Contactless spectroscopy of thermal emission centres in hadron heavily irradiated and annealed Si

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The radiation induced deep traps of large density are the most detrimental damage of particle detectors operating in harsh areas of high energy physics experiments. Traditional techniques, such as DLTS and TSC, are limited to low and moderate fluences in spectroscopy of radiation induced deep traps. Complementarily, spectroscopy of deep traps, acting as the main source for increase of detector leakage current, is commonly performed on diode structures where additional factors of detector damage, as radioactivity of metals composing a sensor structure, appear. Heat treatments are possible means to restore radiation damaged detectors. Therefore, spectral changes of thermal emission in the heavily irradiated Si particle detectors due to anneal determined configurational transforms of radiation defects might be a promising technology to recover functionality of irradiated sensors. However, the spectral changes of heavily hadron irradiated and annealed at elevated temperatures Si materials are studied insufficiently.

In this work, the contactless technique of temperature dependent carrier trapping lifetime measurements on homogeneous Si wafer samples was applied for spectroscopy of thermal emission centres in 26 GeV/c proton and 300 MeV/c pion irradiated n- and p-Si samples, with fluences up to 10^{16} cm^{-2}. The carrier trapping lifetime was extracted from microwave-probe photoconductivity (MW-PC) decay transients. The variations of carrier trapping lifetime dependent on temperature represent a spectrum of the prevailing deep emission centres. These carrier trapping lifetime spectra were correlated with optically excited I-DLTS measurements. The configurational transforms of the radiation introduced deep traps have been identified. It has been shown that a few of deep radiation traps can be annealed out by applying the heat treatments in the temperature range of 80^0 -300^0 C. However, this anneal is followed by formation of rather shallow centres, which leads to the rather strong trapping effect, where competition of recombination (deep ones) and trapping (shallow) centres determines fast and slow components of excess carrier decay.