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Making non-magnetic surfaces ferromagnetic

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It would be very interesting to make only the surface atomic layer ferromagnetic while keeping the substrate non-magnetic, because of physics on nano-scale magnetism as well as possible applications to spintronics. There may be two approaches for it. One is to imitate diluted magnetic metals/semiconductors in three-dimension by introducing magnetic impurities. The conduction electrons/holes mediate the magnetic interaction among the magnetic impurity adatoms. Another approach to make the surface magnetic may be to utilize spin-orbit coupling by combining the Rashba effect at surface. Due to the breakdown of inversion symmetry at surfaces, the spin degeneracy can be lifted at surface-state bands, and the bands can be spin-split.

In my talk, I will introduce some trials on these lines carried out in my group. To make a diluted magnetic surface, magnetic atoms such as Mn, Co, and Gd were deposited on metallic surface superstructures on Si(111) crystal, and STM and MCD were done. We expect RKKY interaction between the magnetic adatoms and surface-state electrons. But we have not yet obtained positive results. As for another approach using the Rashba effect, we have done spin- and angle-resolved photoemission spectroscopy (PES) of Bi(001) surface without magnetic impurities, and confirmed that the surface-state band is spin-split [1,2]. This is a first step to the goal. The ultrathin Bi(001) film was grown on Si(111) substrate, and the band dispersion of quantum-well state as well as the surface state was measured by PES, and compared with the first-principles calculations. The quantum-well states were spin-degenerated, while only the surface states were spin-split. Furthermore, we measured the electrical conductivity of the Bi film [3]. It was turned out that the conductivity of the ultrathin film mainly comes from the surface states due to their strong metallic character in contrast to the semi-metal character of the bulk. Therefore, we can expect spin-polarized current flowing through the spin-split surface-state bands.

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