Claims

1. A semiconductor device comprising a wafer (1) with a semiconductor substrate (2) and at least one integrated electronic component (3) extending in and/or on the semiconductor substrate (2), the wafer (1) having a front-end-of-line (5) and a back-end-of-line (6) lying there above, the front-end-of-line (5) comprising the integrated electronic component or at least one of the integrated electronic components (3), and a photonic platform (8) fabricated on a side (9) of the wafer (1) facing away from the front-end-of-line (5), wherein the photonic platform (8) comprises at least one waveguide (12) and at least one electro-optical device (15), wherein the electro-optical device (15) or at least one of the electro-optical devices (15) of the photonic platform (8) is connected to the integrated electronic component (3) or at least one of the integrated electronic components (3) of the wafer (1), wherein the photonic platform (8) comprises a planarization coat (10) of a dielectric material and at least one further planarization coat (13), **characterized in** that at least one of the planarization coat (10) and the further planarization coat (13) is characterized on its side (11) facing away from the wafer (1) by a roughness of less than 2.0 nm RMS.

2. The semiconductor device according to claim 1, **characterized in** that the back-end-of-line (6) of the wafer (1) and the photonic platform (8) comprise interconnection elements (7) through which the integrated electronic component (3) or at least one of the integrated electronic components (3) of the wafer (1) is connected to the electro-optical device (15) or at least one of the electro-optical devices (15) of the photonic platform (8).

3. The semiconductor device according to claim 1 or 2, **characterized in** that the photonic platform (8) comprises material deposited on the side (9) of the wafer (1) facing away from the front-end-of-line (5).

4. The semiconductor device according to claim 3, **characterized** in that the planarization coat (10) is a coat formed by at least one of chemical vapor deposition, physical vapor deposition and atomic layer deposition of at least one coating material on the side (9) of the wafer (1) facing away from the front-end-of-line (5) and subsequent processing of the deposited material on the side (11) facing away from the wafer (1) by means of chemical-mechanical polishing or by means of resist planarization, and/or
in that the planarization coat (10) is characterized on its side (11) facing away from the wafer (1) by a roughness of less than 1.0 nm RMS.

5. The semiconductor device according to any of the preceding claims, **characterized in** that the planarization coat (10) is fabricated on the side (9) of the wafer (1) facing away from the front-end-of-line (5).

6. Th semiconductor device according to any of the preceding claims, **characterized** in that the further planarization coat (13) or at least one of the further planarization coats (13) is being made of the same material as the planarization coat (10).

7. The semiconductor device according to any of the preceding claims, **characterized in** that the further planarization coat (13) or at least one of the further planarization coats (13) is formed by at least one of chemical vapor deposition, physical vapor deposition and atomic layer deposition of at least one coating material on the side (9) of the wafer (1) facing away from the front-end-of-line (5) and subsequent processing of the deposited material on the side (14) facing away from the wafer (1) by means of chemical-mechanical polishing or by means of resist planarization,
and/or

in that the further planarization coat (13) or at least one of the further planarization coats (13) is characterized on its side (14) facing away from the wafer (1) by a roughness of less than 1.0 nm RMS.

8. The semiconductor device according to any of the preceding claims, **characterized in** that the at least one waveguide (12) comprises at least one of a group comprising titanium dioxide, aluminium nitride, tantalum pentoxide, silicon nitride, aluminium oxide, silicon oxynitride, lithium niobate, silicon, indium phosphite, gallium arsenide, indium gallium arsenide, aluminium gallium arsenide, at least one dichalcogenide, chalcogenide glass, resin, resin-containing materials, polymers, polymer-containing materials.

9. The semiconductor device according to any of the preceding claims, **characterized** in that the photonic platform (8) comprises a plurality of waveguides (12).

10. The semiconductor device according to any one of the preceding claims, **characterized** in that the photonic platform (8) comprises at least one coupling device (20) associated with at least one of the waveguides (12).

11. The semiconductor device according to any one of the preceding claims, **characterized** in that the electro-optical device (15) or at least one of the electro-optical devices (15) comprises at least one active element (16, 16a, 16b) comprising at least one material, which absorbs electromagnetic radiation of at least one wavelength and generates an electrical photosignal as a result of the absorption and/or whose refractive index changes as a function of at least one of a voltage, a presence of a charge and an electric field.

12. The semiconductor device according to claim 11, **characterized** in that the electro-optical device (15) or at least one of the electro-optical devices is provided by a modulator (15) comprising an active element (16a) having or consisting of at least one material, whose refractive index changes as a function of at least one of a voltage, a presence of charge and an electric field,
and a further active element (16b) comprising at least one material, whose refractive index changes as a function of at least one of a voltage, a presence of charge and an electric field,
or an electrode,
wherein the two active elements (16a, 16b) or the active element and the electrode are spaced apart from one another and/or are arranged offset from one another in such a way that they lie one above the other in sections.

13. The semiconductor device according to any of the preceding claims, **characterized** in that the electro-optical device (15) or at least one of the electro-optical devices is given by a photodetector (15) comprising one active element (16) comprising at least one material which absorbs electromagnetic radiation of at least one wavelength and generates an electrical photosignal as a result of the absorption.

