学位論文要旨

Electronic structure and carrier dynamics of ferromagnetic shape memory alloys and topological insulators
(強磁性形状記憶合金とトポロジカル絶縁体の電子構造とキャリア
ダイナミックス)

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Recently, spintronics utilizing both change and spin degrees of freedom play a more and more important roles in the condensed matter physics. Many interesting spin-related materials including ferromagnetic shape-memory alloys and topological insulators, will be expected to contribute more to spintronics field.

Heusler type ferromagnetic shape-memory alloys exhibiting the first order structural transition are known to show a substantial magnetocaloric effect. This property is important to realize an environmentally friendly and energy-efficient technology with the potential to outperform conventional gas-compression refrigeration. It exhibits a structural transition so called martensitic phase transition (MPT) from austenite phase to martensite phase while cooling down and recovers while warming up, which is a key property for the magnetocaloric effect. To address the origin of the MPT, photoemission spectroscopy has been used to measure the electronic structure. Previous photoemission studies for Ni_2MnGa and $Ni_2Mn_{1+x}Sn_{1-x}$ systems showed that a sharp peak near the Fermi energy, which is attributed to the Ni 3d e_g states, was responsible for the phase transition. Further study showed that the hybridization between the Ni 3d e_g state and the 3d state of excess Mn atoms at Sn sites was the driving force for the instability of the cubic phase. $Ni_2Mn_{1+x}In_{1-x}$ have attracted much more attention due to its giant magneto-resistance and the substantial magnetocaloric effect, which is a key to the magnetic refrigeration at room temperature. Since the excess Mn spin couples parallel to the ordinary Mn spin in $Ni_2Mn_{1+x}In_{1-x}$, which is just opposite to the case of $Ni_2Mn_{1+x}Sn_{1-x}$, one expect that a different mechanism works for the phase transition. To study the change of electronic structure caused by martensite phase transition, we employed hard X-ray photoelectron spectroscopy for the $Ni_2Mn_{1+x}In_{1-x}$ with x=0, 0.12, 0.24 and 0.36. The sharp peak near the Fermi energy was observed in the martensite phase. It totally disappeared in the austenite phase. In sharp contrast to the

$Ni_2Mn_{1+x}Sn_{1-x}$ system, the shift of this peak was not observed. We have also measured the hysteresis behavior to confirm that the observed change of electronic structure was caused by the structural transition. The results show that the increasing/decreasing of the Ni-3d-e_g minority-spin-state peak is strongly related with the structural transition.

Three-dimensional (3D) topological insulators have gapless surface states protected by time-reversal symmetry. An odd number of massless Dirac cones (a single Dirac cone as the simplest case) with a helical spin texture in momentum space is a manifestation of the 3D topological insulators. After its discovery, topological insulators have attracted a great attention to future spintronic applications. Several topological insulators, like Bi2Se3, Sb2Te3, Bi2Te3and TlBiSe2, have been experimentally realized. Magnetically doped topological insulators (TIs) can open an energy gap at the Dirac point by breaking time-reversal-symmetry. It will lead to the quantized anomalous Hall (QAH) effect, which shows a great potential in the development of low-energy-consuming devices using electron spins. Though several candidates of magnetically doped TIs were demonstrated to show long-range magnetic order, QAH are realized only in the Cr/V-doped $(Sb,Bi)_2Te_3$ systems. In the second part of thesis, we studied the ultrafast electron dynamics of Sb_2Te_3 with the time-resolved angle-resolved photoemission spectroscopy (TrARPES). An hourglass effect induced by the low density of state near Dirac node is observed and it is reproduced by simulation. In the third part of thesis, we studied the elemental specified magnetic properties of magnetic doped topological insulator $V_{0.018}Sb_{1.98}Te_3$ with X-ray magnetic circular dichroism (XMCD). We find that long-range magnetic order is mediated by the p-hole carriers of the host lattice, and the interaction between the Sb (Te) p and V d states is crucial.