Angle-resolved photoemission spectroscopy of Dirac nodal-line superconductor $ZrSi_{1-x}P_xSe$

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Recently, Dirac line node (DLN) has been observed in the superconductor ZrPSe, which belongs to the nonsymmorphic space group, with the P square lattice as the glide plane, forming at E-EF = -1.2 eV [1,2]. On the other hand, the Dirac semimetal ZrSiSe with the glide plane as Si does not exhibit superconductivity, and its DLN is located near the Fermi level [3]. This indicates that the substitution of P with Si causes the emergence of superconductivity and the change in the electronic structure. Therefore, by observing the evolution of the electronic structure with x in the mixed crystal $ZrSi_{1-x}P_xSe$, it is expected that the mechanism of superconductivity in ZrPSe will be elucidated. In this study, we performed angle-resolved photoemission spectroscopy (ARPES) on single crystal samples of $ZrSi_{1-x}P_xSe$ (x = 0.2, 0.45, 0.72, 1) to directly observe the electronic structure.

Figure 1 (a) shows the Fermi surface at x = 0.72. Electron pockets at the Γ point and point, as well as two large Fermi surfaces (α, β), were observed. As the energy moves away from the Fermi energy, the α and β approach each other and form a diamond shaped DLN at -1.15 eV. On the other hand, the Fermi surface at x = 0.2 shown in Figure 1 (b) has no electron pockets, and the α and β approached each other, and a DLN is formed at -0.2 eV. This observation indicates that the energy of the DLN changes continuously with the change in the substitution amount.

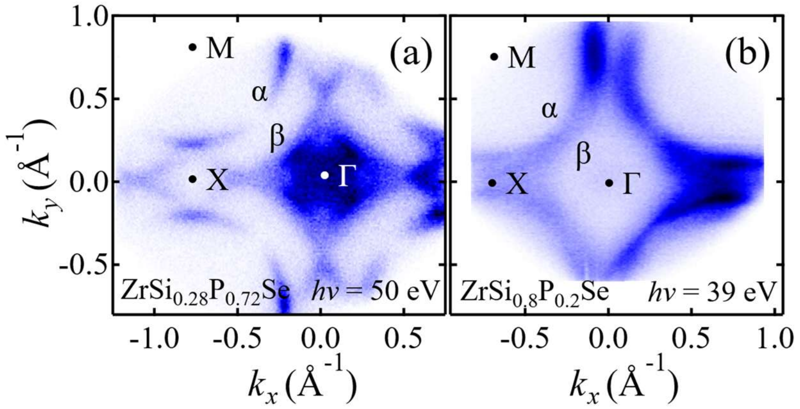

Figure 1: Fermi surface of $ZrSi_{1-x}P_xSe$, (a) x = 0.72 ($h\nu$ = 50 eV), (b) x = 0.2 ($h\nu$ = 39 eV)

In addition, the electron occupancy was determined from the area of the Fermi surface. For all Fermi surfaces (α, β, γ, ε), the electron occupancy increases as the amount of P increases. In particular, the increase is large for the α and β and small for the γ and ε. The total electron occupancy also increases with the amount of P . This means that the amount of change in the α and β accounts for most of the total change. This suggests that the P substitution introduces electrons into the DLN derived from the square lattice.

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