UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

October 31, 2002

NRC INFORMATION NOTICE 2002-32: ELECTROMIGRATION ON SEMICONDUCTOR INTEGRATED CIRCUITS

Addressees

All holders of operating licenses for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of a failure mechanism identified in semiconductor components at the Kashiwazaki-Kariwa Nuclear Power Station Unit 5 of the Tokyo Electric Power Company, Inc. (TEPCO). The failure mechanism has been attributed to electromigration. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. Suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

In July and September of 2001, control rods at the Kashiwazaki-Kariwa Nuclear Power Station were temporarily rendered inoperable due to defective control rod transponder cards. The Nuclear and Industrial Safety Agency (NISA) of Japan identified the failure mechanism as integrated circuit (IC) wire breakage and attributed it to electromigration in aluminum (Al) wires with small crystal grains. The root cause has been determined to be inadequate quality control methods in the IC manufacturing process. All of the ICs that failed were traced to the HITACHI Takasaki Works and were manufactured in September of 1986. Further investigation revealed that between 1985 and 1990, ICs in which Al vapor was deposited by electron beam had small Al crystal grains.

TEPCO implemented an action plan to evaluate other systems and replace transponder cards where a single defect in an IC could affect plant safety functions or plant control. Other businesses operating nuclear reactors where the same phenomenon has occurred have been advised to develop appropriate management and maintenance plans and to report defects.

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Discussion

Electromigration—the drift of metal atoms—is an age-related phenomenon that has been confirmed to occur in Al wires and traces. It appears to correlate with high current densities in traces or wires with small cross-sectional areas. The movement of the atoms creates voids that may eventually present themselves as electrical interconnect failures. Recent research has shown that this failure mode is strongly affected by the grain structure size of the Al trace or wire, and can be delayed or overcome by metallurgical modifications to the microstructure. Other methods for reducing the effects of electromigration include limiting the current density and minimizing flaws during the deposition process.

While electromigration has the potential to adversely affect all ICs that have Al wires with small cross-sectional areas and operate at high current densities, the interconnect failure mechanism would not be expected to occur simultaneously in redundant safety-related components. It is also expected that failures in safety-related circuits due to manufacturing defects or operational conditions would likely be detected by routine surveillance, testing, or diagnostics and that the followup root cause analyses and corrective actions would address the generic aspects of the failure.

It is expected that 10 CFR Part 21, “Reporting of Defects and Noncompliance,” would be the method used by licensees to notify the NRC of component failures. Therefore, IC failures due to electromigration would be reportable under 10 CFR Part 21 for safety-related instrumentation and control components.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation project manager.

/RA/
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