14. The semiconductor device according to any one of claims 11 to 13, **characterized in** that, on or above the active element or at least one of the active elements (16, 16a, 16b), at least one plasmonic structure (29) comprising a plasmonically active material is provided, the plasmonic structure (29) comprising at least one pair of plasmonic elements (30) arranged next to one another and comprising the plasmonically active material, wherein the plasmonic elements (30) are characterized by a section tapering in the direction of the respective other plasmonic element (30).

15. The semiconductor device according to claim 13, **characterized** in that on at least one side of the active element or at least one active element (16, 16a, 16b) a waveguide (12) is provided with an end section (31) tapering in the direction of the active element, wherein the tapering end section (31) extends up to the active element or the at least one active element (16, 16a, 16b), and/or wherein a contact element (19) is provided on each of two sides of the tapering section (31), wherein the contact element (19) is connected to the active element or the at least one active element (16, 16a, 16b) and wherein the contact element (19) has a section (19a) tapering in the opposite direction and lying next to the tapering end section (31) of the waveguide (12).

16. The semiconductor device according to claim 15, **characterized** in that the waveguide (12) having an end section (31) tapering in the direction of the active element or the at least one active element (16, 16a, 16b) is provided on two sides of the active element or the at least one active element (16, 16a, 16b) in each case, wherein the respective tapering end section (31) extends as far as the active element or the at least one active element (16, 16a, 16b), and/or wherein a contact element (19) is provided on each of two sides of the respective tapering section (31), wherein the contact element (19) is connected to the active element or the at least one active element (16, 16a, 16b) and wherein the contact element (19) has a section (19a) tapering in the opposite direction and lying next to the tapering end section (31) of the respective waveguide (12).

17. A method of manufacturing a semiconductor device, comprising the steps:

- a wafer (1) having a semiconductor substrate (2) and at least one integrated electronic component (3) extending in and/or on the semiconductor substrate (2) is provided, the wafer (1) having a front-end-of-line (5) and a back-end-of-line (6) lying there above, wherein the front-end-of-line (5) comprises the integrated electronic component (3) or at least one of the integrated electronic components (3),
- a photonic platform (8) is fabricated on a side (9) of the wafer (1) facing away from the front-end-of-line (5), the photonic platform (8) comprising at least one waveguide (12) and at least one electro-optical device (15),

wherein the fabrication of the photonic platform (8) includes fabricating a planarization coat (10), the fabrication of the planarization coat (10) including that a coating material is applied to the side (9) of the wafer (1) facing away from the front-end-of-line (5), and wherein the fabrication of the photonic platform (8) includes fabricating at least one further planarization coat (13),

characterized in that

the coating material of at least one of the planarization coat (10) and the at least one further planarization coat (13) is at least on its side (11) facing away from the wafer (1) subsequently subjected to a planarization treatment in such a way that a roughness of the side of less than 2.0 nm is obtained.

18. The method according to claim 17, **characterized in** that the back-end-of-line (6) of the provided wafer (1) comprises interconnection elements (7) connected to the integrated electronic component (3) or at least one of the integrated electronic components (3) of the front-end-of-line (5) and, in the photonic platform (8), interconnection elements (7) are fabricated which are connected, on the one hand, to the interconnection elements (7) of the back-end-of-line (6) and, on the other hand, to the electro-optical device (15) or at least one of the electro-optical devices (15).

19. The method according to claim 17 or 18, **characterized in** that the fabrication of the photonic platform (8) includes depositing material on the side (9) of the wafer (1) facing away from the front-end-of-line (5).

20. The method according to any of claims 17 to 19, **characterized in** that the or at least one of the waveguides (12) is fabricated on the side (11) of the planarization coat (10) facing away from the wafer (1).

21. The method according to any of claims 17 to claim 20, **characterized in** that the fabrication of the planarization coat (10) includes that the coating material is at least on its side (11) facing away from the wafer (1) subsequently subjected to a planarization treatment in such a way that a roughness of the side of less than 1.0 nm RMS is obtained.

22. The method according to any of claims 20 or 21, **characterized in** that the at least one further planarization coat (13) is fabricated following the fabrication of the at least one waveguide (12).

23. The method according to claim 22, **characterized in** that the fabrication of the further planarization coat (13) includes that a coating material is applied to the side (11) of the planarization coat (10) facing away from the wafer (1) and/or of the at least one waveguide (12) and the coating material is then, at least on its side (14) facing away from the wafer (1), subjected to a planarization treatment.

24. The method according to any of claims 20 to 23, **characterized in** that the fabrication of the planarization coat (10) and/or the further planarization coat (13) includes applying a further coating material to the treated side following the planarization treatment.

25. The method according to any of claims 20 to 24, **characterized in** that the fabrication of the at least one waveguide (12) includes applying a waveguide material to the side (11) of the planarization coat (10) facing away from the wafer (5) and then carrying out a structuring of the applied waveguide material.

26. The method according to any of claims 17 to 25, **characterized in** that for the or for at least one of the waveguides (12) at least one coupling device (32) is manufactured, which serves for coupling electromagnetic radiation into the at least one waveguide (12) and/or for coupling electromagnetic radiation out of the at least one waveguide (12).

27. A method of manufacturing at least one semiconductor apparatus (38), wherein a semiconductor device according to any one of claims 1 to 16 is provided and fragmented.