Patent Claims

1. Electronic switching element (1) which comprises, in this sequence, a first electrode (20),
a molecular layer (18) bonded to a substrate, and
a second electrode (16),
where the substrate consists of the first electrode (20) and optionally one or more layers lying on top of this, and
where the molecular layer is essentially formed from one or more compounds of the formula **I,** as defined below:

$$R^1\text{-}(A^1\text{-}Z^1)r\text{-}B^1\text{-}(Z^2\text{-}A^2)s\text{-}Sp\text{-}G \qquad (I)$$

in which

R^1 denotes H, an alkyl or alkoxy radical having 1 to 15 C atoms, where, in addition, one or more CH2 groups in these radicals may each be replaced, independently of one another, by

-C≡C- , -CH=CH-,  ,  ,  , 

 , -O-, -S-, -CF_2O-, -OCF_2-, -CO-O-, or -O-CO- ,

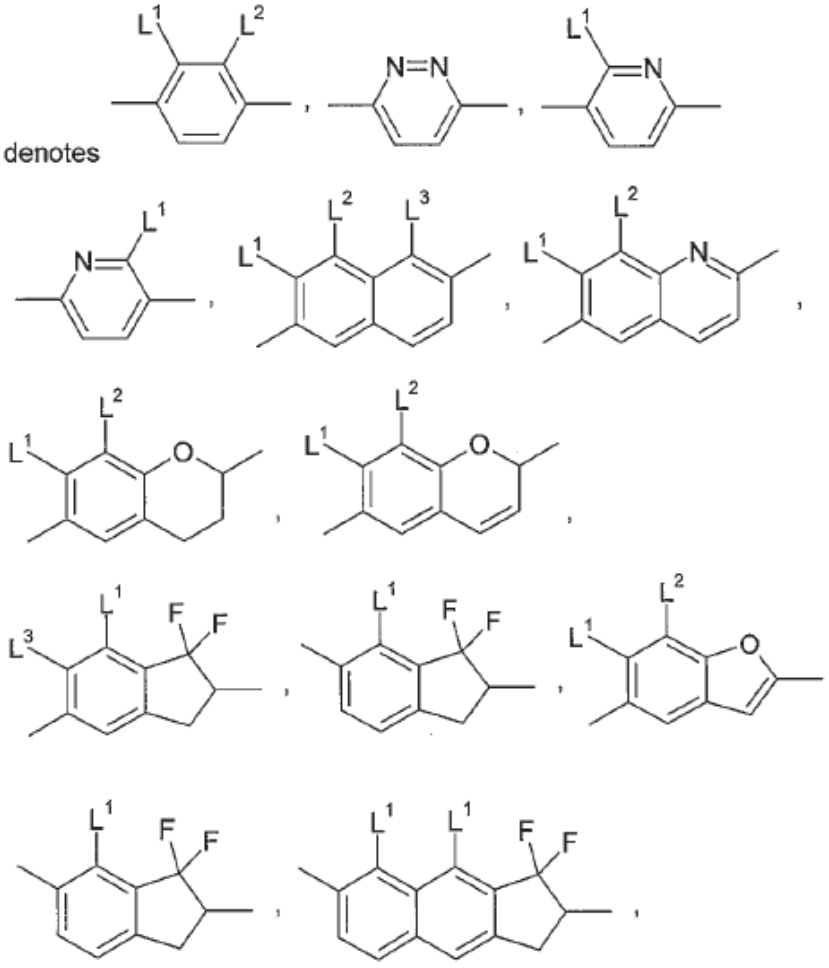
-SiR^oR^{oo}- , -NH- , -NR^o- or -$S0_2$- in such a way that 0 atoms are not linked directly to one another, and in which, in addition, one or more H atoms may be replaced by halogen, CN, SCN or SF_5,

