Magnetic Structures of $SrIrO_3/SrTiO_3$ Superlattices Studied by Resonant X-Ray Diffraction

5*d* Ir oxides have an interplay of spin-orbit coupling and electron correlations. We investigated the magnetic structure of a $SrIrO_3/SrTiO_3$ superlattice by resonant X-ray diffraction. We observed the (0.5, 0.5, 5) peak, which indicates in-plane antiferromagnetic ordering and interlayer ferromagnetic coupling. Together with the weak ferromagnetic moment in the superlattice observed only for magnetic field parallel to the IrO_2 plane, we concluded that in-plane canted antiferromagnetism is realized in this superlattice. These results show that we can design and realize novel electronic phases in the unit of the $SrIrO_3$ monolayer.

The novel interplay of spin-orbit coupling (SOC) and electron correlations in complex Ir oxides (iridates) has recently emerged as a new paradigm for correlated electron physics. The transition from semimetallic $SrIrO_3$ to magnetic insulator Sr_2IrO_4 is reported in Ruddlesden-Popper series $Sr_{n+1}Ir_nO_{3n+1}$ (n = 1, 2, and ∞), suggesting a dimensionality controlled bandwidth via n [1]. Matsuno *et al.* reported transport and magnetic behaviors of synthesized artificial superlattice $[(SrIrO_3)_m, SrTiO_3]$ with m = 1, 2, 3, 4, and ∞ [2]. We tracked the evolution of electronic ground states by varying m to understand the close links among semimetal-insulator transition, magnetism, and underlying lattice structures. **Figure 1a** shows the schematics of the superlattices $[(SrIrO_3)_m, SrTiO_3]$ (m = 1, 2, and ∞). In this work, we investigated the magnetic structure of the $SrIrO_3/SrTiO_3$ (m = 1) superlattice by resonant X-ray diffraction to clarify the exact magnetic structure [2].

The $SrIrO_3/SrTiO_3$ superlattice sample was fabricated on $SrTiO_3$(001) substrate by a pulsed laser deposition (PLD) technique. The details of the sample fabrication were described elsewhere [2]. Resonant X-ray diffraction measurements were performed at beamline 3A at Photon Factory, KEK. Photon polarization of the σ-π' channel was selectively measured by using a Mo(400) analyzer crystal.

Figure 1b shows the temperature dependence of the magnetization measured at 0.1 T for the $SrIrO_3/SrTiO_3$ superlattice. The weak ferromagnetic moment in the superlattice was indeed observed only for magnetic field parallel to the IrO_2 plane. This is consistent with the idea that weak moments originate from the Dzyaloshinskii-Moriya (DM) interaction associated with the in-plane rotation of IrO_6 octahedra. **Figure 1c** shows the temperature dependence of the magnetic X-ray diffraction intensity for the (0.5, 0.5, 5) peak measured at Ir L_3 edge with σ-π' polarization to extract the magnetic contribution [3]. Here, the unit cell dimensions are a × a × 2a (a ~ 0.39 nm). This peak shows the in-plane antiferromagnetic ordering. From these results, we conclude that an in-plane canted antiferromagnetism is realized in this superlattice, similar to the single layer perovskite Sr_2IrO_4.

Since magnetic diffraction with the integer c-axis index (0.5, 0.5, 5) was observed, the interlayer coupling of Ir local moments is ferromagnetic, in marked contrast to the bulk Sr_2IrO_4. This is naturally expected because the interlayer coupling of Ir moments through the hybridization with the inserted $SrTiO_3$ layer should give rise to a ferromagnetic Ir-Ir coupling regardless of whether the Ir-Ti coupling is ferromagnetic or antiferromagnetic. **Figure 1d** shows the obtained magnetic and lattice ordering pattern of this superlattice. Here, the IrO_6 octahedra in the two adjacent IrO_2 layers rotate in the same direction, which can account for ferromagnetic coupling of both canted moments and Ir moments.

