Charge Density Waves and Superconductivity in Uranium

J. BOUCHET[1], S. RAYMOND[2], M. LE TACON[3], G. GABARINO[3], M. HOESCH[3], M. KRISCH[3], J. C. LASHLEY[4], R. C. ALBERS[4], J-P RUEFF[5], G. LANDER[6]

[1]CEA, DAM, DIF Arpajon, France
[2]CEA-DSM, DRFMC, Grenoble, France
[3]European Synchrotron Radiation Facility, Grenoble, France
[4]Los Alamos National Laboratory, USA
[5]Synchrotron Soleil, Gif-sur-Yvette, France
[6]Institut Laue-Langevin, Grenoble, France

In the α-U phase there are remarkable phonon anomalies in the [100] direction[1]. At low temperature (T_0 = 43 K) a phase transition take place to a new complicated structure, which is described as a charge-density wave (CDW)[2]. Uranium is the only element discovered so far to exhibit such a phase transition at ambient pressure. As a function of pressure the CDW disappears at ~ 1.5 GPa[3], and, at the same pressure, the superconducting temperature reaches a maximum of ~ 2 K, and then decreases with further pressure[4]. Here we used inelastic x-ray scattering (IXS) to explore the behavior of the phonon anomalies in pressure and test the theoretical predictions[5].
Our experiments, performed at the ID28 beamline at the ESRF demonstrate the robustness of the calculations and confirm the disappearance of the soft mode under pressure.
Then, using density functional perturbation theory (DFPT) we calculate the electron-phonon coupling, the phonon linewidth and their evolution in pressure to discuss the interplay of charge-density waves and superconductivity in uranium. The theory predicts a maximum in T_c at pressures of ~ 1.5 GPa , observed in the 1970s, and associated with the suppression of the CDW.

[1] W. P. Crummett, H. G. Smith, R. M. Nicklow, and N. Wakabayashi, Phys. Rev. B **19**, 6028 (1979)
[2] H. G. Smith, N. Wakabayashi, W. P. Crummett, R. M. Nicklow, G. H. Lander, and E. S. Fisher, Phys. Rev. Lett. **44**, 1612 (1980)
[3] C. W. Chu and G. S. Knapp, Physics Lett. A **46**, 33 (1973)
[4] M. B. Maple and D. Wohlleben, Physics Lett. A **38**, 351 (1972)
[5] J. Bouchet, Phys. Rev. B **77**, 024113 (2008)

E-mail for corresponding author: johann.bouchet@cea.fr