

CLAIMS:

1. A method for embedding a deterministic number of dopant atoms in a surface portion of a group IV semiconductor lattice, the method comprising the steps of:
 - a) forming one or more lithographic sites on the surface portion;
 - b) dosing, at a temperature below 100 K, the surface portion using a gas with molecules comprising the dopant atom and hydrogen atoms in a manner such that, a portion of the molecules bonds to the surface portion; and
 - c) incorporating one or more dopant atoms in a respective lithographic site by transferring an amount of energy to the dopant atoms;wherein the number of dopant atoms incorporated in a lithographic site is deterministic and related to the size of the lithographic site.
2. The method of claim 1, wherein the surface portion of a group IV semiconductor lattice is a pure crystalline silicon portion or pure crystalline germanium portion.
3. The method of claim 1 or 2, wherein, during incorporating, atoms that are not incorporated in a respective lithographic site are released from the surface portion.
4. The method of any one of claims 1 to 3, wherein the molecules in the dosing gas contain phosphine (PH_3) and the dosing process is performed in a manner such that the surface portion is saturated with PH_3 molecules.
5. The method of any one of claims 1 to 4, wherein the dosing process is performed in a manner such that only PH_3 molecules are absorbed and bond with the surface portion at the lithographic sites.
6. The method of any one of claims 1 to 5, wherein the dosing process is performed at a temperature such that dissociation of PH_3 into PH_2 is prevented.
7. The method of claim 6, wherein the dosing process is performed at a temperature below 40K.
8. The method of any one of claims 1 to 5, wherein the dosing process is performed at a temperature such that dissociation of PH_3 into PH_2 occurs spontaneously.
9. The method of claim 6, wherein the dosing process is performed at a temperature between 40K and 100K.
10. The method of claim 9, wherein the dosing is performed at 77 K.
11. The method of any one of claims 1 to 10, wherein the one or more lithographic sites are: 1 by 1 silicon atomic sites, 2 by 1 silicon dimer patches, 3 by 1 silicon dimer patches, 4 by 1 silicon dimer patches, or 5 by 1 silicon dimer patches.

12. The method of any one of claims 1 to 11, wherein the one or more lithographic sites are 3 by 1 silicon dimer patches and the step of incorporating one or more dopant atoms in a respective lithographic site comprises the step of annealing the surface portion in a manner such that single dopant atoms from a first portion of the bonded molecules are incorporated in respective lithographic sites in the surface portion; and a second portion of the bonded molecules is released from the surface portion.
13. The method of claim 12, wherein each dimer patch bonds with six PH_2 molecules.
14. The method of any one of claims 12 or 13, wherein during the step of annealing the bonded PH_3 molecules lose one hydrogen atom.
15. The method of any one of claims 12 to 14, wherein during the step of annealing, PH_2 molecules bond with an additional hydrogen atom and are released from the surface portion.
16. The method of any one of claims 12 to 15, wherein the step of annealing the surface portion is performed in two phases:
- a first phase during which the bonded PH_3 molecules lose one hydrogen atom to form a plurality of PH_2 molecules bonded to the surface;
 - a second phase during which the bonded PH_2 molecules lose their two hydrogen atoms to other PH_2 molecules and a single P atom is embedded in a single 3 by 1 silicon dimer patch.
17. The method of claim 16, wherein the first annealing phase is performed by exposing the surface to room temperature.
18. The method of claim 14 or 15, wherein the second annealing phase is performed between 200°C and 400°C .
19. The method of any one of claims 1 to 11, wherein the step of incorporating one or more dopant atoms in a respective lithographic site comprises the step of positioning a tip of a scanning tunnelling microscope above one of the molecules and transferring an amount of energy to the dopant atoms through the tip.
20. The method of claim 19, wherein the step of transferring an amount of energy to the dopant atoms comprises applying a current to the dopant atoms and the semiconductor surface through the tip while the tip is positioned in proximity of the dopant atom.
21. The method of claim 20, wherein in order to apply the current through the tip, a feedback control loop of the scanning tunnelling microscope is deactivated and, to increase the magnitude of the current, the tip is controlled to move closer to the dopant atom.

22. The method of claim 20 or 21, further comprising monitoring the magnitude of the applied current for sharp variations triggered by incorporation of a dopant atom.
23. The method of any one of claims 20 to 22, wherein the magnitude of the current is between 0.1nA and 10nA.
24. The method of any one of claims 20 to 23, further comprising applying a voltage between the tip and the semiconductor surface, the voltage having a magnitude between 2V and 4V.
25. The method of claim 19, wherein the step of transferring an amount of energy to the dopant atoms comprises applying a voltage or current to the dopant atoms and the semiconductor surface through the tip while the feedback control loop of the scanning tunnelling microscope is active.
26. The method of claim 25, comprising increasing the magnitude of the current and monitoring the distance between the tip and the dopant atom for sharp variations triggered by incorporation of a dopant atom.
27. The method of claim 26, wherein the step of transferring an amount of energy to the dopant atoms comprises applying a voltage pulse with a duration between 0.1s and 1s and a magnitude between 2V and 4V.
28. The method of claim 26, wherein the step of transferring an amount of energy to the dopant atoms comprises applying a current pulse with a duration between 0.1s and 1s and a magnitude between 0.1nA and 1nA.
29. The method of any one of claims 25 to 28, wherein the distance between the tip and the atom is between 0.1nm and 10nm.