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NEUTRON TRANSMUTATION DOPING OF SILICON AND OTHERS SEMICONDUCTOR MATERIALS

ARTUR W. CARBONARI AND RAJENDRA N. SAXENA

Instituto de Pesquisas Energéticas e Nucleares IPEN-CNEN/SP
São Paulo, SP

The doping of semiconductor materials is of crucial importance in determining their final properties such as the resistivity. The Neutron Transmutation doping (NTD) of semiconductor materials is a way of doping in which the quantity of dopant material can be precisely controlled and homogeneously distributed throughout all the material. Samples such as a small thin films up to large single crystal can be irradiated in a nuclear reactor.

The NTD method is based on a nuclear reaction where some nuclei of the semiconductor material capture thermal neutrons and form unstable radioactive nuclei which beta decay to nuclei of a different element. Since the resultant element has at least the atomic number $Z = \pm 1$, where Z is the atomic number of the starting material, it belongs to one of the neighbouring columns (in the periodic table) to that of the start element, hence it is a N or P type dopant. In silicon, for example, nuclei of the ^{30}Si isotope (~3.1% of natural silicon) capture thermal neutrons producing ^{31}Si nuclei which decay to the stable isotope ^{31}P which is a N type dopant. Irradiation of Germanium with neutrons produces Ga (P type), As (N type) and Se (N type) dopants simultaneously, while in the case of Ga(As) the NTD produces both Ge and Se dopants with ratio of Se and Ge concentration of $N_{Se}/N_{Ge} = 1.46$. Since the Se and Ge atoms are expected to act as donors, NTD produces mainly N-type Ga(As).

This work presents a short review of the NTD technique and the experiments of silicon irradiation performed at the IEA-R1 research reactor in São Paulo, where an irradiation rig with simple design has been constructed and installed. The rig permits the irradiation of silicon crystals with diameter up to 4 inches. By adopting a procedure in which two ingots 25 cm long each are irradiated simultaneously and their positions interchanged at a point when precisely half the total necessary neutron dose has been received, it has been possible to achieve the desired axial uniformity of the neutron dose. This method avoids the use of neutron absorbing shields around the crystals which necessarily compromise the overall irradiation capacity of the reactor. Test irradiations were performed with 100 float zone silicon crystals and the results of radial and axial uniformities in the final resistivity values as well as the doping accuracy obtained show an excellent doping quality achieved.