Laser induced breakdown of dielectrics and impact ionization.

Stéphane Guizard[1*], Alexandros Mouskeftaras[1], Sergey Klimentov[2],

1- Laboratoire des Solides Irradiés, CEA-IRAMIS, CNRS, Ecole Polytechnique, 91128 Palaiseau, France,
2- General Physics Institute of the Russian Academy of Sciences, Vavilova St 38,
*e-mail: stephane.guizard@cea.fr

Abstract :

Although observed almost immediately after laser invention, the physical processes involved in the damaging of dielectrics by intense light pulses are still not completely understood. The problem is complex due to the high number of elementary mechanisms that paly a role : non-linear excitation from valance band to conduction band, followed by a competition between the different relaxation channels (electron-phonon, electron-electron, electron-hole, plasma expansion, etc.). The model initially proposed is derived from breakdown in D.C. fields: acceleration of carriers in the electric field (or absorption of a sequence of photons in the case of laser) gives rise to hot electrons that have enough energy to produce secondary electrons by impact ionization. This process of electronic avalanche is repeated until some critical density of carriers is reached, leading to destruction of the solid.

We have investigated the problem of optical breakdown using an original optical pump-probe technique with femtosecond time resolution, which allows to measure in real time the density of carriers excited in the solid. The experiments findings are the following:

- we could for the first time observe directly and unambiguously, the mechanism of electronic avalanche induced by a laser pulse.
- There is no link between electronic avalanche and laser induced breakdown, which occur at different carrier density, depending on the material and the pulse duration.
- More interestingly, the avalanche is not observed in all dielectrics: it is observed in SiO_2 and Alkali-halides (NaCl, KBr), but not in Al_2O_3 or MgO.
- This last result is the most surprising, and gives some indication that there could be a link between the formation self-trapped exciton and the efficiency of impact ionization, at the origin of electronic avalanche.

We will present and explain the experimental results, and discuss in particular the consequence for what is known from impact ionization in dielectrics.