strength (Q12005).
- Grade 122 steel is a 12Cr ferritic steel which has had its performance improved by tungsten addition for use in current ultra-super critical power plants. We have developed new creep strain equations for Grade 122 to describe creep deformation behavior with sufficient accuracy (Fig. 1).
- The "Handbook on Water Treatment for Thermal Power Plants" was issued in 2012. This is a revision of the original version "Handbook on Water Treatment for Steam Power Plants" issued in 1985 by Japanese utilities and CRIEPI. State-of-the-art scientific understanding as well as the operation experiences of conventional steam power plants, advanced ultra-super critical plants and combined cycle plants are included in the revised handbook.

Materials for Energy Conversion and Storage

We will develop technologies to evaluate the field performance of photovoltaic (PV) systems to prepare for mass installation in the future. The application of ionic liquid and the fabrication of functional ceramic will also be studied for the effective use of renewable energy.

- A power simulation model applicable to crystalline Si PV modules oriented towards all azimuths was developed based on the correlation analysis between solar irradiance and PV performance. The accuracy of the model was demonstrated through comparison with the field data of 18 months measurement (Fig. 2). (Q12002)
- We investigated the performance of solvate ionic liquid as the electrolyte of lithium secondary batteries using a glyme – lithium salt equimolar complex electrolyte. The battery with a positive electrode of 3.5V-class $LiFePO_4$ showed a long charge/discharge cycle life of more than 500 cycles, while 400 cycle stable operation was also achieved with a sulfur positive electrode which is a candidate for the next-generation positive electrode.

Advanced Functional Materials

We will develop new functional materials such as superconductors and various organic semiconductors by utilizing our in-house techniques of growing high-quality crystals and controlling their basic physical properties.

■Transmission electron microscopy observation was performed on various kinds of iron-based superconducting thin films on several substrates. We found that chemical substitution between the substrate and the film induces lattice distortions leading to the change of superconducting properties.

■We have succeeded in fabricating a new type of organic light-emitting device using a very simple printing processsuitable for mass production. The device works at relatively low voltage achieving a light intensity of 1500 cd/m^2,which is three times higher than that of a conventional LCD TV.

Nondestructive Inspection

Our goal is to develop tailored ultrasonic testing (UT) methodologies, not only fornondestructive inspections of defects in power plant components, but also for evaluation of the degradation of material properties.

■A phased-array UT technique with a 5 MHz frequency was applied to defect detection in buried base bolts. A fatigue crack 2 mm in height was detected at a depth of 90 mm from the top of a bolt with a diameter of 24 mm, suggesting the applicability of the technique to the field inspection (Q12009).

Materials Science Research Fundamentals

We will promote fundamental research for predicting material properties and evaluating localized stress state by a combination of computer simulations and advanced materials analysis methods aiming at a breakthrough in materials research.

■First-principles molecular dynamics simulations have been performed to investigate the transportation mechanism of lithium ion between the positive electrode of $LiCoO_2$ and the electrolyte of ethylene carbonate (EC) in a lithium secondary battery. The results showed the binding between the oxygen of an EC molecule and the lithium and cobalt of $LiCoO_2$, suggesting the importance of oxygen in the transportation mechanism at the interface.

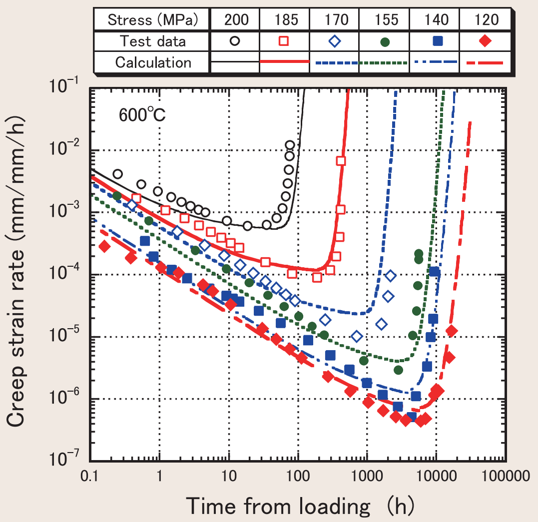

Fig. 1: Comparison of test data and calculation on the variation of creep strain rate

Creep strain equations incorporating the principal features of Grade 122 steel, such as an early transition to tertiary creep stage under high temperature/low stress conditions, have been developed in order to accurately describe the variation of creep strain rate throughout the steel's life under various loading conditions.

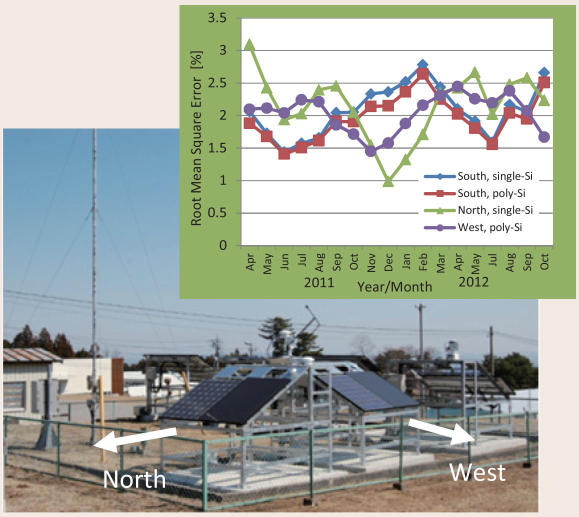

Fig. 2: Photovoltaic module test facility at Akagi Testing Center

The panels are oriented not only to the south, but also to the west and north, and tilted by 30°. Arrows indicate the azimuths. Power output can be predicted with an error of around 3% regardless of the panel azimuth.