

## Development of a pulsed beam method for slow metastable helium atoms

## 低速準安定ヘリウム原子のパルスビーム技術開発

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The use of desorption measurements to identify the adsorbed species on surfaces is important for characterizing plasma facing and tritium breeder materials. Among them the knowledge of molecules adsorbed on outermost surfaces is indispensable to elucidate the rate-determining surface reaction. A slow metastable helium atom beam can exclusively stimulate the adsorbate to desorb. To efficiently detect desorption signals and to attain a higher mass resolution, a mechanical chopper is considered here as a fundamental technique of pulsing a slow metastable helium beam.

## 1. Introduction

To develop plasma facing materials with high plasma resistance, surface reactions, such as chemical sputtering or tritium inventory, have to be clarified. In the case of tritium release from breeder materials, the rate-determining surface reaction can be explained as the adsorption / desorption characteristics of surfaces. The dissociation of the surface constituents followed by desorption from the surface during dissipation of the electronic excitation energy is known as desorption induced by electron transition (DIET), which provides the basis for surface analysis techniques.

## 2. Desorption Measurements

The major approaches for DIET have been electron- and photon-stimulated desorption (ESD, PSD). It is usually assumed in ESD and PSD that the desorbed ions stem from the outermost layer although beams of energetic electron or photons are used and their transmissivities are large enough to excite the atoms in deeper layers. The possibility of ion transport from deeper layers to the vacuum has arisen against the conventional assumption. Shorter transmissivity can be provided by using low-energy ions as the primary beam. Since ions carry potential energies (ionization energy) in their internal potential energies besides kinetic energies, ion-stimulated desorption (ISD) (or ion sputtering) consists of the kinetic energy-dependent component and the potential component (or potential sputtering). The potential component is due to DIET at the outermost surface where the potential energy transferred from the primary ion. ISD can be purified into genuine DIET right on the outermost surface by using thermal atoms in their metastable states instead of primary ions. Thermal metastable

atoms are reflected above the surface so that interactions are definitely restricted within atoms at the outermost surface. This is the metastable-atom-stimulated desorption (MSD) [1]. Furthermore, the electron spin of metastable atom beams that can be polarized has the potential to offer an insight into DIET [2].

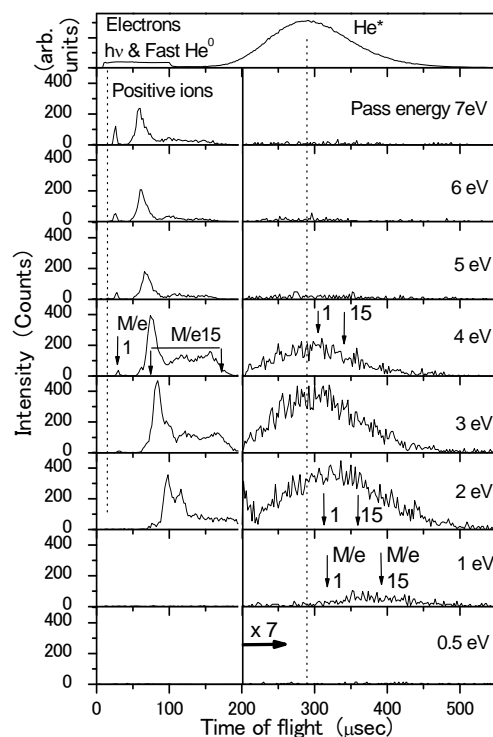


Fig.1. TOF spectra for dodecanethiolate-SAM formed on an Au substrate obtained by a pulsed beam consisting of metastable He, fast He and UV photon. Top panel displays emitted electron intensity. Emitted positive ion intensities are plotted in the lower eight panels for various pass energies [3].

