1. Executive Summary

On September 20-22, 2009, a workshop entitled Research Needs and Opportunities for Characterization of Activated Samples at X-Ray and Neutron User Facilities, sponsored by Los Alamos National Laboratory, was held in Santa Fe, New Mexico. The workshop was motivated by the potential that light and neutron sources have to proffer advances in our understanding of radiation damage and to validate new science-based materials performance models. The charge of the workshop addressed measurement needs, current activity, and opportunities that can be realized in the next five years and insights that could be realized by new diagnostics and experimental methods. This report outlines the content and discussion of the workshop.

Discussions of the anticipated need covered fuels, structural applications, and materials discovery for fission and fusion reactors. For fuels priority, needs included characterization of defect distributions, voids, bubbles, cracks, precipitates, new chemical phases, alloy species redistribution, recrystallization, and grain growth. For structural components, priorities included the improved understanding of the changes in yield, ultimate tensile strength, embrittlement, and fracture toughness. Radiation-assisted stress corrosion cracking was also identified as very important. For new materials, an improved understanding of the interactions between strengthening features and radiation-induced defects was considered crucial.

When considering the opportunities available at existing facilities, the provision of three-dimensional spatial distributions of defect and chemical distributions with atomistic resolution were areas of opportunity, especially if they have temporal resolution consistent with the phenomena of interest. However, realizing the full potential of user facilities will, in many cases, require changes in the infrastructure and the requirements that are necessary for safe and efficient handling of activated material. Moreover, facilities need to provide sample preparation areas and bring to bear the full range of diffraction and spectroscopic techniques on increasingly small (and thus more radiologically manageable) samples.

Plausible priority research opportunities identified for the next five years included the following: 1. In situ crystallographic response to applied stress in archived irradiated materials; 2. Crack growth under fatigue conditions in irradiated alloys (e.g. zirconium) containing hydrides; and 3. Small angle scattering and diffraction of precipitates (e.g. M23C6 particles in Fe9%Cr steels) to explore the formation and strain fields around deformation-induced voids.

In workshop discussions concerning a decadal future facility, numerous opportunities were identified that coupled X-ray or neutron probes with an irradiation source: examination of individual grains in activated samples; handling and characterization of “large” components; in situ measurement of creep properties in conjunction with radiation and helium ingress; and defect kinetics measurements and characterization of spent fuel. No less important are handling facilities and hot cells. The requirement to have all the classical post-irradiation microscopy, such as electron microscopy and ion beam facilities, was integral to the vision. On the decadal time scale, the following areas of interest were identified of special import: 1. Materials for Generation 4 reactors; 2. In situ fatigue testing at temperatures that allow the quantification of fatigue-irradiation-creep interaction; and 3. Examination of individual particles to see how these interact under deformation with and without irradiation.

If the promise of the so-called nuclear renaissance is to be realized, especially in the United States, the breadth and depth of the nuclear science and engineering community must be enhanced substantially. In particular, there is a need to revitalize the materials science of radiation damage. It was clear to workshop participants that x-ray and neutron sources at national user facilities have an important role to play in this endeavor. Further, in addition to cultural changes that would allow the full exploitation of currently available tools and techniques, new capabilities need to be developed if science-based certification is to play a role in the resurgence of nuclear energy. Finally, given the magnitude and urgency of the need for carbon-neutral energy, approaches must be found to reduce the time and cost associated with licensing and certification.