Determine damage depth profiling by high-energy ion channeling in Monocrystalls

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RBS analytical technique in channeling mode can be used to study the dependences of the radiation damage with ion implantation energy, direction and temperature.

The channeling implantation and elevating temperature implantation results in the decrease of the damage. The RBS/channeling technique is often used for defect depth profiling. The energy loss of channeled particles differs from the random case. If the defects are located in a well defined depth, deviations have been observed between the measured and expected defect depth, that may be attributed to the reduction of the stopping power in the channeling direction [1].

The stopping power of channeled particles differs markedly from that of particles following random trajectories. In ion channeling measurements, the ions are directed upon a single crystal along a major crystallographic direction as compared to a random direction during standard RBS measurements. Prior to being backscattered, incident ions are steered preferentially into the interstices of the lattice by a series of correlated small-angle collisions with the target atoms. Therefore, the channeled ions preferentially probe the interstices of the crystal and are sensitive to the location of impurity atoms. The redistribution of the ion flux provides RBS with structure-sensitive capabilities useful for probing defects and lattice strain.

Furthermore, the average energy loss and the straggling are influence the depth resolution of the damage depth profiles. In an amorphous solid the straggling is described approximately by the Bohr theory. According to this theory the spread in energy loss is a Gaussian with a width increasing with the square root of depth.

In a single crystal when the incident beam is aligned with a channel the energy loss is different for the different kinds of trajectories and the width of the energy loss distribution increases roughly linearly with depth.

In a Monte Carlo calculation different trajectories have different energy losses if one includes impact parameter dependent energy losses. The deflection by the nearest atom is treated as a binary collision in the impulse approximation. The influence of the more distant strings of atoms is taken into account in the continuum string approximation. To simulate the channeling spectra, the Monte Carlo program include the energy dependent cross section for backscattering. If combines existing theories on the dependence on the impact parameter of the energy loss with a Monte Carlo program calculating the trajectories of channeled particles it is possible to compare measured and calculated energy loss distributions. Measured channeling spectra are compared with computer simulations.

Rutherford backscattering and channeling spectrometry (RBS/C) studies are performed with 2.0MeV 4He+ ion beam. In order to conduct RBS/channeling measurements, the sample must be mounted on a goniometer, so that the crystal axis direction can be aligned with the incident beam.

At Institute of Applied Physics of NAS of Ukraine equipment for location of impurity atoms and damages in monocrystals is being developed. The facility is based on recoil nuclei [2] of analytic accelerating facility on electrostatic accelerator with ion energy up to 2 MeV. The main purpose of the channel is quantitative non-destructive investigation of hydrogen in materials by elastic recoil detection technique.

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2. A.O.Vnuchenko, A.B.Kramchenkov, V.L.Denisenko, O.M.Buhay, S.Ignatenko, Yu.A.Pavlenko, R.Y.Lopatkin, V.Ye. Storizhko // VANT (DIIS), № 2, p.152-156. (2013).