Contribution ID: **76** Type: **not specified**

Two Photon Absorption Transient Current Technique for 3D field, time response and efficiency mapping of semiconductor detectors

Conventional device characterization based on light-matter interaction uses the photoelectric effect and lasers as standard tools. The problem is that the photoelectric effect, even with collimated light beams, doesn't allow to resolve device structures in full 3D due to absorption and charge generation along the full penetration path.

In recent years new near infrared femtosecond pulsed lasers are revolutionizing the field, from basic characterization to high precision mapping. It is now possible to put ultrahigh power ultrashort pulsed laser light in micron voxels without disturbing the surrounding material because photon absorption operates in the non-linear regime. The key for that feat is low energy (mJ) but ultrashort wavelength-tunable pulsed (fs) laser light. This technology is now used into art and nanomanufacturing, as subsurface laser engraving and 3D litography, and make it possible nanosculptures and nanomachines.
For chemistry, multiple photon absorption (in short, Two Photon Absorption) permits precise spatial-temporal control of reactions in liquid media. For biomedicine, TPA induced fluorescence pinpoints structures in living cells without damage.

The TPA revolution now finds its way to semiconductor detectors, the origin of the photoelectric applications. As it's well known, the core of semiconductor detectors design is to locate a huge electric field by means of selectively doped pn junctions. The totally important electric field region needs an accurate experimental technique for characterization.

We present a new experimental method, TPA-TCT or Two Photon Absorption Transient Current Technique. TPA-TCT takes advantage of the non-linear photoelectrics in silicon associated to near infrared femtosecond laser pulses to generate eh pairs in a few cubic microns around the focal point, deep inside the device. Fast current amplifiers with state of the art DAQ electronics can resolve in time the current pulse shape generated in response to the laser pulse. Combining the 3D spatial pair generation volume and the DAQ timing, it is possible to determine the depletion volume in the semiconductor device, resolving the electric field distribution.

Spatially resolved electric field and efficiency characterization in semiconductor detectors opens the door to detector design optimization for highest performance in many fields. Other possible applications of TPA-TCT, specially by tuning the wavelength, are defect spectroscopy, application to diamond sensors or radiation tolerance characterization of depleted silicon sensors (bulk and HV-CMOS). Examples on High Energy Physics particle detectors will be given in the presentation including the monitoring of radiation damage.

Summary

We present a new non-linear laser technique for 3D tracing of the electric field in semiconductor detector pn junctions. The precise knowledge of the electric field distribution is key to semiconductor design and operating life monitoring. Examples on High Energy Physics particle detectors will be given in the presentation including the monitoring of radiation damage.

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