Electron beam irradiation effect in LEED measurement of Si(001) below 40 K

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The Si(001) surface exhibits an order-disorder transition in the arrangement of asymmetric dimers at around 150 K. Its surface periodicity changes from p(2x1) to c(4x2) with decreasing temperature as observed by low-energy electron diffraction (LEED) [1,2]. Recently, however, symmetric-appearing dimers and the p(2x2) domains of the asymmetric dimers have been observed by scanning tunneling microscopy (STM) below 60 K [3-6]. The STM observations sometimes cause perturbation on the surfaces, and such effects were confirmed experimentally [7-10]. Therefore, it is unclear whether these results reflect intrinsic properties or artifacts. The structure at lower temperatures should be studied by other techniques that would not produce significant influence on the surface structures. LEED was expected one of such tools. Matsumoto et al. measured LEED spot intensities as a function of temperature [11]. They obtained the intensity diminution of the quarter-order spots below 40 K, and proposed a new order-disorder phase transition.

Although we confirmed the same intensity diminution of the quater-order spots (Fig. 1(a)), we obtained evidence that the disappearance of the c(4x2) pattern was caused by the electron beam effect [12]. The effect of electron beam irradiation has been demonstrated by following two procedures: (i) The sample position was changed quickly at 20 K during LEED observation; (ii) A shutter between LEED optics and the sample was closed during cooling down to 20 K, and was opened quickly. With both procedures, clear c(4x2) patterns were observed immediately after LEED observation. However, the patterns changed streaky ones within 20 seconds at 50 eV and 1μA. The intensities of (3/4 1/2) and (1/2 1/2) spots were plotted in a semi-logarithmic scale with respect to the irradiation time as shown in Fig. 1(b). These results clearly demonstrate that the most stable structure is the c(4x2) at 20 K. The intensity changes at 40 K observed in previous LEED study [11] is not intrinsic but caused by the electron beam irradiation. Thus, there is no new phase transition at 40 K. Current and energy dependence of the irradiation effects will be also discussed.

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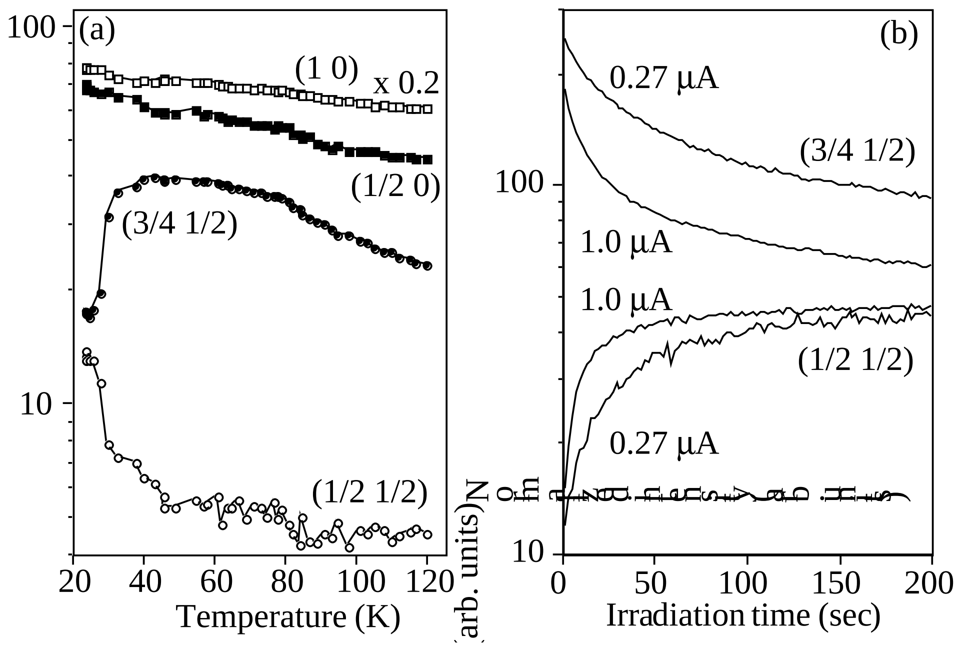

Fig. 1. (a) Spot intensities as a function of sample temperatures. E_K = 50 eV. (b) Spot intensities as a function of time after a shutter was opened. E_K = 50 eV.