MgB$_2$: Novel properties due to multibands$^1$

GIRSH BLUMBERG, Bell Laboratories, Alcatel-Lucent

About 40 years ago A.J. Leggett proposed a new collective mode arising from cross-tunneling of Cooper pairs residing on different Fermi surfaces of a multiband superconductor: Leggett’s collective mode is caused by a counter flow of the interacting superfluids leading to small fluctuations of the relative phase of the condensates while the total electron density is locally conserved.$^2$ Here we present direct spectroscopic observation of the Leggett’s excitation in the MgB$_2$ superconductor containing two pairs of Fermi surfaces resulting from $\pi$- and $\sigma$-bands. Electronic Raman scattering studies have revealed three distinct superconducting (SC) features: (i) a clean threshold of Raman intensity at 4.6 meV consistent with the $\pi$-band SC gap; (ii) the SC pair breaking coherence peak at 13.5 meV consistent with excitations above the $\sigma$-band gap; and (iii) the SC collective mode at 9.4 meV which we assign to an excitation first discussed by Leggett.$^3$ Our calculation of the Raman response function for MgB$_2$ superconductor based on multiband interaction matrices by first principle computations show good agreement with spectroscopic observations. The temperature and field dependencies for all three features (i) – (iii) have been established; the effects of magnetic field on the pair cross-tunneling in multiband system will be discussed. In addition, anharmonicity and superconductivity-induced self-energy effects for the $E_{2g}$ boron stretching phonon have been studied.$^5$ We show that anharmonic two-phonon decay is mainly responsible for the unusually large linewidth of the $E_{2g}$ mode. We observe 2.5% hardening of the $E_{2g}$ phonon frequency upon cooling into the SC state and estimate the electron-phonon coupling strength associated with this renormalization.

$^1$In collaboration with A. Mialitsin, B.S. Dennis, M.V. Klein, N.D. Zhigadlo, and J. Karpinski.


