# Turn-off Time Improvement by Fast Neutron Irradiation on pnp Si Bipolar Junction Transistor

**Sung Ho Ahn**[1*], **Gwang Min Sun**[1], **Hani Baek**[1]

[1]Neutron and Radioisotope Application Research Division, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
[*]E-mail: shahn2@kaeri.re.kr

**Keywords**: turn-off time; fast neutron; irradiation; BJT; switching

A BJT (Bipolar Junction Transistor) is useful in amplifiers and switches because the current at the emitter and collector are controllable by the relatively small base current. When BJTs are used as switch devices, BJTs can have a slow turn-off speed because long time is required for the removal of the minority carriers in the recombination process. To satisfy the performance requirements of the BJT, the speed of the devices is enhanced by the introduction of recombination centers into the lattice in a controlled manner. Two functional approaches have been developed for the control of the lifetime. The first method is based upon the thermal diffusion of impurity that exists at deep levels in the Si band gap. Gold and platinum have been extensively used for the thermal diffusion method. Small variations of the diffusion temperature can produce a large variation in the device characteristics, resulting in a poor distribution of the device parameters during manufacturing. The second method entails the creation of lattice damage in the form of vacancies and interstitial atoms in the Si crystal by irradiation with high energy particles. The recombination rate of the minority carriers is increased with an increase in the lattice damage. High energy radiation produces defect complexes in semiconductor materials that reduce the minority carrier lifetime, change the majority carrier density, and mobility. The lattice damage can be achieved by bombardment using the energetic particles such as electrons, a gamma beam, protons, and neutrons. There are many advantages to using these irradiation methods. The irradiation can be performed at room temperature and the lifetime can be precisely controlled by accurately monitoring the radiation dose. The uniformity of the lattice damages is the important performance factor. The uniform lattice damages can be achieved by fast neutron irradiation. The lattice damage increases the recombination rate of injected holes with electrons, and decreases the hole lifetime in the base region of pnp Si BJT. This study investigates the turn-off switching characteristics through the fast neutron irradiation on a pnp Si BJT. The fast neutrons generated from the Be target with 30MeV protons by the MC-50 cyclotron were irradiated onto a pnp Si BJT. The experimental results show that the base current was increased, the collector current and base-to-collector current amplification ratio were decreased by the fast neutron irradiation. In the turn-off switching, the storage time and fall time were decreased with an increase in the fast neutron fluence. As a result, the turn-off switching time was decreased by the fast neutron irradiation.

**Acknowledgments**
This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (NRF-2017M2A2A6A05018529).