### 3. Metastable-Atom-Stimulated Desorption

As an example of MSD, the results of time-of-flight (TOF) measurement for a SAM surface are shown in Fig. 1. Larger peaks distributed from 0 to 200  $\mu$  sec in the TOF spectra of positive ions (the second to the seventh panel from the top) correspond to secondary ions of  $H^+$  and  $CH_x^+$  sputtered by fast helium neutral atoms contained in the primary beam. Smaller and broader peaks after 200  $\mu$  sec in the fifth to the eighth panel of Fig. 1 correspond to MSD ions of  $H^+$  and  $CH_x^+$  induced by slow metastable helium atoms. From the comparison of these peaks and the arrows, each of which indicates the calculated arrival time for the mass charge ratios (M/e) of 1 (H) or 15 ( $CH_3$ ), it can be seen that the species of M/e 15 or so is dominant at a pass energy of 1 eV.

### 4. Double Chopper

The rather poor mass resolution in this MSD measurement is a result of the wide pulse width of the primary beam at the sample position. Though the pulse width is narrow at the metastable helium beam source which is operated in the pulsed discharge mode, it becomes wider at the sample point due to the flight distance and wide energy distribution of an effusive beam. In order to attain a fine mass resolution we have to introduce a mechanical chopper close to the sample to get a

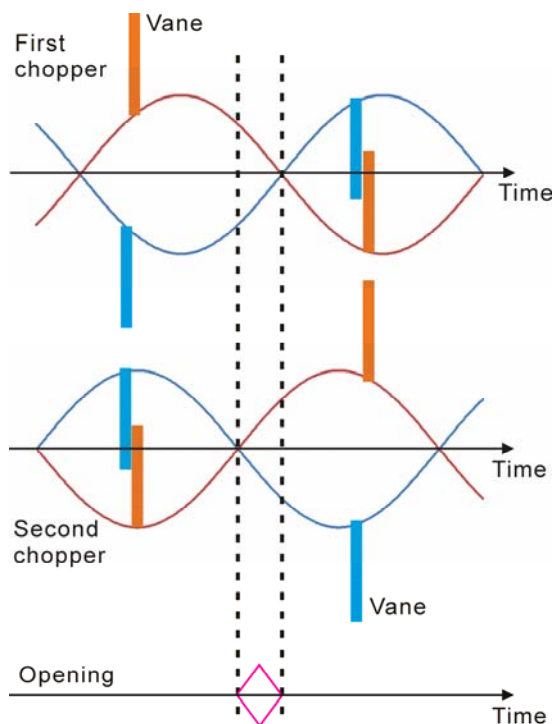


Fig.2. Operation schematics of the double tuning fork chopper system. The first and the second chopper are placed as close as possible.

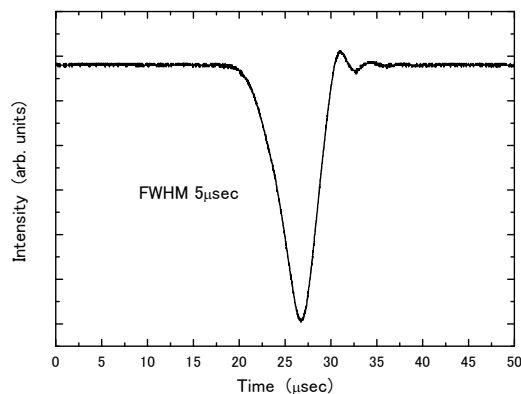


Fig.3. Chopping performance of the double tuning fork chopper system. A laser beam was used to simulate pulsing the metastable He beam.

narrow pulse width at the sample position.

Aside from conventional chopper wheels, we adopted tuning fork choppers instead because of their ultra high vacuum compatibility (Electro-Optical Products Corporation CH10). By vibrating two choppers in an almost opposite phase, a narrow pulse can be formed as illustrated in Fig. 2.

Figure 3 shows its pulsing performance examined by the laser beam experiment. With the aid of a phase-locked loop that precisely controls the phase difference between two choppers, the chopping system successfully pulsed the laser beam down to an FWHM of 5  $\mu$  sec at a repetition rate of 300 Hz.

We infer that the chopping performance is feasible for use in pulsing the metastable-atom beam. The pulsed beam method employing the double chopper will be expected to improve the mass resolution by an order of magnitude or so.

### Acknowledgment

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### References

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