Graphene quantum dot may solve some quantum computing problems

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Around the world, many scientists are working on various models of a quantum computer. One of the proposed models is a quantum computer that makes use of electron spins. And while quantum dots in gallium arsenide have been used to accomplish the first steps in this direction, there are certain problems that come with a spin-based quantum computer that uses gallium arsenide. Klaus Ensslin, a scientist at the Solid State Physics Laboratory in Zurich, believes that he and his colleagues may have found a new approach.

Ensslin, along with fellows at the Solid State Physics Laboratory, Stampfer, Güttinger, Molitor, Graf and Ihn, believe that they can use electron spins from a tunable graphene quantum dot to create qubits, the building blocks of a quantum computer. These graphene-based qubit could rectify some of the problems found with gallium arsenide. As a first step they present a graphene single electron transistor in *Applied Physics Letters*: “Tunable Coulomb blockade in nanostructured graphene.”

One of the main problems with spin-based quantum computers, Ensslin explains, is that spins won’t keep their direction indefinitely. “Spin is up or down in a magnetic field,” he tells *PhysOrg.com*, “which can be identified with zero or one.” He explains that in a quantum set up, it can even be both simultaneously. But spin states don’t always stay in the same state. “They interact with different parameters in their environment, and that can change things.” Electrons have their own spin, and the nuclei of neighboring atoms also have spin. Eventually, the electron spin used in quantum computing will couple with other nuclear spins, causing a breakdown of coherence in the quantum system.

“Graphene turns out to be a material which is expected to overcome this,” Ensslin says. He is careful to explain that even though he and his peers have created a graphene quantum dot, extrapolations of how it would work in a quantum computer are still at the theory stage. “When you look at this theoretically, you find that 98 percent of carbon has no nuclear spin. This means that the coupling between nuclear spins and electron spins would be strongly reduced.”

The expectation is that this would be a nice system to “realize a spin qubit, provided one can make a quantum dot in graphene – which has now been done – and provided one finds ways to manipulate individual spins in this system.”

Ensslin calls the work the Zurich team has done a first step. “We have shown that a quantum dot made from graphene is possible. Basically it’s a proof of principle.” But there are subsequent steps that need to be taken as well. The quantum dot needs to be tested, and it needs to be made smaller, so there are challenges ahead.

“We need to be able to distinguish between individual electrons,” Ensslin says. “Right now we don’t know how many there are.” The whole point is to figure out how to get the quantum dot to a point where there are no more than one or two electrons.

Another issue is the edge, Ensslin says. “In contrast to semiconductors, which generally have smooth edges, graphene has a rougher edge. Theoretically, the edges play a role in graphene. It will be important to figure out where the atoms are on the edge, and to gain experimental control over the edge. This is crucial to control the electrons.”

Ensslin believes that if this can be done, perhaps a couple of years into the future, it will be possible to test the fitness of a graphene quantum dot for spin-based quantum computing. “ There is no fundamental reason why it shouldn’t work.”