The canted moment observed for the $SrIrO_3/SrTiO_3$ superlattice was 0.02 μ_B/Ir mol. This is ~1/4 of the 0.075 μ_B/Ir mol value in the bulk Sr_2IrO_4 [4], which implies the reduction of the local Ir moment and/or the reduction of DM interaction. The in-plane lattice constant a ~ 0.3905 nm for the superlattice sample is larger than the 0.3890 nm value for Sr_2IrO_4 [4] and therefore a smaller rotation of the IrO_6 octahedra is expected for the superlattice. We estimated a rotation angle of approximately 8° in the superlattice. The Ir-O-Ir bond closer to 180° in the superlattice should decrease the strength of the DM interaction and increase the bandwidth. The latter makes the system more itinerant and reduces the magnitude of the magnetic moments. We therefore conclude that the reduced distortion of the lattice is responsible for the reduced canted moments in the superlattice.

In summary, we performed a resonant X-ray diffraction study of the $SrIrO_3/SrTiO_3$ superlattice to determine the magnetic structure. We observed in-plane canted antiferromagnetism similar to the bulk Sr_2IrO_4, and ferromagnetic interlayer coupling in contrast to Sr_2IrO_4. These results show that we can design and realize novel electronic phases in the unit of the $SrIrO_3$ monolayer.

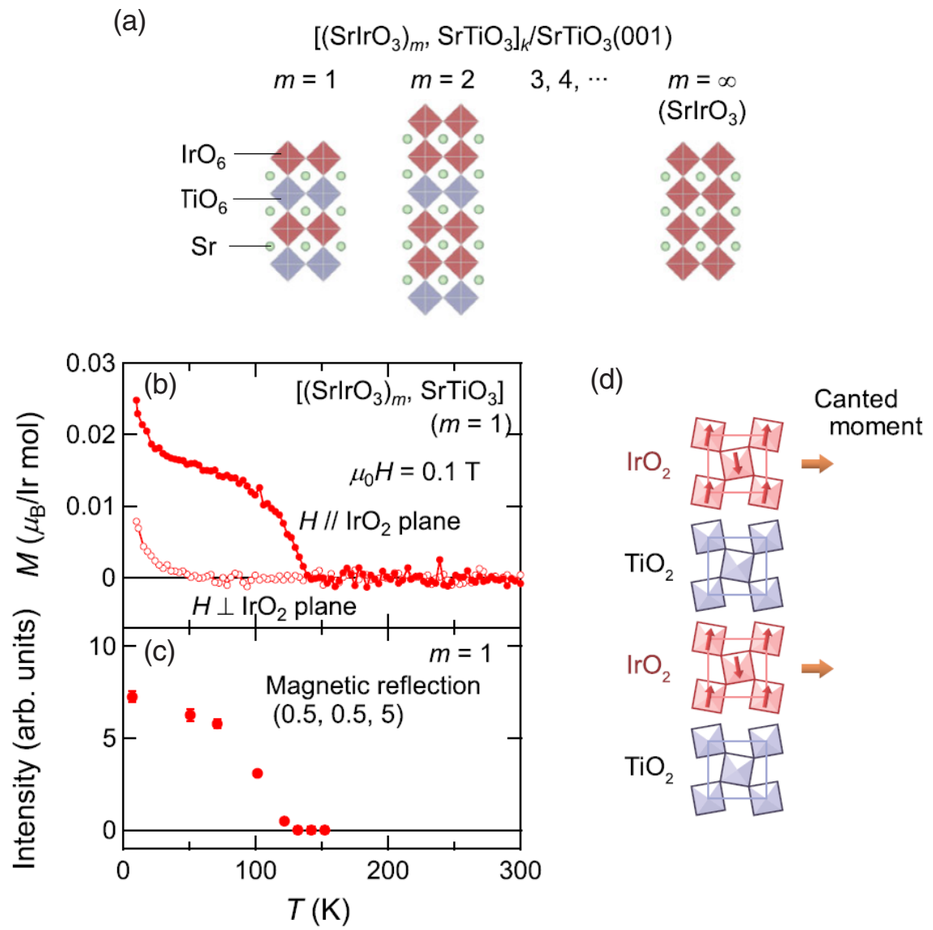

Figure 1: (a) Schematics of the superlattices $[(SrIrO_3)_m, SrTiO_3]$ (m = 1, 2, and ∞). **(b)** Temperature dependence of the magnetization measured at 0.1 T for the $SrIrO_3/SrTiO_3$ superlattice. **(c)** Temperature dependence of the magnetic X-ray diffraction intensity for the (0.5, 0.5, 5) peak. **(d)** Magnetic structures of the $SrIrO_3/SrTiO_3$ superlattice.

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