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Manipulation of nitric oxide molecule by attractive force using scanning probe microscopy

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1. Introduction

Two states of upright and flat-lying NO were found on Cu(110), and the repulsive force between the NO-tip and the surface NO were successfully used to switch upright NO to flat-lying NO [1]. However, due to the large mutual attraction between flat-lying NO and substrate, it is difficult to use the attractive force to switch it to upright NO. So in order to reduce the interaction between NO and substrate, we used copper nitride (Cu_2N) as the new substrate and used the direct attractive force between the metal tip and NO and successfully switched bent NO to upright NO.

2. Sample and method

Nitrogen atoms insert into the outermost surface of Cu(001), resulting in a surface reconstruction, which form the copper nitride (Cu_2N). The adsorption and insertion of nitrogen atoms will also cause the outermost Cu layer to expand by 2-3%, which results in the accumulation of tension in plane [2]. Therefore, line defects are formed approximately every 6-7 nm to release these stresses, and the defects with the smallest width are called monoatomic lines. On the monoatomic line, NO in upright and bent states was also found. Similarly, switching NO was also studied. We found that the attractive force or repulsive force can be selected by modifying the tip. Metal tip provides the attractive force to switch bent NO to upright NO, and the NO-decorated tip gives a possibility to switch upright NO to bent NO.

3. Manipulation

In Fig. 1(a), there are two upright NOs and one bent NO on the monoatomic line in the STM image. In Fig. 1.(b), the upright NO looks dark in the AFM image, which represents the attractive force between the metal tip and NO. When tip scanning on the bent NO, the attractive force between the tip and the NO molecule switched the bent NO to upright NO. There is no difference between the upright NO after switching and the original upright NO under AFM and STM scanning. Fig. 1(d) and (g) show the height profiles on the lobes at the green dash line in (a) and (c) respectively. Fig. 1(e) and (f) magnified AFM and STM image of the black frame in (b) and the switching point is indicated by the arrows.

In Fig. 2, the tip-surface distance sweep is used to switch bent NO to upright by attractive force contributed by metal tip. Tip approached on the blue spot in Fig. 2 (a), and the force and potential curves could be converted by the measured frequency shift, as shown in Fig. 2(c) and (d). The bent NO is switched to the upright NO when the attractive force rises up to 35 pN and the energy provided to 32 meV. Fig. 2(b) shows the AFM image after switching.

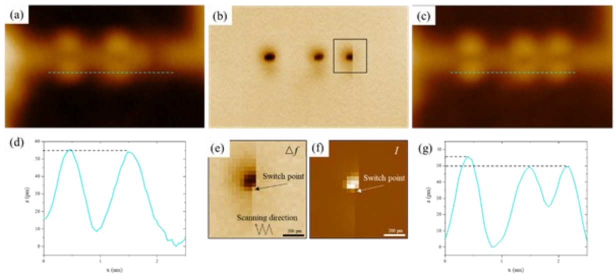

Fig. 1. (a) STM image before switching. (b) AFM image during switching. (c) STM image after switching. (d) and (g) Height profiles on the lobes at the green dash line in (a) and (c) respectively. (e) and (f) the magnified AFM and STM image of the black frame in (b).

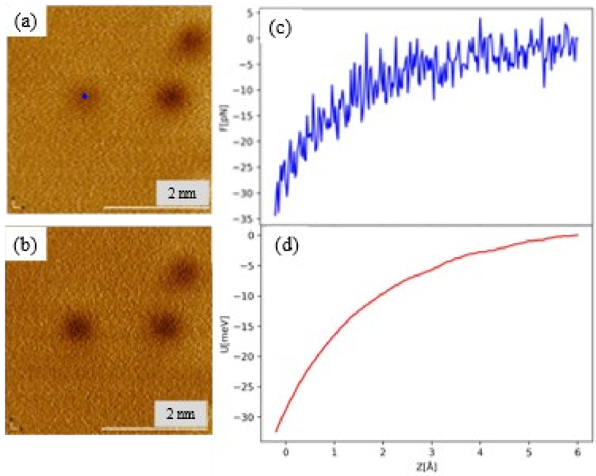

Fig. 2. AFM images (a) before switching and (b) after switching. (c) and (d)Force curve and potential curve on the blue spot in (a).

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References

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