LA-UR-17-24526

Title: Magnet Lab Highlight: Upper critical field reaches 90 tesla near the Mott transition in fulleride superconductors

Author(s): Mcdonald, Ross David

Intended for: Report

Issued: 2017-06-05

Upper critical field reaches 90 tesla near the Mott transition in fulleride superconductors

Y. Kasahara[1], Y. Takeuchi[2], R.H. Zadik[3], Y. Takabayashi[4], R.H. Colman[3], R.D. McDonald[5], M.J. Rosseinsky[6], K. Prassides[4,7] & Y. Iwasa[2,8]

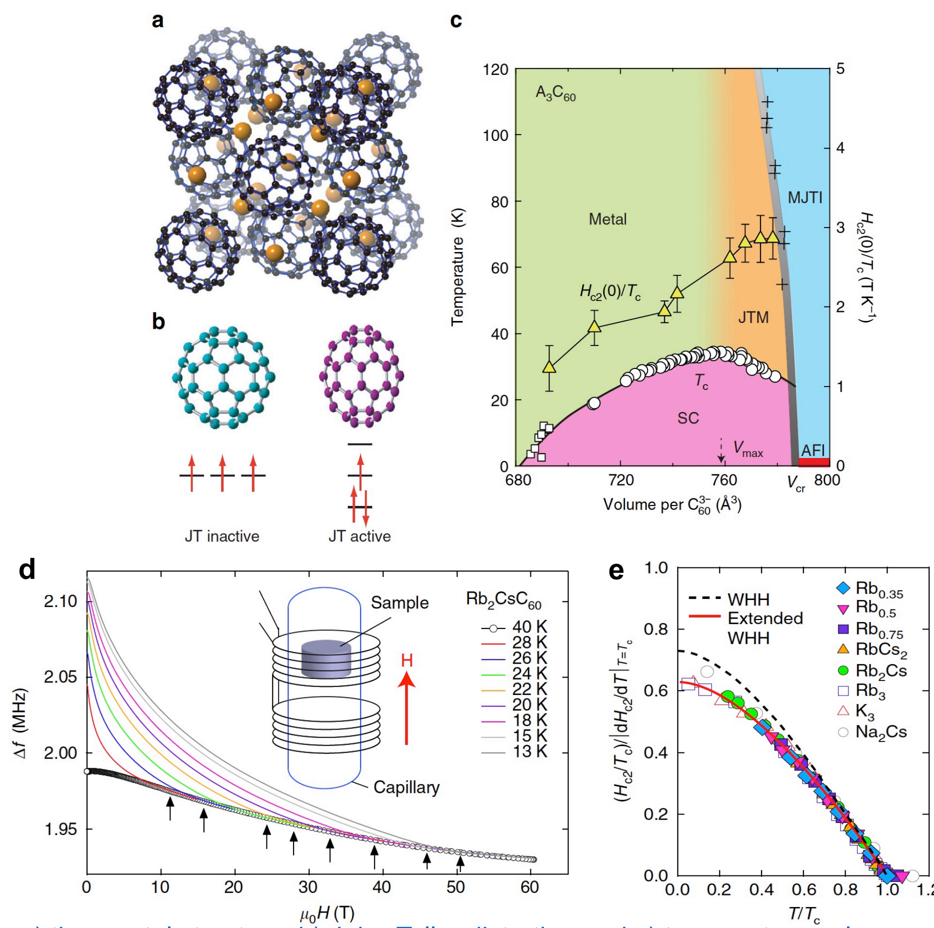
[1] Kyoto University, Japan [2] QPEC & University of Tokyo, Japan [3] Durham University, UK [4] WPI-Tohoku University, Japan [5] NHMFL,-LANL USA [6] University of Liverpool, UK [7] JST-Tohoku University, Japan [8] RIKEN –CEMS, Japan;

Funding Grants: G.S. Boebinger (NSF DMR-1157490);

The alkali-doped fullerides provide the first example of a transition from a three-dimensional Mott insulator to a superconductor, enabling the effects of both dimensionality and electron correlation on superconductivity to be explored. Chemically the alkali species tunes the superconductivity in the vicinity of the the Mott transition via sample volume.

Measuring the relationship between the superconducting transition temperature and upper critical field reveals a crossover from weak- to strong-coupling associated with the dynamical Jahn–Teller effect as the Mott transition is approached. The use of pulsed magnets is required because the upper critical field is enhanced in the vicinity of the Mott insulating phase, reaching 90 T for $Rb_xCs_{3-x}C_{60}$ — the highest among cubic crystals. This required close collaboration between Prof Kasahara's group and the Mag Lab to design *rf*-measurements compatible with sample encapsulation in an inert atmosphere.

The concomitant increase of pairing strength with lattice volume near the Mott transition suggest that the cooperative interplay between molecular electronic structure and strong electron correlations plays a key role in realizing robust superconductivity (with high-T_C and high-H_{C2}).



a) the crystal structure, b) Jahn-Teller distortion and c) temperature-volume phase diagram of the A_3C_{60} family of superconductors. d) the upper critical field measured via the *rf*-frequency shift and e) unified H_C/T_C scaling for all alkali metal compositions.

Facilities: Pulsed Field Facility, short pulse magnet systems.

Citation: 'Upper critical field reaches 90 Tesla near the Mott transition in fulleride superconductors' Y. Kasahara, Y. Takeuchi, R.H. Zadik, Y.Takabayashi, R.H. Colman, R.D. McDonald, M. J. Rosseinsky, K. Prassides & Y. Iwasa – Nature Communications 14467. January 2017.