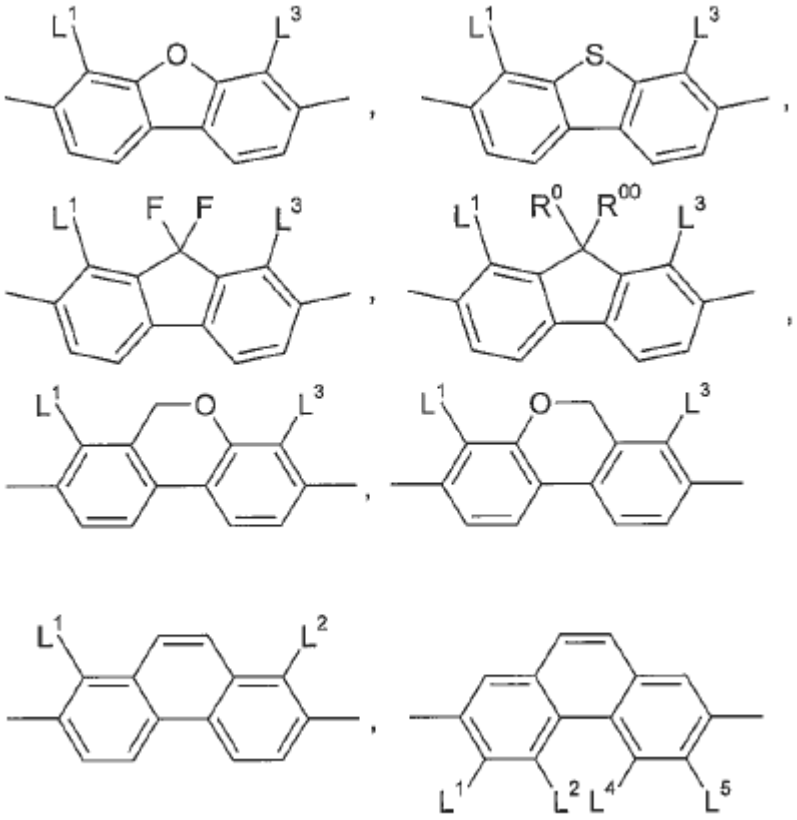
R^o, R^{oo}, identically or differently, denote an alkyl or alkoxy radical having 1 to 15 C atoms, in which, in addition, one or more H atoms may be replaced by halogen

A^1, A^2 on each occurrence, identically or differently, denote an aromatic, heteroaromatic, alicyclic or heteroaliphatic ring

having 4 to 25 ring atoms, which may also contain condensed rings and which may be mono- or polysubstituted by Y

Y on each occurrence, identically or differently, denotes F, Cl, CN, SCN, SF_5 or straight-chain or branched, in each case optionally fluorinated alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having 1 to 12 C atoms, preferably F or Cl,

B^1 



where the groups may be oriented in both directions,

L^1 to L^5,independently of one another, denote F, Cl, Br, I, CN, SF_5, CF_3 or OCF_3, preferably Cl or F, where L^3 may alternatively also denote H,

Z^1, Z^2 on each occurrence, identically or differently, denote a single bond, $-CF_2O-$, $-OCF_2-$, $-CF_2S-$, $-SCF_2-$, $-CH_2O-$, $-OCH_2-$, $-C(O)O-$, $-OC(O)-$, $-C(O)S-$, $-SC(O)-$, $-CH_2-$, $-(CH_2)_2-$, $-(CH_2)_3-$, $-(CH_2)_4-$, $-CF_2-$, $-CF_2-CF_2-$, $-CF_2-CH_2-$, $-CH_2-CF_2-$, $-CH=CH-$, $-CF=CF-$, $-CF=CH-$, $-CH=CF-$, $-(CH_2)_3O-$, $-O(CH_2)_3-$, $-C\equiv C-$, $-O-$, $-S-$, $-C=N-$, $-N=C-$, $-N=N-$, $-N=N(O)-$, $-N(O)=N-$ or $-N=C-C=N-$,

Sp denotes a spacer group or a single bond,

G denotes -CH=CH_2, -OH, -SH, -SO_2OH, -OP(O)$(OH)_2$, -$PO(OH)_2$, -C(OH)$(PO(OH)_2)_2$, -COOH, -Si$(OR^x)_3$ or -$SiCl_3$,

R^x denotes straight-chain or branched alkyl having 1 to 6C atoms, and

r and s, independently of one another, denote 0, 1, 2 or 3, where r + s ≤ 4, and wherein the anchor group (G) of the compounds of the formula I is bonded to the substrate by a covalent bond.

2. Electronic switching element (1) according to Claim 1, characterised in that the first electrode (20) represents the substrate for the molecular layer.

3. Electronic switching element (1) according to Claim 1, characterised in that a diode (22), which represents the substrate for the molecular layer (18), is arranged between the first electrode (20) and the molecular layer (18).

4. Electronic switching element (1) according to Claim 3, characterized in that the diode (22) comprises an n+-doped layer (24) and a p+-doped layer (26), where the n+-doped layer (24) or the p+-doped layer (26) is designed as a combined electrode together with a semiconducting first electrode (20).

5. Electronic switching element (1) according to Claim 1 or Claim 2, characterised in that a diode (22) is arranged

between the second electrode (16) and the molecular layer (18).

6. Electronic element (1) according to any one of Claims 1 to 5, characterised in that an interlayer is arranged between the substrate and the molecular layer (18), where the interlayer is selected from an oxidic or fluoridic material and in that the molecular layer (18) is bonded to this oxidic or fluoridic interlayer.

7. Electronic switching element (1) according to Claim 6, characterised in that the oxidic or fluoridic interlayer is formed from TiO_2, Al_2O_3, HfO_2, SiO_2 or LiF.

