CLAIMS

1. A method of operation of a quantum processing element, the quantum processing element comprising:

a semiconductor,

a dielectric material forming an interface with the semiconductor,

a plurality of dopant dots embedded in the semiconductor, each of the dopant dots comprising one or more dopant atoms and one or more electrons or holes confined within the dopant dots, wherein spin of an unpaired electron or hole of each dopant dot forms at least one qubit;

the method comprising the step of:

dynamically controlling orientation of nuclear spins of the one or more dopant atoms in a pair of dopant dots and/or controlling a hyperfine interaction between nuclear spins of one or more dopant atoms and electron or hole spins of the unpaired electron or hole in the pair of dopant dots to perform a quantum logic operation on a corresponding pair of qubits.

2. The method of claim 1, wherein at least one of the dopant dots in the pair of the dopant dots includes multiple donor or acceptor atoms.

3. The method of any one of claims 1-2, wherein at least one of the dopant dots in the pair of the dopant dots includes multiple electrons or holes.

4. The method of any one of claims 1-3, wherein controlling the hyperfine interaction includes at least one of: changing a number of dopant atoms in the dopant dots, arranging the dopant atoms within a dopant dot, controlling the number of electrons or holes in a dopant dot, controlling the background electrical field applied to the quantum processing element.

5. The method of any one of claims 1-3, wherein the pair of the qubits are used to perform a controlled ROT (CROT) gate and a controlled PHASE (CPHASE) gate and wherein dynamically controlling the orientation of the nuclear spins of the one or more

dopant atoms in the pair of dopant dots comprises maximizing an energy difference between the qubits.

6. The method of claim 5, wherein to maximize the energy difference between the qubits for CROT and CPHASE gates, the nuclear spins in one dopant dot are oriented anti-parallel to the nuclear spins in the other dopant dot of the pair of dopant dots.

7. The method of claim 5, wherein to maximize the energy difference between the qubits, at least one of the pair of dopant dots includes a plurality of dopant atoms, and the plurality of dopant atoms are positioned within the corresponding dopant dot such that the probability density of the wavefunction of the confined electrons or holes at these atomic sites is maximized.

8. The method of any one of claims 1-4, wherein the pair of the qubits are used to perform a controlled ROT (CROT) gate and a controlled PHASE (CPHASE) gate and wherein controlling the hyperfine interaction comprises controlling the hyperfine interaction such that an energy difference between the qubits is optimised.

9. The method of claim 8, wherein controlling the hyperfine interaction such that the energy difference between the pair of qubits is optimised includes shielding the nuclear spins of the pair of dopant dots by adding multiple electrons or holes to each of the pair of dopant dots.

10. The method of any one of claims 1-3, wherein the pair of dopant dots are used to perform a $SWAP^{\alpha}$ gate, where α is between $0\text{-}4\pi$ and wherein dynamically controlling the orientation of the nuclear spins of the one or more dopant atoms in the pair of dopant dots comprises minimizing an energy difference between the qubits.

11. The method of any one of claims 1-3, wherein different gate operations can be performed on the pair of qubits by dynamically controlling the nuclear spins to create an optimal energy difference between the pair of qubits.

12. A quantum processing element comprising:

a semiconductor,

a dielectric material forming an interface with the semiconductor,

a plurality of dopant dots embedded in the semiconductor, each dopant dot comprising one or more donor or acceptor atoms and one or more electrons or holes confined within the corresponding dopant dots, wherein spin of an unpaired electron or hole of each of the dopant dots forms a qubit,

wherein to perform a quantum logic operation between at least a pair of the qubits, an orientation of nuclear spins of the one or more dopant atoms in at least a corresponding pair of dopant dots is dynamically controlled.

13. The quantum processing element of claim 12, wherein at least one of the dopant dots in the pair of the dopant dots includes multiple donor or acceptor atoms.

14. The quantum processing element of any one of claims 12-13, wherein at least one of the dopant dots in the pair of the dopant dots includes multiple electrons or holes.

15. The quantum processing element of any one of claims 12-14 where the donor atoms are phosphorus atoms.

16. The quantum processing element of any one of claims 12-15, wherein the pair of the qubits are used to perform a controlled ROT (CROT) gate and a controlled PHASE

(CPHASE) gate and wherein dynamically controlling the orientation of the nuclear spins of the one or more dopant atoms in the pair of dopant dots comprises maximizing the energy difference between the qubits.

17. The quantum processing element of any one of claims 12-15, wherein the pair of dopant dots are used to perform a $SWAP^{\alpha}$ gate, where α is between 0-4π and wherein dynamically controlling the orientation of the nuclear spins of the one or more dopant atoms in the pair of dopant dots comprises minimizing the energy difference between the qubits.

18. The quantum processing element of any one of claims 12-15, wherein the fidelity of the logic gate operation performed on the at least pair of qubits can be increased by controlling a hyperfine interaction between the nuclear spins of the one or more dopant atoms and electron or hole spins of the unpaired electron or hole in the at least pair of dopant dots.

19. The quantum processing element of claim 18, wherein controlling the hyperfine interaction includes at least one of: changing a number of dopant atoms in the dopant dots, arranging the dopant atoms within a dopant dot, controlling the number of electrons or holes in a dopant dot, controlling the background electrical field applied to the quantum processing element.

20. The quantum processing element of claim 19, wherein the hyperfine interaction is controlled to optimise the energy difference between the pair of qubits by shielding the nuclear spins of the pair of dopant dots and adding multiple electrons or holes to each of the pair of dopant dots.