Artificial Two-dimensional Lattice Structures Assembled by Atom Manipulation Technique

M. Nantoh[a], K. Takashima[b], T. Yamamoto[b, c] and K. Ishibashi[a,d]

[a]*Advanced Device Laboratory, RIKEN, Wako, Saitama 351-0198, Japan*
nantoh@riken.jp
[b]*Department of Electrical Engineering, Tokyo University of Science, Katsushika, Tokyo 125-8585, Japan*
[c]*Department of Liberal Arts (Physics), Tokyo University of Science, Katsushika, Tokyo 125-8585, Japan*
[d]*RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan*

The appearance of Dirac materials, such as topological insulators and graphene, let us have a new understanding that a solid surface itself or a monatomic layer fabricated on it can be utilized as a functional material. The material surface, consequently, is expected to play an important role in an advanced device using massless Dirac fermions. Gomes *et al*. have recently demonstrated that the periodic assemblies of CO molecules on Cu(111) 'molecular graphene' can be used in synthesis and control of the Dirac fermions.[1] These trends attract interest in atom manipulation technique using a low temperature scanning tunneling microscope (LT-STM) as an ultimate tool for nanofabrication. In view of its future application to produce advanced devices, it is significant to establish this technique and understand the physics related.

In this study, we fabricate artificial lattice structures of Fe atoms and CO molecules on a Cu(111) surface by the atom manipulation. A triangular lattice and a square lattice of Fe show different standing waves patterns, reflecting different electronic states (Figure 1). However, it is difficult to examine them by tunneling spectroscopy due to the mobile nature of Fe adsorbed atoms. On the other hand, a triangular lattice of CO, strongly bound to the substrate, allows us to perform scanning tunneling spectroscopy (STS) measurements, and investigate the electronic structure and its spatial variation in relation to the positions within the CO triangular lattice. The tunneling spectra measured near the CO molecules commonly show reduction of the density of states at the energy, corresponding to the bottom of the surface state band of the Cu(111). The spectra measured at the centers of the CO triangles have asymmetric features near the Fermi level, which show difference depending on the measurement locations corresponding to sublattice A or sublattice B of the honeycomb of the molecular graphene. This symmetry breaking can be understandable if we consider the influence from the second layer of the substrate enhanced by the absorption process of the surface state electrons into the bulk, which is caused by

[1] K. K. Gomes, W. Mar, W. Ko, F. Guinea, H. C. Manoharan, Nature 483, 306-310 (2012).

the strong repulsive scatterers, i.e., CO adsorbed molecules. This result indicates that the pseudospin symmetry of the molecular graphene is originally broken.

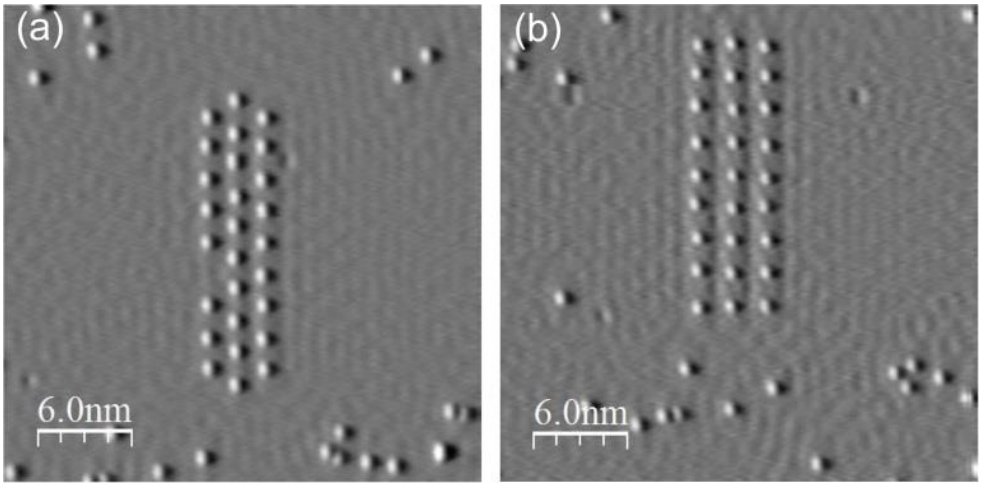

Figure 1: STM images of the artificial lattices of 27 Fe atoms formed on the Cu(111) surface assembled by the atom manipulation, measured at T = 6.2 K. Sample bias voltage V_b = 0.01 V, tunneling current I_t = 0.2 nA, scanning range 20 × 20 nm^2 (derivative display). Setpoint for dragging Fe atoms is V_b = 0.01 V and I_t = 70 nA.