Fast Neutron Detectors based on Semiconductor Device

Introduction

- SI (semi-insulating) GaAs detectors are proved to be very useful for detection of energetic charged particles and photons.The relatively high resistance of bulk SI GaAs to the damage by neutrons and high energy photons predestines SI GaAs to be a perspective candidate for fabrication of neutron detectors.

  Semiconductor devices are sensitive to charged particles and photons.

  In order to achieve sensitivity to neutrons, a device have to be coated with a conversion layer, for instance HDPE (high density polyethylene), which have relatively high elastic cross sections for neutron scattering.

  Detectors coated with such a layer should be sensitive to recoil protons produced from elastic scattering (reaction (n,p.)) in the medium rich of hydrogen.

- Detectors investigated were prepared from bulk LEC (Liquid Encapsulated Czochralski) SI GaAs at the Institute of Electrical Engineering SAS, Bratislava. Blocking Schottky contact was prepared using evaporation of AuZn (100-120 nm thick), whereas the full area back-side ohmic contact using AuGeNi eutectic alloy. The thickness of both-side polished wafer used is about 300 micrometers, the resistivity in the range of 9.5x10^7-1.2x10^8 Ohm cm and the Hall mobility 4990-5120 cm^2/Vs. The wafer was produced

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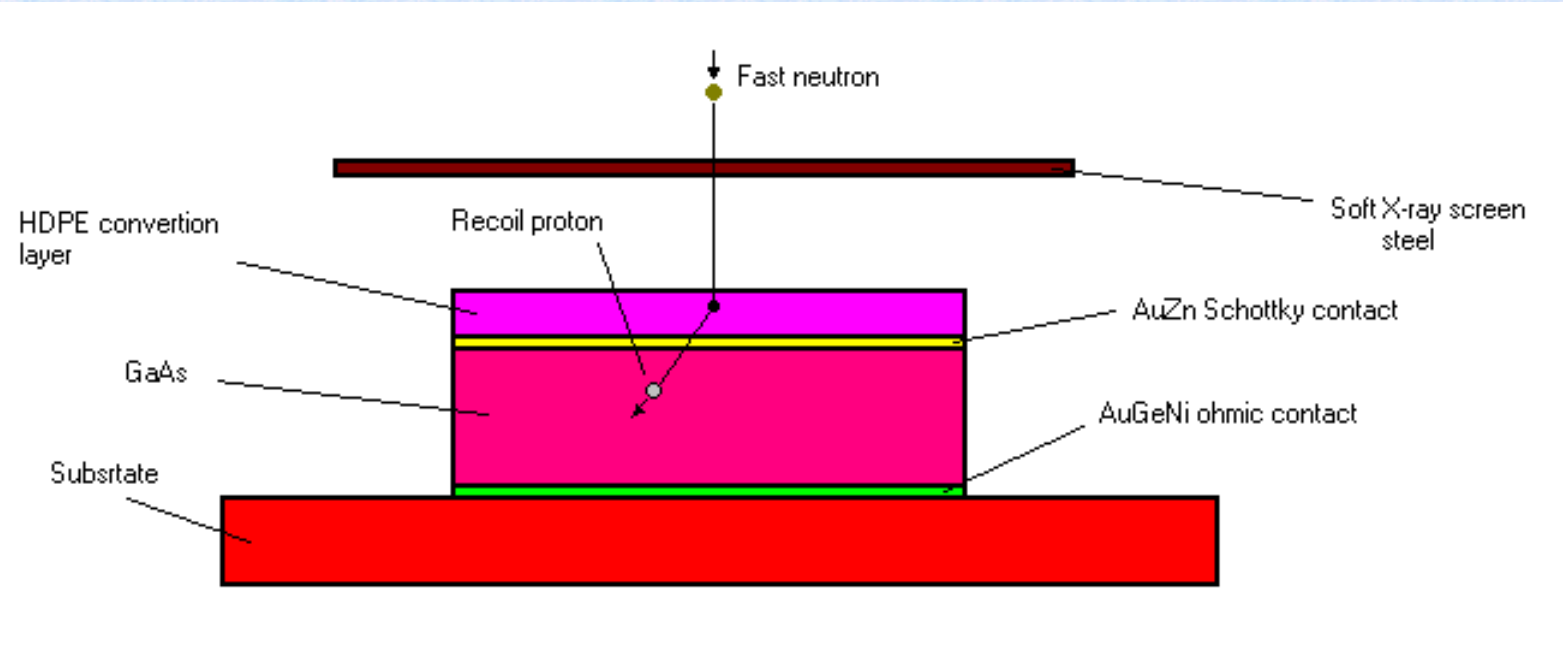
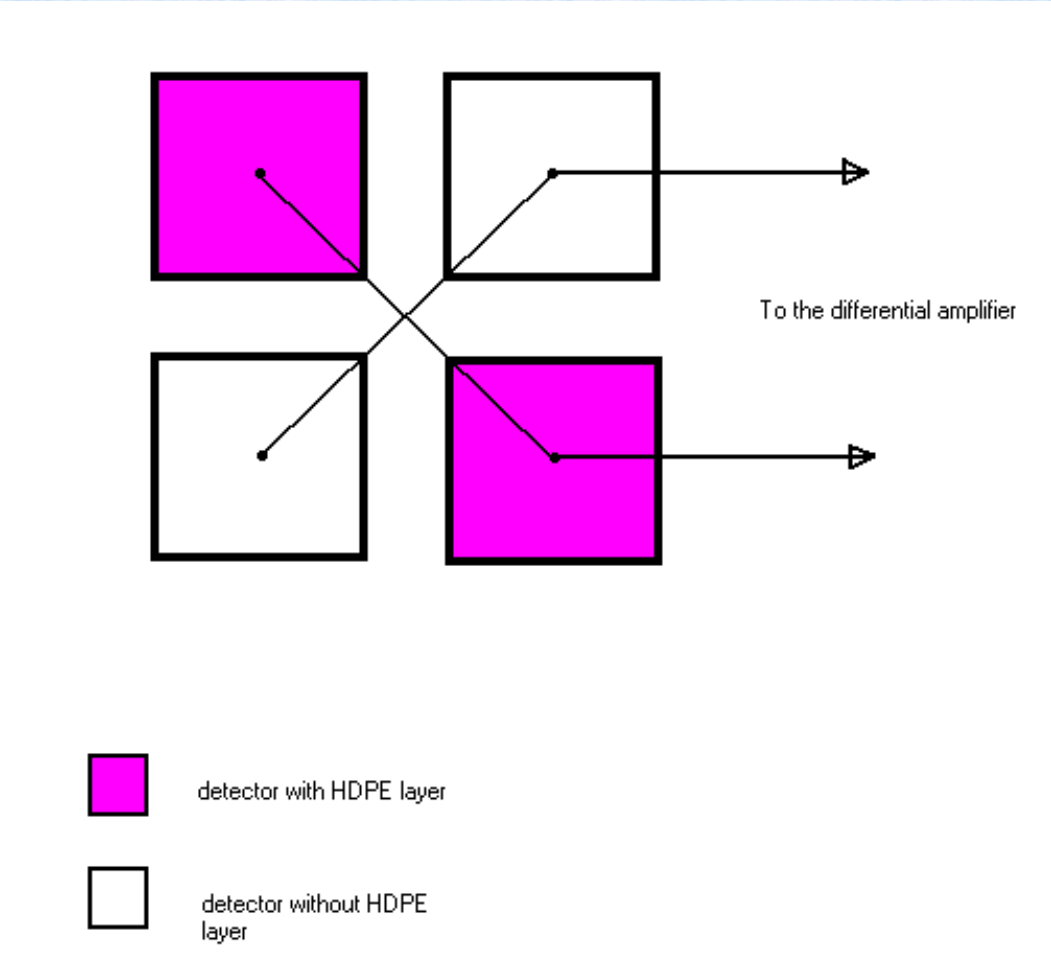


Schematic view of neutron detection by a SI GaAs detector with layer deposited containing hydrogen.

- In order to achieve insensitivity of the detector to X-rays a differential configuration is used with one detector coated with a conversion layer and another one uncoated.

  In order to compensate X-ray flux non-uniformity, four-chip configuration was used.

  Due to HDPE shielding effect, differential detector gives signal (negative) for soft X-rays. This effect could be easy eliminated by means of soft X-ray shield (a steel or lead plate is proposed for this purpose).



4-detector configuration

Estimation of detector sensitivity for 2.45 MeV neutrons.

