Graphene and carbon nanotubes in quantum computing for the development of scalable qubit architectures

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ABSTRACT

The power within quantum computing has the potential to revolutionize computation by solving problems classical computers couldn't by miles. Even if they could, it would take so long. Google's 2019 53-qubit Sycamore quantum processor solved a circuit sampling problem in 200 seconds while the fastest supercomputer at that time would take approximately 10,000 years to complete that same task. However when it comes to scalability in quantum hardware, it shows itself as a critical challenge whether it be through decoherence or hardware limitations. Nanomaterials such as graphene and carbon nanotubes (CNTs) have unique electronic, mechanical and thermal properties, making them worthy for next gen qubit architectures. The following paper explores how graphene and CNTs contribute and have the potential to contribute to the growth of quantum computing through enhancement of qubit coherence times, reduced error rates and better scalability thanks to their physical properties.

INTRODUCTION

Quantum computing is used for complex problem solving that is currently intractable for traditional computers by using principles such as superposition and entanglement in order to perform computations, resulting in exponentially faster computation (Brown et al., 2021). Despite the significant progress in said type of computing, the development of stable and scalable qubits remains a turbulence due to decoherence and error correction issues. The carbon nanomaterials, graphene and CNTs (rolled up graphene) exhibit great electrical conductivity, minimal decoherence and excellent mechanical strength, making them possible fit for the future of scalable qubit architectures for quantum computing (Brown et al., 2021). This paper discusses the role of graphene and CNTs in overcoming such scalability challenges in quantum computing.

PROPERTIES

Graphene and CNTs possess unique properties that make them suitable for quantum computing (Benjamin et al., 2025). Graphene has a high electrical conductivity, having near-ballistic transport and reducing energy dissipation. It also has low decoherence rates as graphene qubits demonstrate longer coherence times due to weak spin-orbit coupling and low nuclear spin density. CNTs have exceptional mechanical stability, which improves their qubit integration and reduces external noise interference. Examples of this noise interference are Wi-Fi signals. Due to their nanoscale size, these nanomaterial-based qubits enable high density qubit arrays, meaning more qubits in less space, fit for scalable quantum processors (Benjamin et al., 2025).

CONTEXT OF GRAPHENE AND CNTs IN QUBIT ARCHITECTURES

Graphene-Based Qubits

Graphene quantum dots have been presented for qubit platforms due to their tunable bandgap and charge transport properties. Graphene Josephson junctions (a device that connects two superconducting materials with a thin layer of a non-superconducting material) enable superconducting qubits.

Carbon Nanotube Qubits

CNTs have been researched as single-electron transistors for such applications, exhibiting loyal quantum gate operations (Johnson & Lee, 2023). CNT-based spin qubits show reduced error rates due to the low spin-orbit coupling and hyperfine interactions. Both Graphene and CNTs can be integrated for making hybrid qubit architectures, harnessing the advantages of both materials which leads to better performance and scalability (Smith at el, 2022).

CHALLENGES AND FUTURE DIRECTIONS

While these nanomaterials showcase promising paths for scalable quantum computing, several challenges remain. Fabrication challenges, precise placement and control of these nanomaterials require advanced nanofabrication techniques (Kim et al., 2022). Then there is the issue of decoherence reduction: although coherence times are great, further improvements are needed to match the performance of leading qubit technologies. Lastly, compatibility with current superconducting qubit structures must be addressed in order to continue with seamless adoption of these technologies (Kim et al., 2022).

CONCLUSION

Graphene and carbon nanotubes showcase a promising frontier in quantum computing, offering unique advantages thanks to their excellent properties for the development of scalable qubit architectures. Their great electrical, thermal and mechanical properties provide an avenue to reduce decoherence and enhance qubit fidelity. While technical challenges remain, ongoing research in material engineering is expected to unlock the full potential of carbon-based qubits.

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