STM/STS study of electronic states on GaMnAs(110) surface

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The diluted magnetic semiconductors(DMSs) have attracted much interests because of their remarkable properties for future spintronics devices having both magnetic and semiconducting properties, and good compatibility with conventional semiconductor technologies. Although GaMnAs is the most investigated ferromagnetic semiconductor, its band structure and the origin of its ferromagnetism are still under debate. According to the p-d Zener model[1], the Fermi level has been believed to exist in the valence band (VB). On the other hand, according to the impurity band (IB) model[2], recent many studies have concluded that the Fermi level exists in the Mn-induced IB inside the band gap. Contrary to the both models, the nanoscopic study[3] have indicated that the Fermi energy lies within the range of electronic states that are spatially inhomogeneous so that the explanation for the electronic states with any simple model is not suitable. In the report[3], however, the consideration on TIBB(Tip-Induced Band Bending) effect was lacked. In this presentation, we will discuss on the electronic structures near the Fermi level of GaMnAs using by a STM/STS technique with considering the TIBB effect. We prepared a GaMnAs film with the Mn concentration of 5.7% and the Curie temperature of ~40K, the thickness of 2100nm. The GaMnAs was grown on a p-type GaAs(001) substrate by the molecular beam epitaxy. The sample was cleaved in the ultra-high vacuum($<1\times10^{-10}$Torr) and the (110)-surface was observed at a temperature of 4.2K using by W-tips.

The dI/dV image obtained at a negative sample bias(Fig.1(a)) shows a ring-like feature, the radius of which changes depending on the sample biases(Fig.1(b)). The similar rings have been reported on subsurface impurities such as Si in GaAs[4] and Mn in InAs[5] at a positive sample bias, and reported on top-surface layer Mn in GaAs[6] at a negative sample bias. These previous studies have reported that the ring features are due to TIBB. These studies have also explored the relations between the Fermi level and impurity levels (and the VB and impurity levels) by analyzing the ring features. Since GaMnAs has both subsurface and top-surface Mn, which are corresponding to both cases, we will discuss the electronic structures near the Fermi level of GaMnAs, focusing on the relationship among Fermi level, VB top, and impurity levels.

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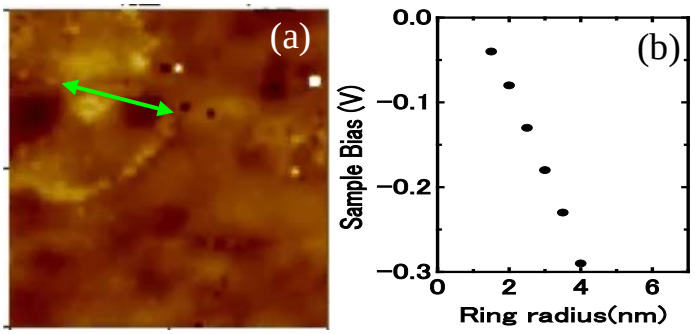

Fig.1(a) 10nm × 10nm dI/dV image measured at a negative bias of -0.2V. The green arrow shows the radius of the ring feature centered on a Mn atom. (b)Sample bias characteristics of ring radiuses evaluated at the several sample biases.