Test of various low cost silicon materials for fluence monitor concluded

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Abstract:
Various Si material wafer samples have been investigated in order to evaluate their suitability for monitoring of high fluence irradiations: high resistivity FZ and CZ silicon, silicon for the microelectronics, silicon for the solar cells. Pure c-Si high resistivity materials appear to be the best option for the reliable monitoring of hadron irradiations over wide fluence range from $10^{11}$ to $5 \times 10^{16}$ cm$^{-2}$. Silicon used in microelectronics is also recommended for high fluence monitoring.
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Executive summary

Various Si material wafer samples have been investigated in order to evaluate their suitability for monitoring of high fluence irradiations: high resistivity FZ and CZ silicon, silicon for the microelectronics, silicon for the solar cells. The pure c-Si high resistivity materials appear to be the best option for reliable monitoring of hadron irradiations over wide fluence range from $10^{11}$ to $5 \times 10^{16}$ cm$^{-2}$. Silicon used in the microelectronics can also be recommended for high fluence monitoring.

1. SUMMARY OF THE CONDUCTED STUDIES

Various Si material wafer samples have been investigated in order to evaluate their suitability for monitoring of high fluence irradiations: high resistivity FZ and CZ silicon (c-Si), silicon wafer-substrates used in fabrication of high-power electronic devices (n-Si), silicon wafer-samples exploited for industrial fabrication of solar cells (mc-Si).

Several mono-crystalline 400 µm thick Si (n-Si) moderately doped wafer samples were examined by evaluating the carrier recombination lifetime ($\tau_R$) dependence after different 9 MeV proton irradiation fluence levels ($\Phi$). However, the short carrier lifetime in the pristine material, containing considerable concentrations of technological defects introduced by the doping, limits control of the irradiation fluence in the range $10^{12}$ - $3 \times 10^{16}$ protons/cm$^2$ (Fig. 1, blue open circles). Thus, the silicon for the microelectronics can be recommended for high fluence monitoring.

A batch of 200 µm thick multi-crystalline Si (mc-Si) wafers was also irradiated with 8 MeV protons. The irradiation showed that defects in mc-Si lead to large carrier trapping effects in this material. The trapping significantly distorts carrier decay transients and affects carrier recombination. Before annealing, the dependence of the free-carrier lifetime on the irradiation fluence was non-linear. In addition, it also showed a dependence on the initial defect concentration in different samples (Figure 1, red open circles). Annealing at moderate temperatures transformed this dependence into something quite similar to the one obtained in n-Si samples (Figure 1, black squares). Therefore, using mc-Si for monitoring of high fluence irradiation requires additional calibrations and careful choice of single crystal regions. These results were discussed in detail during a presentation [1] at the CERN RD50 workshop and at the AIDA-2020 Annual Meeting in Hamburg [2].

![Figure 1: Comparison of carrier lifetime ($\tau_R$) dependence on proton fluence ($\Phi$) measured in irradiated mc-Si and n-Si.](image-url)
Pure c-Si high resistivity materials appear to be the best option for the reliable monitoring of hadron irradiations over wide fluence range from $10^{11}$ to $5 \times 10^{16}$ cm$^{-2}$ as shown in Figure 2. This figure summarises the measurement of the free carrier lifetime dependence on the particle fluence for different hadron irradiations. The precise region of fluence monitoring will be determined after calibration using the chosen material and lifetime-meter VUTEG-AIDA device, which is currently installed at CERN.

Currently about ten pure silicon samples with the passivated surfaces have been prepared for a comparative study with existing but different (for the definite range of irradiation fluence) fluence-meters.

The milestone has been reached, and the team is ready to test new silicon samples.

2. REFERENCES
