Femtosecond laser enhanced transient current technique*

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The aim of this work is to understand the processes involved in laser irradiation of diamond below and close to the graphitization threshold. The study is performed under the same conditions of the experimental procedure used to produce 3D diamond detectors [1], in order to improve the technique of preparation of 3D diamond sensors with optimal performances.

To this purpose a Transient Currents Technique (TCT) has been used to measure laser-induced current signals in a diamond detector, in a wide range of laser intensities, from low fields up to the diamond graphitization threshold, at different bias voltages.

The current transients vs. time and the overall charge collected have been recorded to be compared with theoretical simulations.

Transient currents were produced by laser irradiation in a 500 μm thick monocrystalline diamond detector, biased at different voltage values, from 0 to 600 V.

A Ti:Sa mode-locked laser source has been used for excitation, with central wavelength 800 nm, pulse width 30 fs, repetition rate 1000 Hz. The energy densities at a focus of 8 μm diameter are in the range of 0-8 J/cm^2, i.e., the maximum energy per pulse was 4 μJ.

The current vs. time was acquired by a broadband (6 GHz) oscilloscope.

At low laser fields a 2.5 GHz, 40 dB amplifier was used. In this way it was possible to span on four order of magnitude of current intensity. The lower current signal detectable was 0.4 μA and the highest current 3 mA.

The current transients are observed in a time window increassing from 25 ns to 1.2 μs as the energy per pulse goes from 0.1 μJ to 4 μJ. This increase is due to the high density of the plasma generated by the field and the mutual attraction of holes and electrons.

A semi-quantitative model which accounts for these two processes has been developed to fit the current lineshapes.

Figure 1 shows the plot of the collected charge vs. the energy per pulse I at a 500 V bias voltage. This has been determined from the collected charge by integrating the current transients. The slope of the curve up to 1 μJ is fitted with a power trend $Q \propto I^m$, with an exponent m = 4.4, pointing out that the excitation is a mixed non-linear effect involving four and five photon ionizations.

This is consistent with the fact that the frequency emission of the laser corresponds to a broad photon energy range centered at 1.55 eV and the direct bandgap of diamond is about 7 eV, so that at least four photons are required to excite free carriers. We also observe a flattening of the curve at higher laser intensity. This is probably due to the electron-hole recombination occurring during the very long transients, typical of the high energy irradiation pulses.

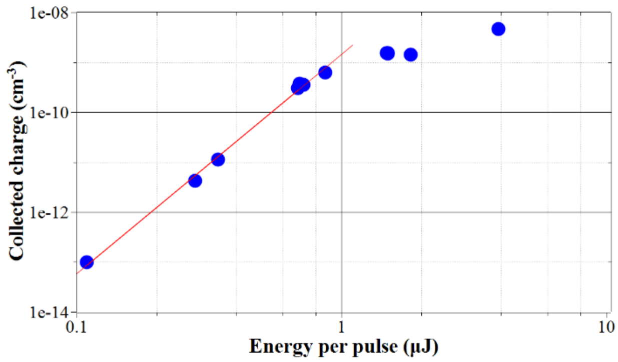

Figure 1: Collected charge vs. energy per pulse

Further measurement aimed to reach the graphitization threshold are under way.

Theoretical modeling aimed to simulate the experimental conditions of excitation and graphitization is also in progress.

References

[1] S. Lagomarsino, M. Bellini , C. Corsi , F. Gorelli , G. Parrini, M. Santoro, and S. Sciortino, Appl. Phys. Lett. 103 (2013) 233507.

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