CLAIMS

1. A method for forming a dielectric barrier layer comprising:

exposing a substrate having a copper surface thereon to a dopant gas to provide a layer of dopant on the copper surface, the dopant gas comprising one or more of phosphorous atoms and nitrogen atoms;

depositing a doped dielectric layer by exposing the substrate to a silicon precursor, the dopant gas and a plasma to form a doped dielectric layer; and

annealing the doped dielectric layer to form a dielectric barrier layer.

2. The method of claim 1, wherein the dopant gas is flowed at a flow rate up to 500 sccm.

3 The method of claim 1, wherein the dopant gas comprises phosphorous atoms.

4. The method of claim 3, wherein the dopant gas consists essentially of phosphine.

5. The method of claim 1, wherein the dopant gas comprises nitrogen atoms.

6. The method of claim 5, wherein the dopant gas comprises one or more of nitrogen (N_2), ammonia, NO_2, and N_2O.

7. The method of claim 1, wherein depositing the doped dielectric layer is performed by a plasma-enhanced chemical vapor deposition process utilizing a silicon precursor comprising carbon and a plasma gas comprising oxygen.

8. The method of claim 7, wherein the doped dielectric layer comprises a doped SiOC layer.

9. The method of claim 1, wherein annealing the doped dielectric layer is performed in an atmosphere comprising N_2.

10. The method of claim 1, wherein the doped dielectric layer is annealed at a temperature of less than 500 °C.

11. The method of claim 1, wherein the doped dielectric layer is annealed for a period in a range of 1 min to 120 min.

12. The method of claim 1, further comprising exposing the dielectric barrier layer to a treatment plasma to improve at least one of elasticity and hardness.

13. The method of claim 12, wherein the treatment plasma comprises ammonia.

14. The method of claim 12, wherein the treatment plasma has a power in a range of 250 W to 500 W and the dielectric barrier layer is exposed for less than or equal to 20 s.

15. A method for forming a dielectric barrier layer comprising:

depositing a dielectric layer on a substrate having a copper surface thereon by exposing the substrate to a silicon precursor, a dopant gas and a plasma to form a doped dielectric layer, the dopant gas comprising one or more of nitrogen atoms, or phosphorous atoms; and

annealing the doped dielectric layer for a period in a range of 60 min to 120 min at a temperature less than 500 °C in a nitrogen (N_2) atmosphere to form a dielectric barrier layer.

16. The method of claim 15, further comprising exposing the dielectric barrier layer to a treatment plasma comprising ammonia to improve at least one of elasticity and hardness.

17. A method for forming a dielectric barrier layer comprising:

exposing a substrate having a metal surface thereon to a dopant gas to provide a layer of dopant on the copper surface, the dopant gas comprising one or more of boron atoms, phosphorous atoms and nitrogen atoms;

depositing a doped dielectric layer by exposing the substrate to a silicon precursor comprising carbon, the dopant gas, and a plasma gas comprising oxygen to form a doped SiOC dielectric layer; and

annealing the doped SiOC dielectric layer to form a dielectric barrier layer.

18. The method of claim 17, wherein the dopant gas consists essentially of diborane.

19. The method of claim 17, wherein the dopant gas consists essentially of phosphine.

20. The method of claim 17, wherein the dopant gas comprises one or more of nitrogen (N_2), ammonia, NO_2, and N_2O.