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Direct Observation of Spin-split Electronic Structures in Antiferromagnet NdBi by Laser-based SARPES

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Rare-earth monopnictides *RX* (*R*: Rare-earth, *X*: N. P, As, Sb, and Bi) have attracted much attention because of their topological electronic structures [1,2] and unusual magnetic transitions [3,4]. Recently, unconventional surface states have been reported in the antiferromagnet NdBi. The surface states, consisting of sharp Fermi-arc-like hole bands and electron bands near Fermi energy E_F, appear below the antiferromagnetic (AFM) transition at $T_N = 24$ K [5]. Density functional theory calculations suggest that the multi-q magnetic structures induce the surface states inside the band-folding hybridization bulk gap [6]. Although the discovery of the unconventional surface states stimulates intense discussion on their origin, the key information on the spin polarization is still missing.

Here, we investigated the electronic structure and the spin polarization of the unconventional surface states. The experiments were performed synchrotron-based angle-resolved photoemission spectroscopy (ARPES) by BL-1 and BL-9A and laser-based spin-resolved ARPES (SARPES) at Hiroshima Synchrotron Radiation Center. The Fermi surface in the paramagnetic state has a square and a surrounding rhomboid hole pocket centered in the Brillouin zone. On cooling below T_N, the electronic structure is reconstructed and the surface states appear, which is consistent with previous reports [7,8]. In addition, we successfully observed different electronic structures depending on the magnetic domain: while the electron bands were recognized along the k_x direction, those appear along perpendicular to the k_x direction in different measurement areas. To obtain the spin information of the surface state, we conducted SARPES measurements. It is revealed that spin polarization for the hole and electron bands emerging in the AFM state is the opposite: the hole and electron bands show negative and positive spin polarization, respectively. Moreover, the spin-resolved measurements of the in-plane spin component demonstrated spin polarizations exceeding ±50%. Our results fill the gap between experimental and theoretical studies and enable us to further understand the origin of the unconventional surface states.

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