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Electronic and vibrational studies of highly doped silicon.

Silicon remains the material of choice for much of the semiconductor industry that is used for a variety of functions in a plethora of devices. Doping plays an integral and vital part to the function of semiconductor material in modern devices, through the introduction of impurities (dopants) that control the electronic properties of the material. Silicon may be doped using a number of methods from those at the time of growth to those post-growth such as through diffusion or ion-implantation. Post-growth doping generally affects surface layers whilst during-growth methods produce homogeneous results throughout the bulk of the material. Neutron transmutation doping is a post-growth doping technique that employs a source of thermal neutrons (usually from a neutron research reactor) to change one element of the material to be doped into another via nuclear interaction. This type of doping does produce exceedingly homogeneous doping levels throughout the material.

Natural silicon atoms are composed of three isotopes, ^{28}Si (abundance: 92.23%), ^{29}Si (abundance: 4.67%) and ^{30}Si (abundance: 3.10%). When ^{28}Si or ^{29}Si absorb a thermal neutron, they are changed into other stable silicon atoms (^{28}Si+n$\longrightarrow^{29}$Si and ^{29}Si+n$\longrightarrow^{30}$Si). Research reactors configured to produce thermal neutrons do also produce higher energy neutrons. In particular the absorption of a fast neutron leads to the direct or indirect (via decay) production of Al or Mg isotopes. To suppress this secondary production which can lead to unwanted silicon properties a well thermalised neutron spectrum is obtained through judicious placement of the Si targets within the reactor.

In the case of ^{30}Si, thermal neutron capture leads to the unstable isotope ^{31}Si, which undergoes beta decay. The product of this process is a phosphorus atom, ^{31}P, resulting in n-type impurity doping in the silicon: $^{30}\mathrm{Si}_{14}$ + n $\longrightarrow$ $^{31}\mathrm{Si}_{14}$ $\longrightarrow$ $^{31}\mathrm{P}_{15}$+ $^{0}\mathrm{e}_{-1}$+$\overline{\nu}$.

This study focuses on the electronic and vibrational structure and lifetimes of highly n-type doped Si:P in the dopant range between 10^{19}-10^{21} cm^{-3} using photoemission and neutron spectroscopy as well as thermoelectric relevant measurements. In particular the study focuses on the role phonon transport has on the lattice thermal conductivity in such a highly doped or degenerate semiconductor regime.

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