Investigation of the internal electric field uniformity in (Cd,Mn)Te, (Cd,Mg)Te and (Cd,Mn)(Te,Se) crystals by using the Pockels effect

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Introduction

- Crystals based on GbTs with addition of manganese Mn, magnesium Mg or vanadium V are currently investigated as new materials in radiating room temperature X- and γ radiation applications. Nowadays in this group of detectors the leading materials are: GbT and (Cd,Mn)Te. They work in energy range from 30 to 1000 keV. These detectors are needed for various radiation applications, for example: in national security, in monitoring and assuring the non-proliferation of nuclear materials, in imaging devices for medicine or in research in space.

- Crystals for nuclear radiation detectors have to fulfill special requirements, for example:
  - High resistivity ρ > 109-1012 cm-1
  - Non-crystallinity – neither grains nor twin boundaries presence.
  - Low concentration of luminescence impurities/defects ≤ 5·1015 cm-3.
  - Uniform distribution of internal electric field – high charge collection efficiency.

- Internal field measurement in nuclear radiation detectors has always been a difficult task. Hopefully, all discussed here materials crystals in zinc-blende structures (they do not have an inversion symmetry), so they have strong linear electromagnetic coefficient, which allows to make use of Pockels effect. Pockels effect occurs in materials which are considered as optically isotropic under field free conditions. The velocities of light waves travelling inside the crystal are same in all directions regardless of the crystal orientation. Under applied electric field each crystals become anisotropic. The velocity of light wave polarized along the direction of applied electric field is different from light polarized perpendicularly to the applied field. Therefore, the two orthogonally polarized light waves travelling at different velocities through the crystal introduce a phase difference between the two waves. The phase difference varies linearly with the internal electric field intensity and the passing length of light inside investigations. A sample with uniform distribution of internal electric field can be lightened up liberally in all sample’s points. When bright and dark areas (areas with different refractive indices) in one sample can be distinguished, that means there is a non-uniform distribution of internal electric field and relying on such sample, the nuclear radiation detector cannot be built.

Experimental setup

Pockels effect setup for internal electric field measurements in GbT-based crystals. Polarizer is set at angle of 45° with the direction of electric field. IR transmission images of unbiased crystal are recorded with analyzer parallel to polarizer then with cross analyzer both biased and unbiased.

Sample with one line of tellurium inclusions – within a distance of about 200 µm from the line of tellurium inclusions there is a non-uniform distribution of internal electric field.

(Cd,Mn)Te

Choosing an optimum intensity of IR Illumination

In both A pictures have been presented IR-images of unbiased samples, when the polarizers are parallel. There are visible thin dark lines related to twin boundaries which are decorated by tellurium inclusions. B pictures are Pockels images. The blue is applied and polarizers are crossed. There can be distinguished bright and darker areas. These areas are separated by twin boundaries and are connected with different refractive indexes, and therefore with different value of electric field. There can be observed a difference of obtained Pockels images, depend on contacts configuration.

Sample with several lines of tellurium inclusions – despite evident presence of defects, the internal electric field is more uniform in comparison to (Cd,Mg)Te crystals.

(Cd,Mg)Te

Sample without any defects – specimen shows a uniform field throughout the volume.

Summary

- [Input: a figure related to the Pockels effect and a table of experimental results]
- The evolution with time of the electric field has also been observed when the same sample was biased at other voltages (100-1000 V).
- The higher voltage, the slower sample’s answer.
- In (Cd,Mn)(Te,Se) crystals it is difficult to achieve a high resistivity sample. In most case the value of resistivity parameter does not exceed 1012 cm. That is why such samples cannot be measured using the Pockels effect.
- In all samples which have higher resistances, there are numerous cadmium and tellurium inclusions. In Pockels effect measurements the only signal comes from tellurium inclusions which are formed in a line. There is no signal in Pockels images from separated over-like cadmium inclusions.
- In the boundary region Pockels image is affected by edge roughness.

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