NANOSCALE PHOSPHORUS ATOM ARRAYS CREATED USING STM FOR THE FABRICATION OF A SILICON BASED QUANTUM COMPUTER

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Nanoscale phosphorus atom arrays created using STM for the fabrication of a silicon based quantum computer

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ABSTRACT
Quantum computers offer the promise of formidable computational power for certain tasks. Of the various possible physical implementations of such a device, silicon based architectures are attractive for their scalability and ease of integration with existing silicon technology. These designs use either the electron or nuclear spin state of single donor atoms to store quantum information. Here we describe a strategy to fabricate an array of single phosphorus atoms in silicon for the construction of such a silicon based quantum computer. We demonstrate the controlled placement of single phosphorus bearing molecules on a silicon surface. This has been achieved by patterning a hydrogen mono-layer "resist" with a scanning tunneling microscope (STM) tip and exposing the patterned surface to phosphine (PH3) molecules. We also describe preliminary studies into a process to incorporate these surface phosphorus atoms into the silicon crystal at the array sites.

Keywords: Quantum computing, nanotechnology scanning tunneling microscopy, hydrogen lithography

1. INTRODUCTION

A quantum computer relies on the laws of quantum mechanics to operate, offering massive parallelism and hence formidable computational power for particular types of problems. Recent intense interest in this field has largely been fuelled by the development of algorithms demonstrated to perform classically intractable problems such as the efficient factorization of large numbers and simulation of quantum systems as well as rapid database searches. These developments, coupled with the discovery of error correction schemes designed to overcome the effects of decoherence, have propelled the start of a vigorous world-wide effort to experimentally build such a computer. A quantum computer operates on entangled states of n qubits where a qubit is a two level quantum system. To date the most advanced realisations of a quantum computer are qubit ion trap and nuclear magnetic resonance systems. However, scaling these systems to large n will be difficult, making solid-state architectures, with their promise of scalability, attractive. In 1998 Kane proposed a novel solid state quantum computer design using phosphorus 31P nuclei (nuclear spin I = 1/2) as the qubits embedded in isotopically-pure silicon 28Si (I = 0). The device architecture is shown in Fig. 1 with phosphorus qubits embedded in silicon approximately 20 nm apart. This separation allows the donor electron wavefunctions to overlap, whilst an insulating barrier isolates them from the surface control A and J gates. These A and J gates control the

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