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 atoms and hydrogen atoms in a manner such that, a portion of the molecules bonds to the surface portion; and

c) incorporating one or more of the dopant atoms in a respective lithographic site of the one or more lithographic sites by transferring an amount of energy to the dopant atoms;

wherein the number of the dopant atoms incorporated in ~~a~~the respective lithographic site is deterministic and related to ~~the~~a size of the respective lithographic site.

2. The method of claim 1, wherein the surface portion of ~~a~~the group IV semiconductor lattice is a pure crystalline silicon portion or a pure crystalline germanium portion.

3. The method of claim 1 or 2, wherein, during incorporating, the dopant atoms that are not incorporated in ~~a~~the 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 one or more 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, wherein the dosing process is performed at a temperature below 40K, or at a temperature between 40K and 100K, or at a temperature of 77K.

~~7. The method of claim 6, wherein the dosing process is performed at a temperature below 40K.~~

~~8.~~7. 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.~~8. The method of any one of claims 1 to ~~10~~7, 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.~~9. The method of any one of claims 1 to ~~11~~8, wherein the one or more lithographic sites are 3 by 1 silicon dimer patches and the step of incorporating the one or more of the dopant atoms in ~~a~~the respective lithographic site comprises ~~the~~a step of annealing the surface portion in a manner such that a single dopant atoms from a first portion of the bonded molecules are incorporated in the respective lithographic site~~s~~ in the surface portion; and a second portion of the bonded molecules is released from the surface portion, wherein each dimer patch bonds with six PH_2 molecules.

~~13. The method of claim 12, wherein each dimer patch bonds with six PH_2 molecules.~~

~~14.~~10. The method of ~~any one of~~ claim~~s~~ ~~12 or 13~~9, wherein during the step of annealing, the bonded ~~PH_3~~ molecules lose one hydrogen atom, or wherein during the step of annealing, PH_2 molecules bond with an additional hydrogen atom and are released from the surface portion.

~~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.~~11. The method of ~~any one of~~ claim~~s~~ ~~12 to 15~~9 or 10, wherein the step of annealing the surface portion is performed in two phases:

i. 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 portion, wherein the first annealing phase is performed by exposing the surface portion to room temperature;

ii. 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, wherein the second annealing phase is performed between 200˚C and 400˚C.

~~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.~~12. The method of any one of claims 1 to 11, wherein the step of incorporating the one or more dopant atoms in ~~a~~the respective lithographic site comprises ~~the~~a 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.~~13. The method of claim ~~19~~12, wherein the step of transferring ~~an~~the amount of energy to the dopant atoms comprises applying a current to the dopant atoms and the surface portion of the group IV~~the~~ semiconductor ~~surface~~lattice through the tip while the tip is positioned in proximity of the dopant atoms, wherein in order to apply the current through the tip, a feedback control loop of the scanning tunnelling microscope is deactivated and, to increase a magnitude of the current, the tip is controlled to move closer to the dopant atoms.

~~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.~~14. The method of claim ~~20 or 21~~13, further comprising monitoring the magnitude of the applied current for sharp variations triggered by incorporation of ~~a~~the one or more dopant atoms.

~~23.~~15. The method of ~~any one of~~ claims ~~20 to 22~~13 or 14, wherein the magnitude of the current is between 0.1 nA and 10 nA.

~~24.~~16. The method of any one of claims ~~20~~13 to ~~23~~15, further comprising applying a voltage between the tip and the surface portion of the group IV semiconductor ~~surface~~lattice, the voltage having a magnitude between 2V and 4V.

~~25.~~17. The method of claim ~~19~~12, wherein the step of transferring ~~an~~the amount of energy to the dopant atoms comprises applying a voltage or current to the dopant atoms and the surface portion of the group IV semiconductor ~~surface~~lattice through the tip while ~~the~~a feedback control loop of the scanning tunnelling microscope is active.

~~26.~~18. The method of claim ~~25~~17, comprising increasing ~~the~~a magnitude of the current and monitoring ~~the~~a distance between the tip and the dopant atoms for sharp variations triggered by incorporation of ~~a~~theft dopant atoms.

~~27.~~19. The method of claim ~~26~~18, wherein the step of transferring ~~an~~the amount of energy to the dopant atoms comprises applying a voltage pulse with a duration between 0.1 s and 1 s and a magnitude between 2V and 4V, or wherein the step of transferring the amount of energy to the dopant atoms comprises applying a current pulse with a duration between 0.1 s and 1 s and a magnitude between 0.1 nA and 1 nA.

~~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.~~20. The method of any one of claims ~~25~~17 to ~~28~~19, wherein ~~the~~a distance between the tip and the dopant atoms is between 0.1 nm and 10 nm.