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 material research for field applications to electric power plants, renewable energy utilization, and new materials development for energy conservation.

Achievements by Research Theme

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.

- The welded portions of 9Cr steel elbow pipe which had been used for a prolonged period of time in an actual plant were evaluated through a creep test, microstructure observation, and a hardness test. The results indicated that the intrados welded portion has a shorter residual life than the extrados welded portion (Fig. 1). Moreover, a correlation was observed between the voids, which represent creep damage, and the hardness of the welded portions[1].
- Strain rate-dependency of rupture ductility (Fig. 2) and fatigue property were obtained on Alloy 617 candidate for an Advanced-Ultra Super Critical (A-USC) thermal power plant as fundamental information required for creep-fatigue evaluation (Q13001).
- The technique for identifying areas of sulfidation on water-wall tube in coal-fired boiler estimated by analyzing the chemical composition of ash on the tube surface has been applied to some commercial boilers. The relationship between gas composition fluctuation in coal-fired boilers and sulfidation behavior of the water-wall tube was investigated, and some important data were acquired in order to improve the predicting method of sulfidation rate.

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 technologies of functional materials based on electrochemistry will also be studied for the effective use of renewable energy.

- A new type of weather classification based on solar irradiance variability was presented to facilitate low cost prediction of power yields of grid-connected PV systems. We have obtained prospects of the utilization of AMeDAS data through analyses of solar irradiance with the developed weather classification (Q13005).
- Electrochemical synthesis of ammonia in a molten salt system has been investigated as an attractive candidate for a carrier of hydrogen energy. The dissolution of the synthesized ammonia was observed in the presence of H^- ion produced by a side reaction on a hydrogen gas electrode, which led to the decrease in the conversion yield of ammonia (Q13004).

Advanced Functional Materials

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

- We improved growth techniques of iron-chalcogenide superconductor thin films, and succeeded in raising superconducting critical temperature from 8 K to 12 K in FeSe, and from 14.2 K to 19 K in $FeSe_{0.5}Te_{0.5}$ composition[2]. These materials exhibited extremely high critical current density in a high-magnetic field, and are expected as one of the candidates of practical superconducting coated conductor materials.
- We developed new kinds of organic devices called light-emitting electrochemical cell, and succeeded in preparing three basic colors, red, green, and blue (RGB) that are indispensable for display applications (Fig. 3). These devices also exhibited a refreshing effect by current alternation, which is one of the key technologies for long-term stability (Patent 2013-145690, 2013-145691, 2013-14562).

High Performance SiC Semiconductor for Power Electronics

To realize next generation low-loss power conversion equipment, we will establish a high-quality silicon carbide (SiC) crystal growth technology which enables the fabrication of low-loss, high-voltage, SiC power devices able to handle large currents.

Achievements by Research Theme

■We established a 6-inch diameter, fast, low-defect density SiC crystal growth (epitaxial growth) technique achieving a high growth rate of 50 μm/h with high uniformity by conducting collaborative development with several companies[3].

■We succeeded in fabrication of ultra-thick, multi-layer SiC crystal wafers capable to be applied to very high voltage (>13 kV) SiC transistor devices and demonstrated the low-loss current conduction performance close to the SiC limit in prototype devices.

Materials Science Research Fundamentals

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

■The coarsening behavior of $Cr_{23}C_6$ precipitates in a high-temperature ferritic steel was investigated at an atomistic scale through molecular dynamics computer simulations using a newly developed inter-atomic potential for Fe-Cr-C ternary alloys.

[1] S. Nagai et al., Proc. 7th Int. Conf. on Advances in Materials Technology for Fossil Power Plants, 609-701, 2013
[2] F. Nabeshima et al., Appl. Phys. Lett., 103, 172602, 2013
[3] H. Fujibayashi et al., Appl. Phys. Express, 7, 015502, 2014

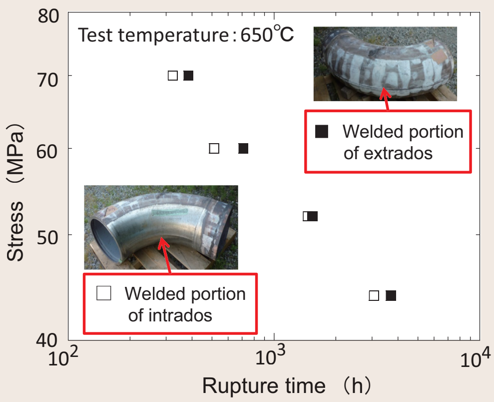

Fig. 1: Creep test results on a 9Cr steel elbow pipe used for long-tem

In the creep test on welded portions of an elbow pipe that had been used in an actual plant for a prolonged period, the creep rupture time was shorter in the intrados side than the extrados side of the elbow pipe.

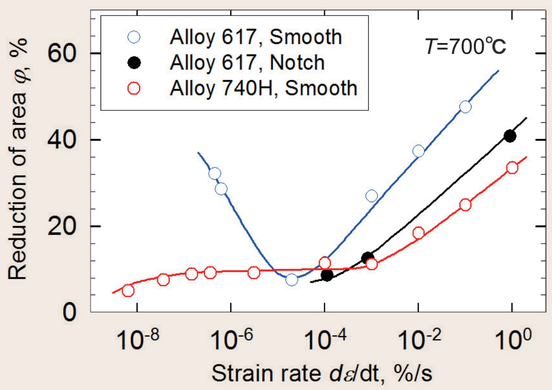

Fig. 2: Relation between strain rate and ductility (700℃)

Ductility significantly changes with strain rate in both materials but smooth specimens of Alloy 617 particularly showed unique behavior, showing the minimum ductility at an intermediate strain rate.

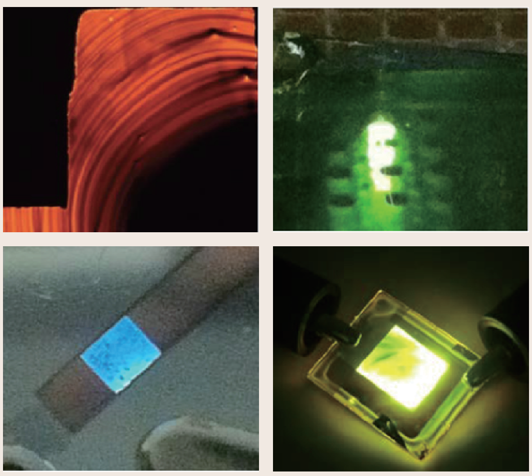

Fig. 3: Multi-colored light emission from Light-emitting Electrochemical Cell devices (red, green, blue, and yellow emission)

We will continue the technology development of these devices to realize new-types of energy-saving lighting device and displays.