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Atomic-scale microscopy of different materials by ultrashort THz-driven Atom Probe Tomography

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Background

Terahertz (THz) radiations with low energetic photons (meV) are used today in a wide range of applications such as imaging, sensing or spectroscopy. The low photon energy of THz radiation has the advantage of inducing low damages on fragile materials by reducing heating encountered when a visible wavelength is used.

Our research is based on the combination of a single-cycle THz source with atom probe tomography (APT) to study THz-assisted field evaporation on a wide range of materials, including metals, ceramics, semiconductors (crystalline silicon), and insulators (amorphous silica). Using our homemade THz-assisted APT setup - "TERA-SAT" - we aim to explore the new impacts of THz pulses on materials characterization at the atomic level.

Methods

Atom Probe Tomography (APT) is an imaging technique based on controlled field evaporation of atoms from a nanometric needle-shaped sample under a strong electric field. Evaporation of atoms is triggered by a laser pulse in the UV or THz domain. The ions are then directed onto a time- and position-sensitive detector. The 3D atomic positions are reconstructed through a back-projection algorithm and the chemical nature is determined by calculating the mass-to-charge ratio.

The experimental setup used (fig. 1(a)) in this study is composed of a pulsed THz source based on the two-color plasma generation process coupled with an APT chamber.

Results

THz radiation has been proven to be beneficial for the reduction of thermal effects in field evaporation of metals and low band-gap materials such as LaB6.

Further tests have also been performed on pure silicon nanotips, where the presence of thermal effect is strongly dependent on the spectrum of the THz radiation.

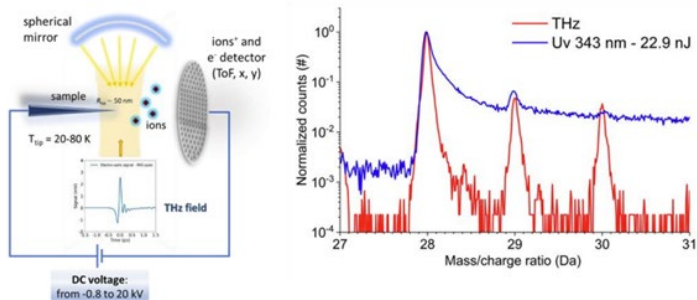
Finally, we analysed nanotips made of sol-gel amorphous silica, which is chosen as matrix for bio-molecules embedding for future studies. First, we demonstrated the possibility of field-evaporating such material in a well-controlled way using THz pulses. A more detailed comparison of the mass-to-charge ratio spectra obtained with THz-APT and UV-assisted APT (fig.1 (b)) reveals an increase of the signal to noise as well as an improvement in the mass resolving power which is inversely proportional to the full width of the peak at 1 and 10% of the maximum.

Conclusion

We have analyzed different materials using our TERA-SAT setup, demonstrating its ability to trigger field evaporation. The use of THz radiation is proven to reduce local heating phenomena, especially in the case of metals, allowing a-thermal field evaporation.

We have obtained encouraging results also for non-metallic samples, but further investigation will be necessary to find out the optimal parameters (THz amplitude, DC field) to improve the accuracy of compositional analyses, thus to increase the signal to noise ratio and the mass resolution power of the mass spectra.

Graphic:



Keywords:

Atomic-scale-microscopy; Atom-Probe-Tomography; pulsed-THz; field-ion-emission

Reference:

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