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Quantum circuits as a tool in materials science: using imperfect devices to build better quantum technology

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Superconducting electronics are one of the best understood and most promising platforms for realising quantum information processing. Unfortunately they suffer from the presence of defects and imperfections. These include uncontrolled two-level systems, which reside in the materials used to construct them. These defects can lead to loss of energy, coherence, device aging and imperfect control pulses.

Interestingly, this observation is directly related to a much older and well-known problem from solid-state physics; what is the origin of the two-level defects thought to dominate the behaviour of amorphous glasses at very low temperatures? At present the precise microscopic origin of these defects remains a mystery, but recent work both experimental and theoretical, is bringing us closer to an answer.

Using superconducting qubits as probes of metallic oxide thin films has opened up new opportunities to study individual two-level defects. New experiments have surveyed and characterised individual defects, as well as studying their electric field, temperature and strain dependence. Direct coupling between individual defects has also been measured for the first time. The next generation of experiments combined these ideas with acoustic probes of defect dynamics, neutron scattering experiments, models of dielectric breakdown and even probes of cosmic ray flux.

In this way, new information is being obtain about defects in amorphous materials. This not only improves low temperature electronics, it moves us closer to large scale fault tolerant quantum computers, as well as increasing our understanding of this critically important phase of matter.

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