- HDPE active layer thickness : 96 micrometers
- neutron collision efficiency : 0.002 (2.59 barn scattering cross section)
- average energy transfer to semiconductor : 0.3 MeV
- mean energy of creation of one electron-hole pair : 4.2 eV (for GaAs)

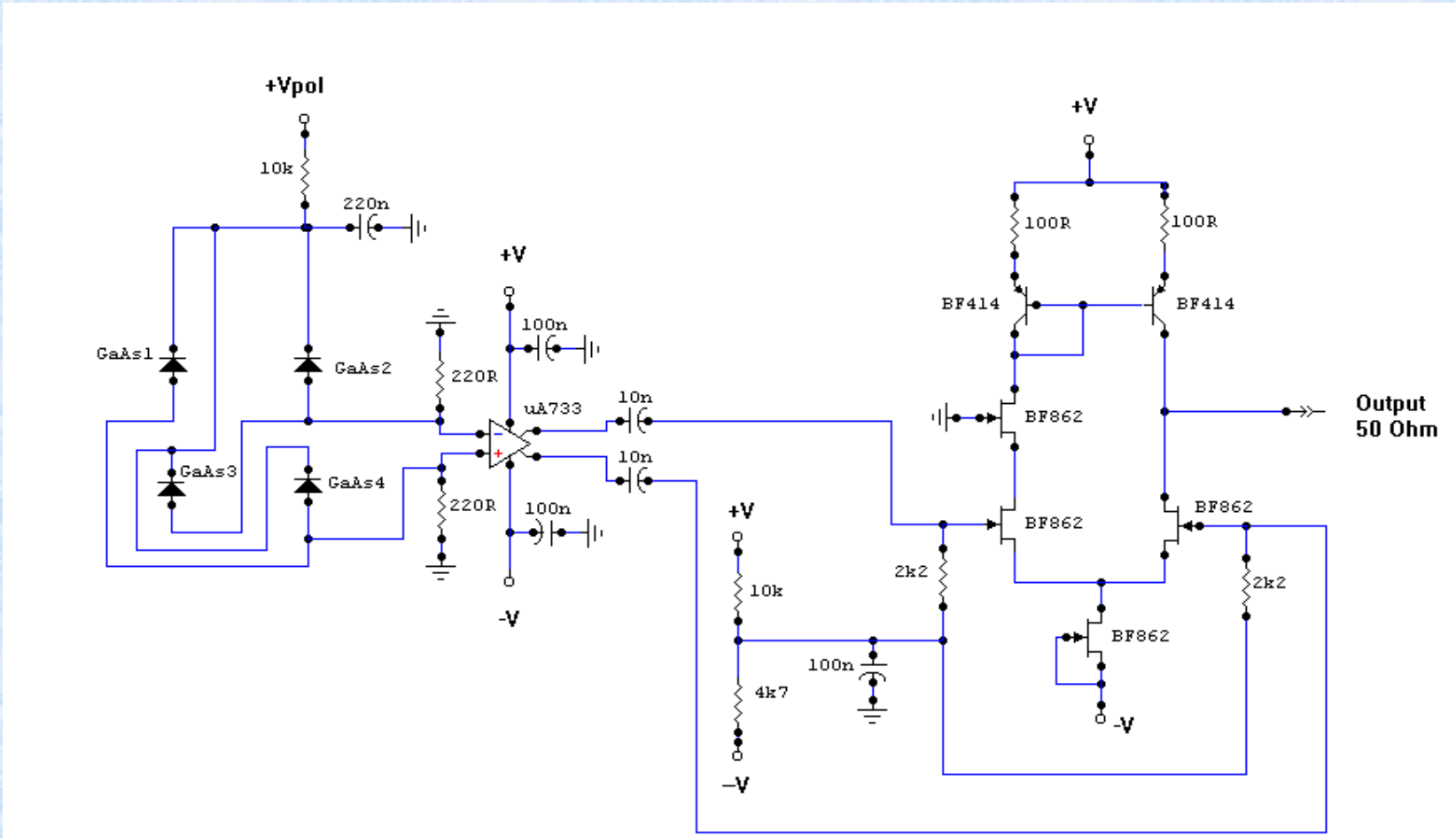
Average charge generated per neutron :

0.002x(3.0x10^5/4.2)x1.602x10^-19=2.29x10^-17 C

Expected neutron fluxes are in the range 10^13 n/s cm^2.
With two detectors with dimensions 2.5x2.5mm^2 and
load resistance 50 ohm it gives signal amplitude about 1.3 mV.

- The serious drawback of proposed neutron detection system is its low sensitivity due to low efficiency of very thin neutron conversion layer.

To overcome this problem signal amplifier is used.



Differential amplifier with 4 detectors

- Detection system described offers better performance for 14 MeV neutrons then for 2.45 MeV neutrons.