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Measurements of Total Photo-Desorption Yields from Solid Krypton by Exciton Creation

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1. Introduction

Desorption induced by electronic transitions (DIET) of various kinds of particles from rare gas solids has been extensively studied in these 10 years [1]. Investigation of the desorption characteristics such as desorption yields, kinetic energies and angular distributions, will reveal the dynamics of the electronic excitations and the relaxations.

We reported the absolute photo-desorption yields from the surface of solid neon [2] and argon [3, 4] at excitonic excitation energy and revealed the main desorption channel by the quantitative analysis. For a thick neon film, the desorption yield was 1-2 atoms/photon by bulk exciton excitation and 2-10 atoms/photon by bulk ionization. These values were quantitatively explained by the internal sputtering mechanism. In the case of argon, the absolute photo-desorption yield was 0.05-0.1 atoms/photon by bulk exciton excitation. The results agreed with the calculated value using the classical molecular dynamics by Cui et al [5]. The dissociation of excimer in the bulk was found to play an important role in the desorption mechanism of argon.

Here, we present the preliminary results of the total photo-desorption yields from the surface of solid krypton. The "total" means that we detected all the krypton particles desorbed, i.e., atoms and clusters in ground, electronically excited, and ionized states. In this report, we show only the relative desorption yields because the absolute number of incident photon have not been measured in the wavelength range of the exciton creation energy for solid krypton (100-130 nm).

2. Experiments

The experimental procedure and set-up have been described in detail elsewhere [2] and are briefly summarized here. Experiments have been carried out at the beam line BL5B in UVSOR of the Institute for Molecular Science, Okazaki. A liquid helium cryostat was installed in an ultrahigh-vacuum chamber with a base pressure of 5×10^{-9} Pa. Krypton gas was introduced into the main vacuum chamber and was condensed on the surface of a platinum substrate attached to the liquid helium cryostat. The temperature of the sample was 6 K or lower. The thickness of a krypton film was calculated from the exposure on the assumption that the condensation coefficient of the krypton on the sample surface was unity. The film thickness was between 10 and 2400 atomic layers.

Desorption rate was calculated from the total pumping speed for krypton and the rise of the krypton partial pressure in the vacuum chamber during the irradiation of the sample. The pumping speed for krypton of a turbo molecular pump and the cold surface of the cryostat was 0.068 ± 0.01 m^3/s in total. The partial pressure of krypton was measured by a quadrupole mass spectrometer which was calibrated with an ionization gauge at each run of the experiment.

3. Results

Figure 1 shows the wavelength dependence of the total desorption yields for solid krypton. In case the film thickness is 10 atomic layers, a peak is observed at 125 nm which corresponds to the excitation energy of the first order surface exciton (S1(3/2)). For the film of 2400 atomic layers in thickness, additional peaks appear at the wavelengths corresponding to the first order bulk (B1, 122 nm (3/2), 114 nm (1/2)) excitons. The small shoulders at 110, 116 and 112 nm in the spectrum for 2400 atomic layers film are due to the creation of the second order bulk (B2(3/2)), the first order surface (S1(1/2)) and the second order surface (S2(3/2)) excitons, respectively. The background signal is mainly due to the ionization by the second order light from the monochromater.

The thickness dependencies of the desorption yields at each exciton excitation energy are shown in figure 2. The desorption yield at the surface exciton creation energy should have no thickness dependence because the "thickness of the surface" is constant for any thickness of the film, which was indeed the case for neon [2] and argon [3,4]. However, in figure 2, the desorption yield at the first order surface exciton (3/2) excitation energy gradually decreases with the increase of the thickness of krypton film. This decrease can be the contribution of the residual gas adsorption on the sample surface. To make a thick krypton film, the substrate was exposed to gaseous krypton with rather high pressure (~ 1 x 10^{-4} Pa) for more than 10 minutes. After the exposure, we had to wait for about 1 hour or more in order to get a low pressure (< 2 x 10^{-8} Pa), which was essential for a good signal to background ratio in the present experiments. The sample surface can be partly covered with the residual gas (H_2, H_2O, CO, etc.) during this period, which resulted in the decrease of the desorption yield. This very slow pressure decrease was not observed in the measurements for neon and argon, which is explained by the difference of their vapor pressure at the temperature of the cryostat which has a temperature distribution from 4.2 K to the room temperature.

The desorption yields at the bulk exciton creation energies increase with the thickness of krypton film and saturated at about 200 atomic layers. The saturated value for B1 (3/2) and B1 (1/2) is roughly estimated at 0.01~0.1 krypton/photon. The measurements of the absolute intensity of the incident light at the wavelengths of the exciton creation for krypton (100-130 nm) will be done in the next machine time, which will give the absolute desorption yield. This will make it possible to discuss the desorption mechanism quantitatively.

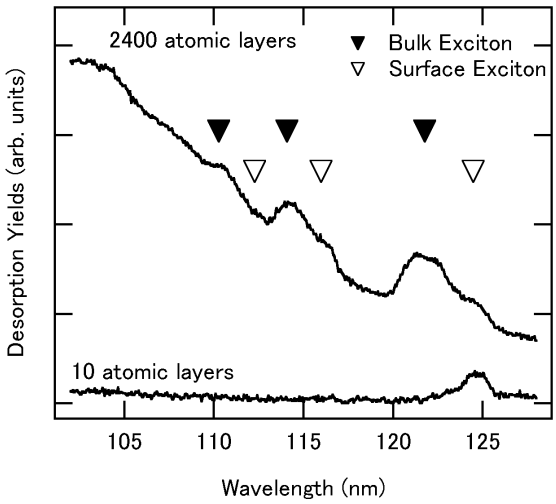

Fig.1 Wavelength dependence of total desorption yields of argon for thin (10 layers) and thick (2400 layers) films.

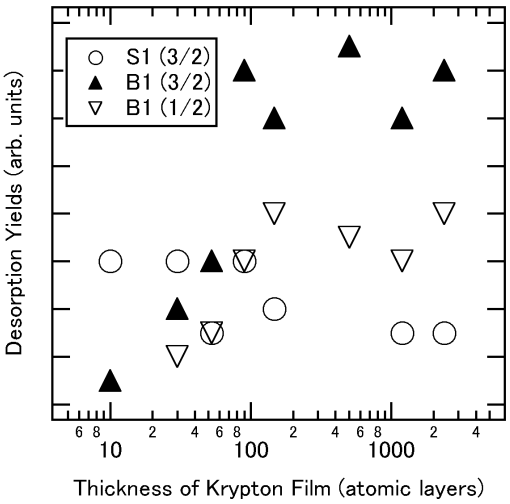

Fig.2 Thickness dependence of desorption yields at the bulk and surface exciton creation energies.

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[5] S. Cui, R. E. Johnson, and P. Cummings, Surf. Sci. **207**, 186 (1988).