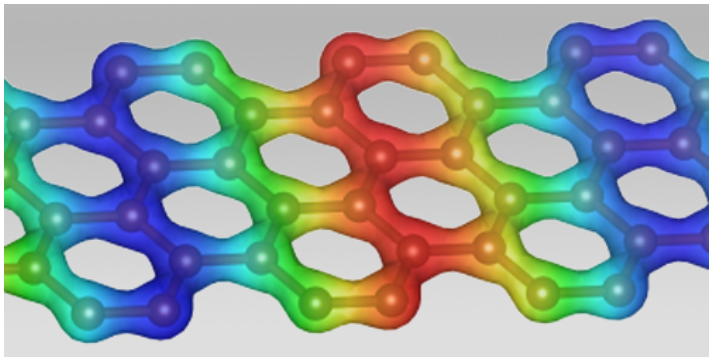
Calculating Superconductors from Scratch

A new formalism yields the quantities that characterize a conventional superconductor without adjustable parameters.

By **Charles Day**

Besides the critical temperature (T_c), below which current flows without resistance, two other quantities characterize a superconductor's nature and usefulness: coherence length and penetration depth. Coherence length ξ corresponds to the diameter of the electron-pair units that carry supercurrent. Penetration depth λ is the distance that a magnetic field can reach into a superconductor before a supercurrent-induced field cancels it. Now Mitsuaki Kawamura of Yokohama National University in Japan and his colleagues have calculated both ξ and λ for seven different conventional superconductors from scratch—that is, using the materials' atomic components and crystal structures as ingredients [**1**]. Their computational coup could enable researchers to prospect for new superconductors.

In a typical superconductor, ξ and λ are tens to hundreds of nanometers, distances that encompass so many atoms that first-principles calculation is computationally impractical. The standard thermodynamic theory of Ginzburg and Landau readily handles those scales but without microscopic resolution. Kawamura and colleagues bridged the gap in scales by finding a superconducting state that both macroscopic Ginzburg-Landau theory and microscopic first-principles theory can describe: one whose electron pairs have low momentum and whose wave functions vary slowly in space.



Credit: M. Kawamura/Yokohama National University

Kawamura and colleagues applied their approach to accurately determine ξ, λ, and T_c for five elemental superconductors and two compound superconductors, one of which—hydrogen sulfide—superconducts only at pressures above 100 gigapascals. The researchers' work thus provides a way to characterize superconductivity under extreme conditions, where measuring ξ and λ is difficult. What's more, the quotient ξ/λ determines whether a superconductor expels a magnetic field or can host one. Using the new approach, researchers may be able to discover new superconducting electromagnets before performing experiments.

Charles Day is a Senior Editor for ***Physics Magazine***.

REFERENCES

1. M. Kawamura *et al.*, "First-principles calculation of coherence length and penetration depth based on density functional theory for superconductors," **Phys. Rev. Lett. 137, 196001 (2026).**