8. Electronic switching element (1) according to any one of Claims 1 to 7, characterised in that the anchor group (G) of the compounds of the formula I, as defined in Claim 1, is bonded to the substrate by physisorption.

9. Electronic switching element (1) according to any one of Claims 1 to 7, characterised in that the anchor group (G) of the compounds of the formula I, as defined in Claim 1, is bonded to the substrate by chemisorption.

10. Electronic switching element (1) according to any one of the preceding Claims, characterised in that the anchor group (G) of the compounds of the formula I, as defined in Claim 1, is selected from the groups $-CH=CH_2$, $-PO(OH)_2$ and $-C(OH)(PO(OH)_2)_2$.

11. Electronic switching element (1) according to any one of the preceding Claims, characterised in that the molecular layer is a molecular monolayer.

12. Electronic switching element (1) according to any one of the preceding Claims, characterised in that the first electrode (20) consists of a material selected from element semiconductors, compound semiconductors from groups III-V, compound semiconductors from groups II-VI, metals, and conductive, oxidic materials.

13. Electronic switching element (1) according to Claim 12, characterised in that the first electrode (20) consists of a material selected from the element semiconductors Si, Ge, C (diamond, graphite, graphene), Sn (alpha modification) and Se, the compound semiconductors GaAs, InAs, InP, GaSb, TaN, TiN, MoN, WN and GaN, CdSe and ZnS, the metals Au, Ag, Cu, Al, W, Ta, Ti, Co, Mo, Pt, Ru and Mg and the conductive oxidic materials ITO, IGO, IGZO, AZO and FTO.

14. Electronic switching element (1) according to any one of the preceding Claims, characterised in that the second electrode (16) consists of a conducting or semiconducting material or combination of a plurality of these materials selected from Hg, In, Ga, InGa, Ag, Au, Cr, Pt, Pd, Au, Pb, Al, Mg, Zn, Yb, W, CNT, graphene and conductive polymers.

15. Electronic switching element (1) according to any one of the preceding Claims, characterised in that the first electrode (20) and the second electrode (16) are metallic conductors or in that the first electrode (20) is semiconducting and the second electrode (16) is a metallic conductor.

16. Electronic component (10) comprising one or more switching elements according to any one of the preceding Claims.

17. Electronic component (10) according to Claim 16, characterised in that the component (10) has a multiplicity of switching elements (1), where the first electrodes (20) and second electrodes (16) of the switching elements (1) form a crossbar array.

18. Electronic component (10) according to Claim 16 or Claim 17, characterised in that the switching elements are set up to change between a state having high electrical resistance and a state having low electrical resistance, where the quotient between high electrical resistance and low electrical resistance is between 10 and 100,000.

19. Electronic component according to any one of Claims 16 to 18, characterised in that it is designed as a memristive component.

20. Method for operating an electronic component (10) according to any one of Claims 16 to 19, characterised in that a switching element (1) of the electronic component (10) is switched into a state of high electrical resistance by setting a corresponding first electrode (20) to a first electrical potential and setting a corresponding second electrode (16) to a second electrical potential, where the value of the voltage between the two electrodes (16, 20) is greater than a first switching voltage and the first potential

is greater than the second potential, a switching element (1) of the electronic component (10) is switched into a state of low electrical resistance by setting a corresponding first electrode (20) to a third electrical potential and setting a corresponding second electrode (16) to a fourth electrical potential, where the value of the voltage between the two electrodes (16, 20) is greater than a second switching voltage and the fourth potential is greater than the third potential, and the state of a switching element is determined by applying a reading voltage whose value is smaller than the first and second switching voltages between corresponding electrodes (16, 20) and measuring the current flowing.

21. Use of a molecular layer as indicated in Claim 1 in a memristive electronic component.

22. Process for the production of the switching element according to any one of Claims 1 to 15, comprising at least the following steps:

I. production of a first electrode (20),
II. deposition of a monolayer (18) comprising one or more compounds of the formula I,
III. application of a second electrode (16).

23. Compounds of the formula I

$$R^1\text{-}(A^1\text{-}Z^1)_r\text{-}B^1\text{-}(Z^2\text{-}A^2)_s\text{-}Sp\text{-}G \qquad (I)$$

in which

G denotes $-OP(O)(OH)_2$, $-P(O)(OH)_2$, or $C(OH)(P(O)(OH)_2)_2$

and the other substituents and parameters have the meaning indicated in Claim 1.

24. Compounds of the formula I

$R^1-(A^1-Z^1)_r-B^1-(Z^2-A^2)_s-Sp-G$ (I)

in which

Sp denotes $-O(CF_2)_{p1}-$ or $-(CF_2)_{p1}-$ and

p1 denotes an integer from 1 to 12,and the other groups and parameters have the meaning indicated in Claim 1.