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RESEARCH HIGHLIGHT

Near-room-temperature superconductivity in hydrogen sulfide

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Room-temperature superconductivity has been a long-held dream and an area of intensive research, despite the common belief—based on more than a century of work in the field—that the highest temperature at which phonon-mediated superconductors can work is only 40 K. Drozdov *et al.*[1] of the Max Planck Institute in Mainz, Germany, has reported surpassing this traditional limit, demonstrating that hydrogen sulfide under a pressure of 1.5 million atmospheres exhibits phonon-mediated superconductivity at 203 K. This discovery opens the door to achieving room-temperature superconductivity in compressed hydrogen-rich materials.

In 1911 a Dutch physicist, Heike Kamerlingh Onnes, observed superconductivity (i.e., conduction of electricity without resistance) below 4 K in solid mercury. Since then, considerable attention has been paid to the goal of achieving superconductivity at ever-higher temperatures for practical use.

In the following century, research effort was devoted mainly to unconventional cuprate and iron-based superconductors, whose superconducting mechanism is not yet fully understood. These putative 'high-temperature' superconductors were believed to represent the sole hope for achieving room-temperature superconductivity. Conventional superconductors follow the Bardeen–Cooper–Schrieffer theory;[2] their superconductivity arises from their acting as superfluids via electron pairing mediated by the exchange of phonons. The highest superconducting transition temperature of 39 K was observed in MgB_2, a finding that led physicists to believe that conventional superconductivity cannot occur above 40 K.

The search for superconductivity in pressurized hydrogen-rich materials was initiated by Ashcroft,[3] who proposed that hydrogen-rich materials, once metalized, have the potential to become high-temperature superconductors. Hydrogen, having the lightest atomic mass, gives these materials the high Debye temperatures necessary for high-temperature phonon-mediated superconductivity.

Solid hydrogen sulfide (H_2S) has not previously been considered a superconductor because, upon metallization under pressure, it was believed to dissociate into its constituent elements. Recent theoretical work[4] indicated that such dissociation would not occur and predicted that H_2S pressurized at 1.6 million atmospheres would show superconductivity at temperatures above 80 K. This led to the practical work of Drozdov *et al.*,[1] who found that H_2S compressed in a diamond anvil cell exhibited two astonishing superconductive states at pressures above 1 million atmospheres: the superconductivity ranging from 30 to 150 K measured in the low-temperature runs (Fig. 1)[1] relates to H_2S, as it is consistent with calculations;[4] the highest superconductivity of 203 K was achieved in samples annealed at the room temperature (Fig. 2).[1] The transition temperature showed a pronounced isotope effect, indicating phonon-mediated superconductivity. The 203 K superconductivity is probably associated with a stoichiometric change to H_3S that was predicted to be a high-temperature superconductor[5] due to the decomposition of H_2S under pressure.

The work by Drozdov *et al.*[1] has disproved the conventional wisdom regarding the 40 K superconduction limit of phonon-mediated superconductors, and, more significantly, it supports the general idea of high-temperature superconductivity in hydrogen-rich materials. A broad range of hydrogen-rich materials is ready for exploration, and they offer the tantalizing prospect of the imminent development of room-temperature superconductors.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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