Upper critical field reaches 90 tesla near the Mott transition in fulleride superconductors

Y. Kasahara[1], Y. Takeuchi[2], R.H. Zadik[3], Y. Takabayashi[4], R.H. Colman[3], R.D. McDonald[5], M.J. Rosseinsky[6], K. Prassides[4,7] & Y. Iwasa[2,8]

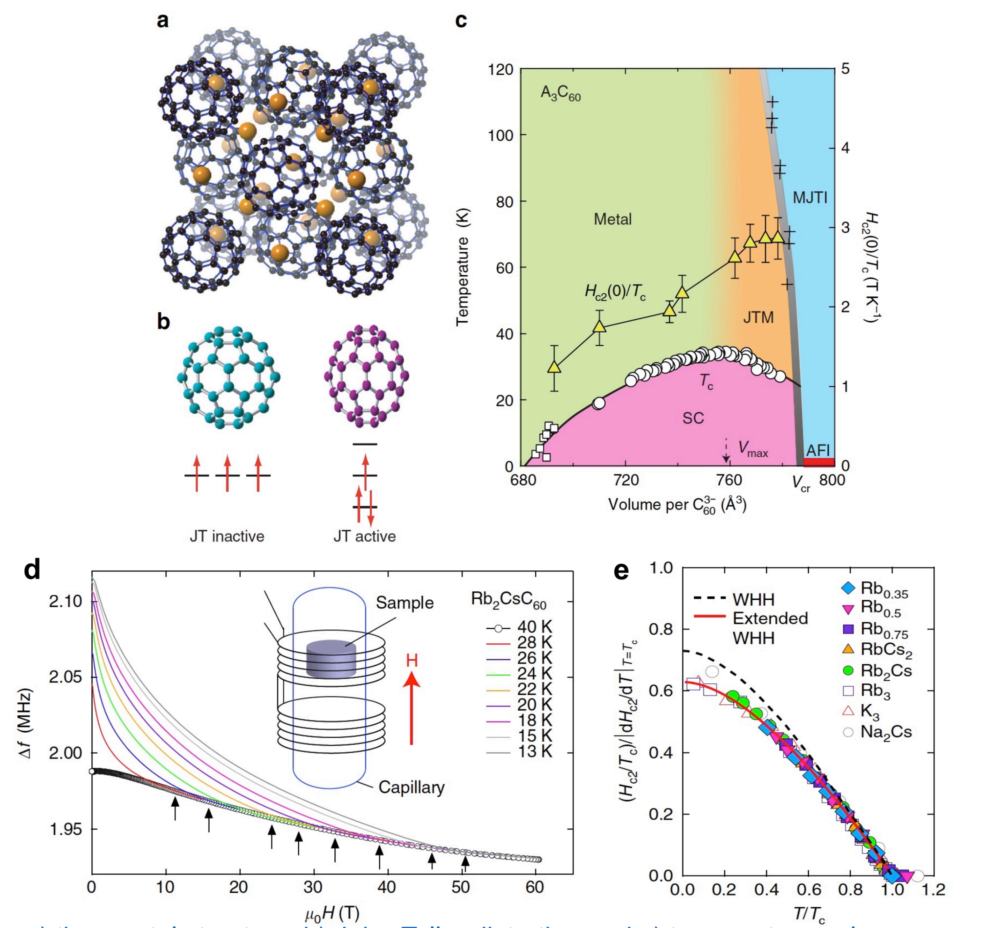
[1] Kyoto University, Japan [2] QPEC & University of Tokyo, Japan [3] Durham University, UK [4] WPI-Tohoku University, Japan [5] NHMFL,-LANL USA [6] University of Liverpool, UK [7] JST-Tohoku University, Japan [8] RIKEN –CEMS, Japan;

Funding Grants: G.S. Boebinger (NSF DMR-1157490); R.D. McDonald (DOE-BES 'Science of 100T'); Author(XXXXXXXXX)

What is the finding? These measurements discovered that in addition to chemical pressure tuning between a Mott insulator (blue region) and superconductor (pink dome) in three dimensional materials (all other unconventional high T_C superconductors exhibiting this relationship are two dimensional), the interaction strength (as measured by the ratio of H_{C2} to T_C) increases in the vicinity of the phase transition.

Why is this important? Understanding the relationship between the strength of the electronic interactions and superconductivity helps scientists *design* more robust superconductors in the future.

Why did this research need the MagLab? For the fulleride superconductors closest to the Mott insulating state, suppressing superconductivity requires extreme magnetic fields. Furthermore, the air sensitivity of the samples required novel *rf*-instrumentation compatible with sample encapsulation to developed at the Mag Lab.



a) the crystal structure, b) Jahn-Teller distortion and c) temperature-volume phase diagram of the A_3C_{60} family of superconductors. d) the upper critical field measured via the *rf*-frequency shift and e) unified H_C/T_C scaling for all alkali metal compositions.

Facilities: Pulsed Field Facility, short pulse magnet systems.

Citation: 'Upper critical field reaches 90 Tesla near the Mott transition in fulleride superconductors' Y. Kasahara, Y. Takeuchi, R.H. Zadik, Y.Takabayashi, R.H. Colman, R.D. McDonald, M. J. Rosseinsky, K. Prassides & Y. Iwasa – Nature Communications 14467. January 2017.