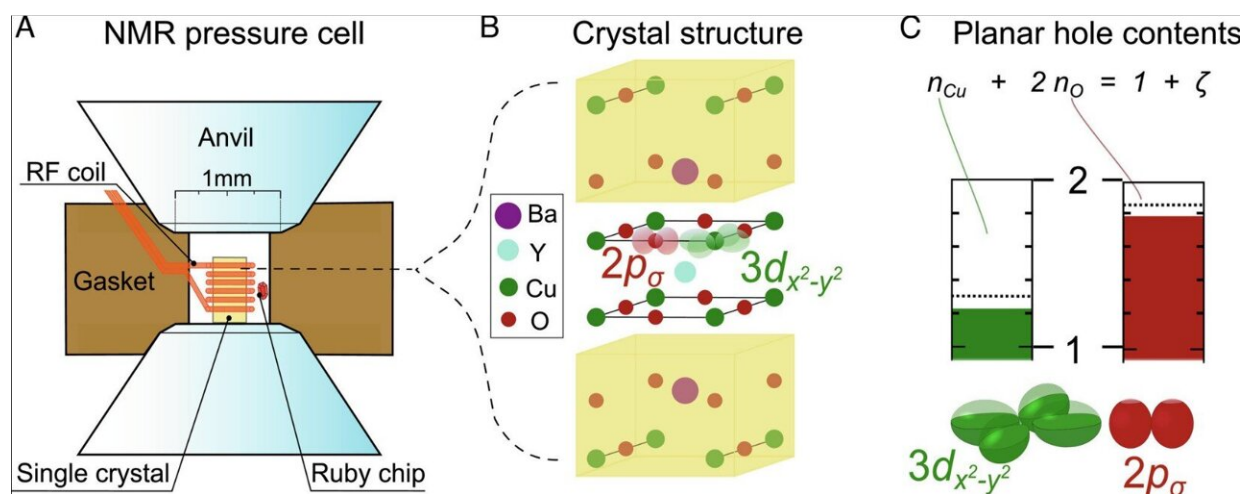


Researchers gain deeper understanding of mechanism behind superconductors

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Anvil cell high-pressure exerted on $\text{YBa}_2\text{Cu}_3\text{O}_{6+y}$ changes the charges in the CuO_2 plane. (A) Schematic of the anvil cell used for NMR; the microcoil surrounds the single crystal of about 1 nano-L volume, and both are placed in the high-pressure chamber with a ruby chip as an optical pressure gauge. (B) Sketch of the crystal structure of $\text{YBa}_2\text{Cu}_3\text{O}_{6+y}$ with highlighted bonding orbitals in one of the CuO_2 planes. (C) The hole content of these bonding orbitals can be measured with Cu and O NMR quadrupole splittings; see Methods. From the measured hole contents for Cu (n_{Cu}) and O (n_{O}), the total doping measured by NMR, ζ , follows ($1 + \zeta = n_{\text{Cu}} + 2n_{\text{O}}$). Credit: *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2215458120

Physicists at Leipzig University have once again gained a deeper understanding of the mechanism behind superconductors. This brings

the research group led by Professor Jürgen Haase one step closer to their goal of developing the foundations for a theory for superconductors that would allow current to flow without resistance and without energy loss. The researchers found that in superconducting copper-oxygen bonds, called cuprates, there must be a very specific charge distribution between the copper and the oxygen, even under pressure.

This confirmed their own findings from 2016, when Haase and his team developed an experimental method based on [magnetic resonance](#) that can measure changes that are relevant to superconductivity in the structure of materials. They were the first team in the world to identify a measurable material parameter that predicts the maximum possible [transition temperature](#)—a condition required to achieve superconductivity at [room temperature](#). Now they have discovered that cuprates, which under pressure enhance superconductivity, follow the charge distribution predicted in 2016. The researchers have published their new findings in the journal *PNAS*.

"The fact that the transition temperature of cuprates can be enhanced under pressure has puzzled researchers for 30 years. But until now we didn't know which mechanism was responsible for this," Haase said. He and his colleagues at the Felix Bloch Institute for Solid State Physics have now come a great deal closer to understanding the actual mechanism in these materials.

"At Leipzig University—with support from the Graduate School Building with Molecules and Nano-objects (BuildMoNa)—we have established the basic conditions needed to research cuprates using nuclear resonance, and Michael Jurkutat was the first doctoral researcher to join us. Together, we established the Leipzig Relation, which says that you have to take electrons away from the oxygen in these materials and give them to the copper in order to increase the transition temperature. You can do this with chemistry, but also with pressure. But hardly

anyone would have thought that we could measure all of this with nuclear resonance," Haase said.

Their current research finding could be exactly what is needed to produce a superconductor at room temperature, which has been the dream of many [physicists](#) for decades and is now expected to take only a few more years, according to Haase. To date, this has only been possible at very low temperatures around minus 150 degrees Celsius and below, which are not easy to find anywhere on Earth. About a year ago, a Canadian research group verified the findings of Professor Haase's team from 2016 using newly developed, computer-aided calculations and thus substantiated the findings theoretically.

Superconductivity is already used today in a variety of ways, for example, in magnets for MRI machines and in nuclear fusion. But it would be much easier and less expensive if superconductors operated at room temperature. The phenomenon of superconductivity was discovered in metals as early as 1911, but even Albert Einstein did not attempt to come up with an explanation back then. Nearly half a century passed before BCS theory provided an understanding of superconductivity in metals in 1957. In 1986, the discovery of superconductivity in [ceramic materials](#) (cuprate superconductors) at much higher temperatures by physicists Georg Bednorz and Karl Alexander Müller raised new questions, but also raised hopes that [superconductivity](#) could be achieved at room temperature.

More information: Michael Jurkutat et al, How pressure enhances the critical temperature of superconductivity in $\text{YBa}_2\text{Cu}_3\text{O}_{6+y}$, *Proceedings of the National Academy of Sciences* (2023). [DOI: 10.1073/pnas.2215458120](https://doi.org/10.1073/pnas.2215458120)

Provided by Leipzig University

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