Radiation Sciences

Electronic Device Response

Cryostat and liquid helium transfer line mounted in the SPR-III test stand. Cold finger and test devices used in the cryostat system.

Cryogenics used to reveal early-time radiation damage to an active semiconductor device

Sandia's new application of cryogenic cooling techniques provides information for better understanding of radiation damage to a device.

As fast-burst reactor test facilities are phased out, Sandia must rely on testing at new facilities with different radiation characteristics. Sandia must extrapolate device performance measured at the new facilities to device performance at the burst-reactor facilities. This goal can only be achieved by understanding the damage equivalence between the new radiation facilities of the future and the old facilities of the past.

Sandia developed a new combination of techniques to compare the damage that the different types of radiation deliver to semiconductor devices: We irradiate devices at low temperatures with cryogenic cooling. What makes this technique new is that we cryogenically cool devices during an active test in a fast-burst reactor, or any other radiation facility, so that defects "freeze" in place and annealing behavior slows, revealing early-time changes in device performance.

This new technique is helping us to better understand radiation damage to a device, which defects form, how they anneal, and ultimately how to model defect evolution, knowledge that could lead to better-performing devices and circuits.

We are currently investigating the early-time response of silicon and gallium arsenide bipolar transistors under fast neutron irradiation at Sandia Pulsed Reactor III (SPR-III). Devices at different bias conditions are irradiated at constant temperatures where defects are still mobile (100 to 300 K) to watch their evolution with time, and at low temperatures in the region of carrier freeze-out (20 K) to watch the defect evolution with temperature.

The data expand our understanding of the relationship between temperature, time, and radiation fluence for defect annealing and are applicable to damage equivalence studies enabling predictions of fast neutron effects in electronics extrapolated from other neutron and charged particle facilities.

For more information:

Technical Contact:
Kyle McDonald, Ph.D.
505-284-3750
jkmcdon@sandia.gov

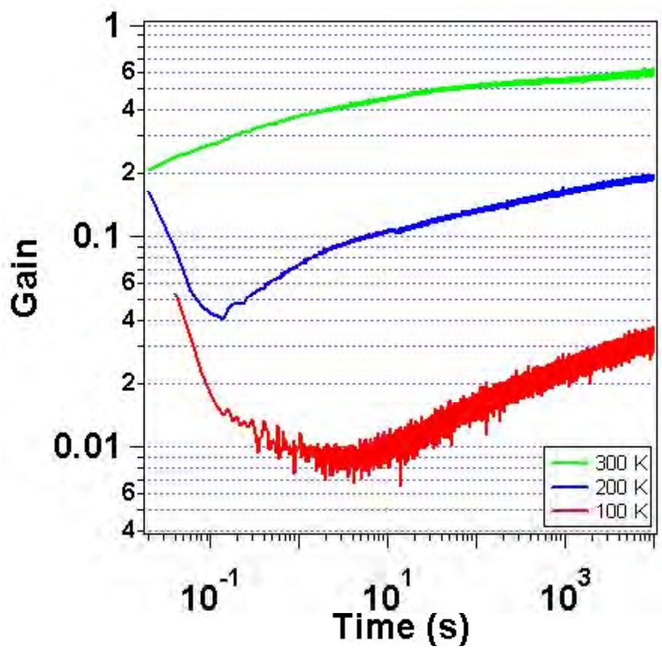
Science Matters Contact:
Wendy Cieslak, Ph.D.
505-844-8633
wrciesl@sandia.gov

Sandia National Laboratories

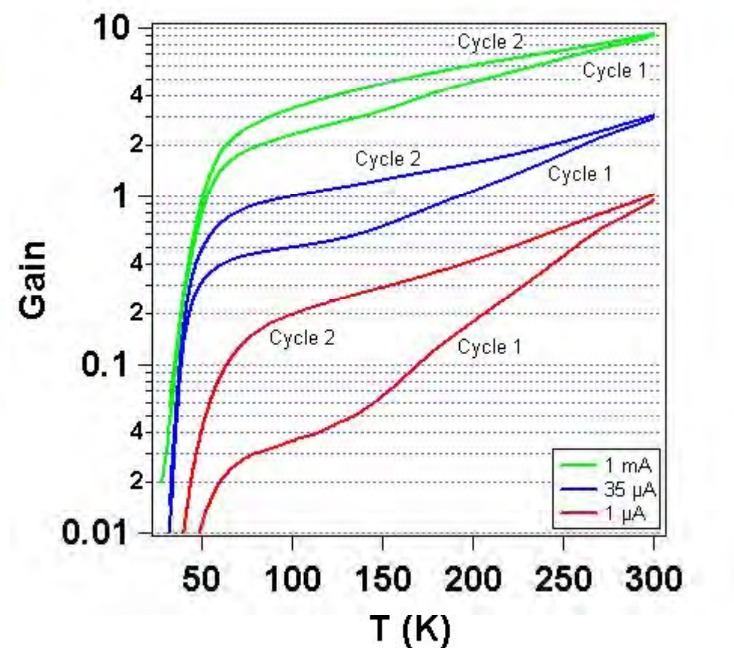
8/2006

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND 2006-5982P

NNSA National Nuclear Security Administration



Gain recovery versus time in 2N2222 Si bipolar transistors after irradiation at the temperatures shown at SPR-III (3E14 n/cm^2 (1-MeV(Si)-Eqv.)). Gain recovery begins at a later time at lower temperatures. The emitter current is 35 µA.



Gain recovery versus temperature in 2N2222 Si bipolar transistors after irradiation at 25 K at SPR-III (6E13 n/cm^2 (1-MeV(Si)-Eqv.)) for the emitter currents shown. Cycle 1 shows the heating after irradiation, and cycle 2 shows a second thermal cycling. A comparison of the curves demonstrates the difference between the temperature dependence of a damaged device and the temperature dependence of defect annealing.

Representative Displacement Damage Simulators

SPR-III (Fast-burst reactor)

Nominal Operating Parameters
(Maximum Pulse Operation)

Peak power	1.5×10^5 MW
Pulse width (FWHM)	76 µs
Peak gamma dose rate	1.5×10^9 rads(Si)/s
Peak neutron flux	8.0×10^{18} n/cm^2/s
Neutron fluence: >10 keV (^{a}total) 1-MeV(Si)-Eqv.	 6.1×10^{14} n/cm^2 5.4×10^{14} n/cm^2