Single parameter fits to data of Redus et al. used to determine the most accurate value of Fano factor to date. (a)The field dependence of deviation from the statistical limit does not fit to variation of $\mu\tau$ product alone. (b) Electric field variance alone gives an excellent fit to the data.
Note that the only unknowns in these terms are the two component variances, since the mean applied field is determined by the voltage and sample thickness, and mobility and trapping time are independently determined by pulse transient analysis, and further verified by Hecht fits. The complete equation for the measured standard deviation of charge collected is:

Quantifying sources of charge variance in CdZnTe

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Introduction

The performance of CdZnTe gamma spectrometers has dramatically improved over the years by the use of single-carrier detector designs, charge trapping correction methods, and reduction of gross material defects. However, substantial increases in electron mobility-lifetime ($\mu\tau$) product reported recently have not resulted in further improvement of energy resolution. Resolution in these devices is currently limited by inhomogeneous charge collection, which cannot be corrected by simple techniques. The cause of the non-uniformity problem must be identified before it can be reduced. Inhomogeneous trapping is one possible cause, but using traditional techniques this is not distinguishable from other effects such as band gap variation due to alloy segregation, or electric field ϕ distortions caused by the mosaic microstructure.

Approach

We report new analysis of charge collection variance in planar CdZnTe devices, which can in principle separate effects due to carrier statistics, band gap variation, inhomogeneous trapping, and electric field perturbations, to determine the dominant sources of peak broadening in gamma spectrometers. The method extends a detailed propagation of errors through the transport equation, to derive distinct field dependencies of these sources of charge variance in planar devices. This straight forward analysis shows that variance due to electric field perturbations is more strongly dependent on the applied field than variance due to inhomogeneous $\mu\tau$ products. We have used this approach to analyze literature data of low-noise x-ray photon photo peaks, as well as alpha particle induced pulses of CdZnTe samples produced by several growth methods.

The previous analysis was applied only to published low energy x-ray data, where carrier statistics can dominate; and the error propagation was analyzed only for carrier statistics and drift length variance*. We have now carried the propagation of errors to a higher level of detail, resolving the drift term into $\mu\tau$ and ϕ components. A key result is that drift variance due to $\mu\tau$ variation depends on the square of electric field, whereas the variance due to electric field perturbations is independent of applied field.

$$\underbrace{\sigma_\lambda^2 = \phi^2\,\sigma_{\mu\tau}^2}_{\text{property variation}} + \underbrace{(\mu\tau)^2\,\sigma_\phi^2}_{\text{electric field variation}}$$

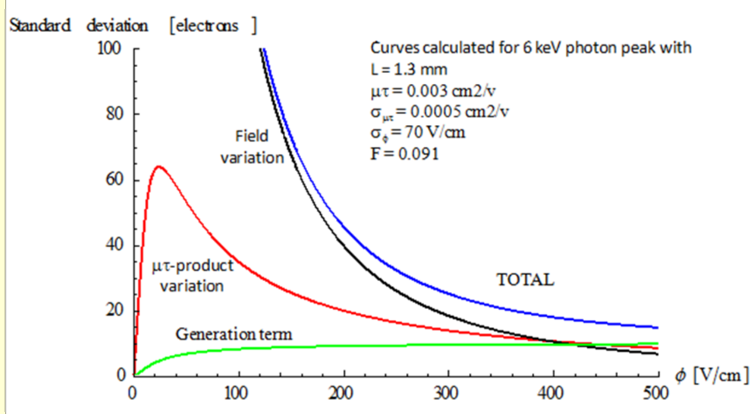
Note that the only unknowns in these terms are the two component variances, since the mean applied field is determined by the voltage and sample thickness, and mobility and trapping time are independently determined by pulse transient analysis, and further verified by Hecht fits. The complete equation for the measured standard deviation of charge collected is:

$$\sigma_Q = \sqrt{(q\epsilon)^2\,FN + (qN)^2\left(\frac{\partial\epsilon}{\partial\lambda}\right)^2\left(\phi^2\,\sigma_{\mu\tau}^2 + (\mu\tau)^2\,\sigma_\phi^2\right)}$$

where Q is charge collected, **q** is charge of the electron, ε is charge collection efficiency, **F** is the Fano factor, and **N** is the mean number of carriers generated. This quantity sums in quadrature with the electronic noise to determine energy resolution, therefore fitting experimental peak widths versus applied field becomes a convenient method to quantify these effects.

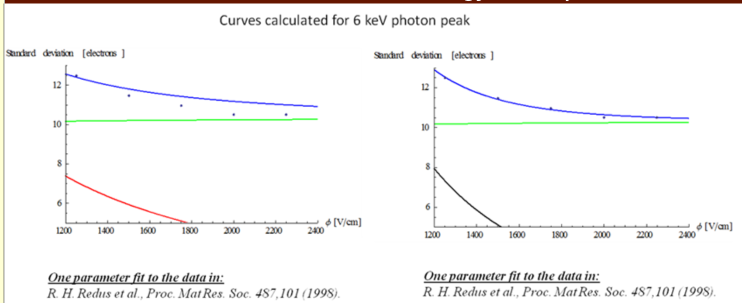
***Fano factor and nonuniformities affecting charge transport in semiconductors, M.J. Harrison, D.S. McGregor, F.P. Doty, Physical Review B 77 (19), 195207 (2008).**

Separable Effects



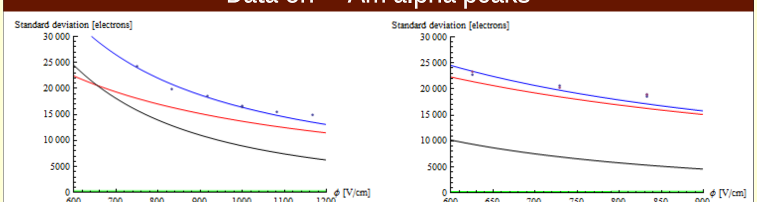
Plot of components of charge collection variance illustrating the distinct applied field dependencies for generation, $\mu\tau$ and, field perturbations.

Literature Data on Low Energy Photopeak



Single parameter fits to data of Redus et al. (used to determine the most accurate value of Fano factor to date). Left: the field dependence of deviation from the statistical limit does not fit to variation of $\mu\tau$ product. Right: Electric field variance alone gives an excellent fit to the data.

Data on ^{241}Am alpha peaks



Two-parameter fits to alpha data. Left: typical Bridgman detector is dominated by electric field variance at low applied field. Right: poor quality detector dominated by $\mu\tau$ variance at low field (breakdown at 850 volts/cm).

Conclusions

Our results show that many samples are dominated by non-uniform fields, leading to spectrometer performance limited by a heretofore unrecognized source of peak broadening.

Possible causes of electric field variance include piezoelectric fields due to residual elastic strains, dislocations, and the commonly observed mosaic microstructure.

Acknowledgements

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