Optical control of metal-insulator transition in nanowire

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1. Introduction

Low-dimensional metals exhibit numerous exotic phenomena such as charge-density waves (CDWs), Jahn-Teller distortions, and Luttinger-liquid behavoir. In particular, CDW has been widely studied for fundamental interest and prototypical applications. The In/Si(111) system exhibits a CDW transition, a metal to insulator transition (MIT) upon cooling, due to intrisic Peierls instability. Since the MIT causes a marked change in electronic properties, controlling the MIT using an external field will open up new possibilities for future devices such as switching, memory, and sensors. Although the MIT is controllable thermally or by introducing impurities, a more efficient method with, for example, high switching speed or reversible process, is necessary to realize versatile applications.

Here we demonstrate a reversible control of the MIT in In/Si nanowire by external photoexcitation. Highly efficient control was realized by combining the photoexcitation with electric field application.

2. Experimental

An In/Si(111) sample was prepared by the in-situ deposition of In onto a Si(111) 7×7 clean surface at 700 K under ultrahigh vacuum (1×10^{-8} Pa). To control the MIT, an optical beam from a laser diode (635 nm, 1 mW) was focused onto the tunneling junction between the STM tip and the sample.

3. Results and discussion

Figure 1 shows the demonstration of reversible control of the MIT in In/Si(111) nanowire. A 4×1 metallic phase is observed under the dark condition (upper area). Upon illumination, the system undergoes a transition to an 8×2 insulating phase (lower area), and the transition is observed to be reversible. The mechanism is clarified by a detailed consideration of the band structures of the STM tip/tunneling junction/In/Si system; The MIT is caused by the shift of the Fermi level in the surface state around the half-filled position, depending on the surface-carrier density optically doped from the substrate.

4. Conclusion

We successfully achieved the reversible control of the MIT via the charge doping by regulating the intensity of photoexcitation. This method is widely applicable to other low-dimensional systems and makes MIT more controllable and suitable for use in nanowires as an active element in future architectures of nanosized functional devices as well as nanoscale interdevice wiring.

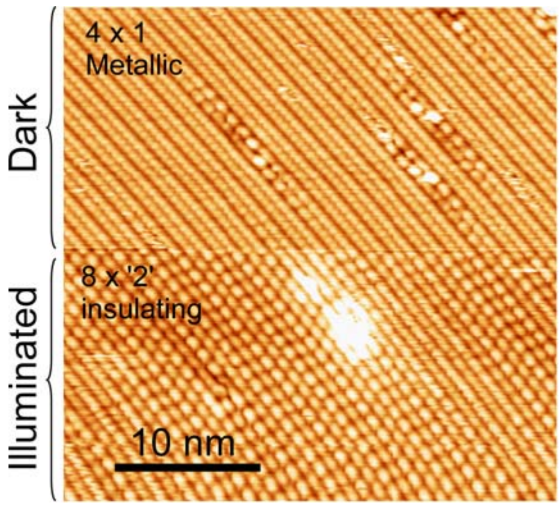

Fig. 1. Optical control of transition from 4×1 metallic (upper area) to 4×1 insulating (lower area) phases.