Superconductivity at 250 K in lanthanum hydride under high pressures

A. P. Drozdov1, P. P. Kong1, V. S. Minkov1, S. P. Besedin1, M. A. Kuzovnikov1,6, S. Mozaffari2, L. Balicas2, F. F. Balakirev3, D. E. Graf2, V. B. Prakapenka4, E. Greenberg4, D. A. Knyazev1, M. Tkacz5, and M. I. Eremets1

1Max-Planck Institut für Chemie, Hahn-Meitner Weg 1, 55128 Mainz, Germany
2National High Magnetic Field Laboratory, Florida State University, Tallahassee, Florida 32310, USA
3NHMFL, Los Alamos National Laboratory, MS E536, Los Alamos, New Mexico 87545, USA
4Center for Advanced Radiation Sources, University of Chicago, 5640 South Ellis Avenue, Chicago, Illinois, 60637, USA
5Institute of Physical Chemistry PAS, Kasprzaka 44/52, 01-224 Warsaw, Poland
6Institute of Solid State Physics RAS, Chernogolovka, Moscow District, 142432 Russia

Keywords: high pressure, superconductivity, hydrides.

e-mail: a.drozdov@mpic.de

The discovery of superconductivity at 203 K in H3S [1] returned attention to conventional superconductors whose properties can be described by the Bardeen-Cooper-Schrieffer (BCS) and the Migdal-Eliashberg theories. These theories predict that room temperature superconductivity (RTSC) is possible in metals possessing certain favorable properties, such as lattice vibrations at high frequencies. However, these general theories are insufficient to predict the properties of real superconductors. Such predictions can now be made with the aid of first principles calculations based on Density Functional Theory (DFT). In particular, the DFT-based calculations suggested a new family of hydrides possessing a clathrate-like structure, where the host atom (Ca, Y, La) is at the center of the cage formed by hydrogen atoms [2-4].

These superhydrides can be considered to be doped versions of metallic hydrogen and therefore are expected to have high $T_c$s. Indeed, DFT predicts a $T_c$ of 235 K at 150 GPa for CaH6, $T_c = 305–326$ K at 250 GPa [3] (or 303 K at 400 GPa) for YH10, and a $T_c$ $\sim$ 280 K at $\sim$ 200 GPa for LaH10.

In the present work we performed an extensive search for superconductivity in the lanthanum hydrides. The samples were synthesized directly from lanthanum or LaH3 and hydrogen under high pressure. We have found superconductivity with a record $T_c$ $\sim$ 250 K within the $Fm-3m$ structure of LaH10 at a pressure P $\sim$ 170 GPa [6]. We demonstrated the existence of superconductivity at 250 K through the observation of zero-resistance, the isotope effect, and the decrease of $T_c$ under an external magnetic field, which suggests an upper critical magnetic field of $\sim$136 T at zero temperature. This jump of $\sim$50 K above the previous $T_c$ record of 203 K is encouraging for achieving room temperature superconductivity in the near future.