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•Editorial•
Editor's Focus

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Superconductivity of lutetium polyhydride at megabar high-pressure scale

The research on high-temperature superconductivity (SC) in polyhydrides at an experimentally accessible megabar high-pressure scale [1-8] has initiated a growing interest in exploring new high-T_c superconductors of polyhydrides.

A number of polyhydrides, such as sulfur [1], lanthanum [2], calcium [3,4], zirconium [5], hafnium [6], and tin hydrides [7], have been synthesized, showing superconducting-like properties at megabar pressure. Lutetium shares a similar profile with lanthanum in terms of electronegativity and the ability to dope electrons that enhance dissociating hydrogen molecules into atoms since its full filled *f* shell. Hence, lutetium polyhydrides are expected to host high-T_c SC. Recently, Li et al. [8] discovered a lutetium polyhydride SC with a T_c of 71 K at 218 GPa, a pressure scale comparable to those reported for other polyhydride SC.

The new lutetium polyhydride was synthesized at ~200 GPa and 1000°C temperature using a diamond anvil cell in combination with an *in situ* laser heating technique. They measured the electrical conductance as a function of temperature of the sample at the same pressure. The transitions shift to low temperature in an applied magnetic field consistent with what is naturally expected for SC. The structure investigation based on a high-pressure synchrotron platform suggests that the superconducting transition could be ascribed to the presence of the Lu_4H_{23} phase with $Pm\bar{3}n$ symmetry, where there exist two types of hydrogen cages, i.e., H_{20} and H_{24}. The shortest H–H bond length in the Lu_4H_{23} phase is ~1.23 Å. Such H–H bond length is within the range of 1.0–1.5 Å for other typical high-T_c polyhydride superconductors studied so far.

The Lu_4H_{23} superconductor showed obvious differences from the N-doped lutetium hydride of $LuH_{3-x}N_y$ that was recently claimed to be a room-temperature SC at a pressure of 1 GPa (*Nature* 615, 244 (2023)). These differences are as follows: (I) Lu_4H_{23} has much more hydrogen in the unit cell (nearly six hydrogen atoms/Lu atom); (II) Lu_4H_{23} can only be stabilized at megabar pressure at the moment, while $LuH_{3-x}N_y$ is claimed to be stable at 1 GPa; and (III) the H–H bond length in Lu_4H_{23} is reasonable in the context of other reported polyhydride superconductors, while the H–H distance in $LuH_{3-x}N_y$ (~2.17 Å) is significantly larger and comparable with that of the solid hydrogen molecule (~2.65 Å). Hence, it is difficult to understand how electrons coherently hop between hydrogen ions at such a far distance.

The discovery of a superconducting binary lutetium polyhydride presents a new example of polyhydride SC that also raises strong doubts about the nearly ambient SC in $LuH_{3-x}N_y$ reported recently.

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