The charge distribution in high-Tc superconductors studied by X-ray absorption spectroscopy

Izabela Biało (AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, 30-059 Krakow, Poland), Wojciech Tabiś (Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria), Neven Barisic (Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria), Martin Greven (School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA), Andrzej Kozłowski (AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, 30-059 Krakow, Poland)

izabela.bialo@fis.agh.edu.pl

The mechanism of high temperature (high-T_c) superconductivity stays undiscovered for last thirty years. A major difficulty in understanding high-T_c systems is the complexity of the materials, the presence of strong electron-electron interplays, and their rich phase diagrams. The delicate balance among a number of coexisting phases makes it hard to identify the principal interactions. High magnetic fields play an important role in studying the high-T_c phenomenon, because such fields suppress the superconducting state and enable the exploration of competing states in the normal state (e.g., in the absence of superconductivity).

First, using polarization dependent X-ray absorption spectroscopy at the O *K*- and Cu *L*-edges, the doping-induced empty states symmetry and distribution in the superconductor $HgBa_2CuO_{4+\delta}$ is studied as a function of the effective hole concentration p. Furthermore, X-ray absorption spectroscopy at the Cu *K*-edge was used to study the origin of the magnetic field induced three-dimensional charge density wave (CDW) order in the cuprate superconductors.

The results confirm that the doping-induced holes have predominantly O2*p* character. We find that the planar $O2p_{x,y}$ hole occupancy increases linearly with doping on the underdoped side of the phase diagram, levels off near p = 0.10, coincident with the doping at which the CDW correlations disappear [1].We have furthermore studied the impact of magnetic field on CDW order in a number of cuprates. While changes in the absorption spectra were observed upon applying magnetic field in orthorhombic $YBa_2Cu_3O_{6+\delta}$ (YBCO), no impact of the magnetic field on the absorption spectra was detected in the other systems. The onset of the field induced changes in the spectra is consistent with the value of the magnetic field above which the three-dimensional charge correlations were detected via X-ray diffraction [2,3]. The energy range of the spectra where the changes were observed corresponds to the Cu-states within the unidirectional Cu-O chains, characteristic to YBCO.

The results suggest a prominent role of out-of-plane oxygen holes in bringing about the superconductivity and an inherent electronic instability as optimal doping is approached. We also conclude, that the magnetic field induced charge correlations are specific to YBCO, due to the existence of the Cu-O chains, and not generic to the cuprate superconductors.

References:

[1] W. Tabis et al., Phys. Rev. B. 2017, 96:134510

[2] S. Gerber et al., Science. 2015, 350(6263):949-52

[2] J. Chang et al., Nature Comm. 2016, 11494