Carbon Materials for Quantum Technologies

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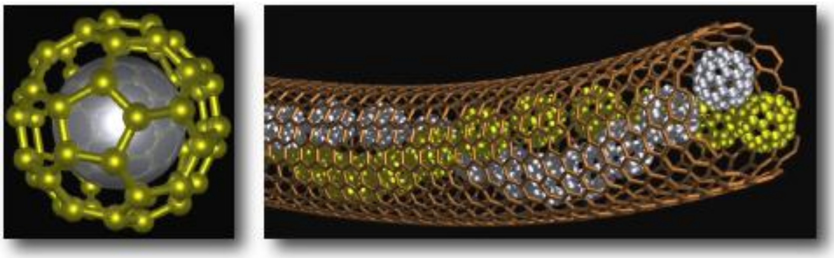
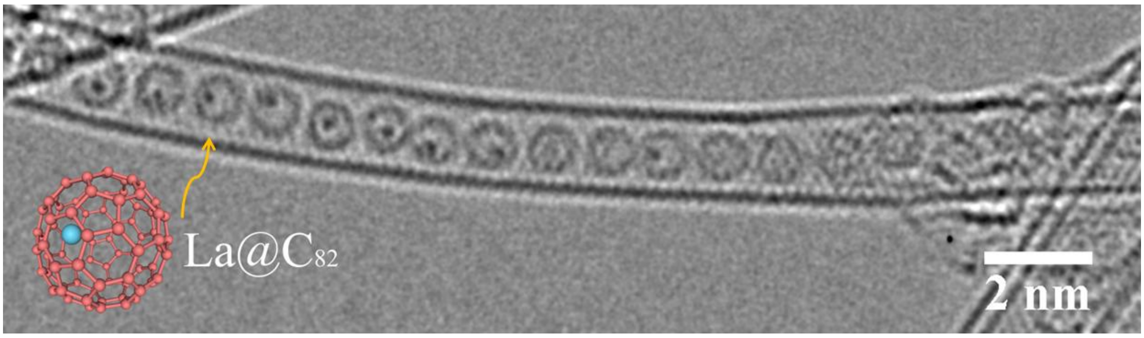


Courtesy of Dr Simon Benjamin

Carbon materials can support quantum superposition and entanglement for practical technologies. Superposition incorporates a phase with information content surpassing any classical mixture. Entanglement offers correlations stronger than any which would be possible classically. Together these give quantum computing its spectacular potential, but earlier applications may be found in metrology and sensing. Fundamental progress is being made in the development of quantum devices incorporating electron and nuclear spins which can be controlled with high precision.[1]



Courtesy of Dr Jamie Warner

Carbon nanomaterials can be structurally characterised with resolution approaching half the length of a carbon-carbon bond.[2,3] Fullerene molecules can be assembled in carbon materials for quantum technologies.[4] N@C_{60} contains a single nitrogen atom in a cage of sixty carbon atoms, whose spin superposition states are coherent for hundreds of microseconds.[5] Other endohedral fullerenes can be almost as good.[6] Information can be transferred from electron to nuclear spins and back again to give even longer memory times,[7] and can be stored and retrieved holographically in collective spin states.[8] Small tip-angle excitations can be used to demonstrate many of the fundamental principles.[9] Correlated spins can be used for magnetic field sensors that surpass the standard quantum limit.[10] Devices can be made with sensitivity to a coupled electron spin.[11]

The way is open for solid state technologies using the remarkable resources of quantum superposition and entanglement,[12] with remarkably long coherence times in some materials.[13] This kind of quantum nanotechnology also enables fundamental concepts such as reality to be tested experimentally, stimulating new philosophical insights.[14] These basic studies serve in turn to push the limits of technology, by extending the range of ‘quantumness’ which can be embodied in practical systems.

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