Study of electron and ion emission by intense THz transient:application to the atomprobe tomography

Doctorant·e
KARAM Michella

Direction de thèse
VELLA ANGELA (Directeur·trice de thèse)

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Rapporteurs de la thèse
ABRAHAM EMMANUEL Universite de Bordeaux
THUVANDER MATTIAS Université de Goteborg (SUEDE)

Membres du jurys
ABRAHAM EMMANUEL, , Universite de Bordeaux
HIDEUR AMMAR, , Université de Rouen Normandie (URN)
HOUARD Jonathan, , Université de Rouen Normandie (URN)
KACHAN ELENA, , Université Jean Monnet
THUVANDER MATTIAS, , Université de Goteborg (SUEDE)
VELLA ANGELA, , Université de Rouen Normandie (URN)

Abstract

Terahertz (THz) radiation, characterized by low-energy photons, has become a promising tool for triggering field emission processes. Recent advancements have enabled the generation of high-amplitude monocycle THz pulses with electric fields in the MV/cm range, which have been applied to nanostructures, enabling both electron emission and ion evaporation. These capabilities open new pathways for improving material analysis techniques, particularly in atom probe tomography, by enhancing resolution and accuracy. This work investigates the physics of field evaporation induced by THz pulses through numerical simulations and experimental measurements. The numerical study explored the dynamics of ions and electrons, highlighting the influence of THz pulse parameters such as amplitude and phase. Experimentally, single-cycle THz transients combined with a static bias voltage were applied to the semi-metal lanthanum hexaboride (LaB6) nanotips, validating numerical predictions and demonstrating that THz pulses act as ultrashort electrical pulses. A comparative analysis of APT using femtosecond NIR lasers and THz pulses revealed that THz radiation increased ion charge states and improved boron detection. The study further explored THz-assisted APT for materials with low free carrier densities, such as semiconductors and oxides. Extensive analyses of germanium, silicon, magnesium oxide (MgO), and zinc oxide (ZnO) revealed distinct challenges and behaviors. Factors such as low conductivity, FIB-induced defects, and Schottky barrier effects significantly influenced emission dynamics. Despite these challenges, THz pulses successfully triggered field evaporation in these materials, while underscoring the need for further optimization of experimental conditions and sample preparation techniques.