CLAIMS

1. A butyl rubber composition comprising butyl rubber and a self-assembled monolayer of organosilanes disposed on at least one surface of the butyl rubber, the butyl rubber comprising repeating units derived from at least one isoolefin, and repeating units derived from at least one multiolefin.

2. The butyl rubber composition according to claim 1, wherein the self-assembled monolayer of organosilanes comprises organotrichlorosilanes covalently bonded to a surface of the butyl rubber.

3. The butyl rubber composition according to claim 2, wherein the organotrichlorosilanes comprise trichloro(1H,1H,2H,2H-perfluorooctyl)silane (FOTS), n-octadecyltrichlorosilane (OTS), or a combination thereof.

4. The butyl rubber composition according to claim 2, wherein the isoolefin comprises a C_4 to C_5 isomonoolefin, and the multiolefin comprises a C_5 to C_{11} conjugated aliphatic diene.

5. The butyl rubber composition according to claim 2, wherein the isoolefin is isobutylene, and the multiolefin is isoprene.

6. The butyl rubber composition according to claim 2, wherein the repeating units derived from the at least one multiolefin comprise the reaction product of halogenation of multiolefins, followed by reaction of the halogenated multiolefins and at least one of a nitrogen based nucleophile and a phosphorous based nucleophile.

7. The butyl rubber composition according to claim 6, wherein 0.5-2.5 mol % multiolefins are present in the butyl rubber prior to the halogenation of multiolefins.

8. The butyl rubber composition according to claim 6, wherein the nitrogen based nucleophiles and the phosphorous based nucleophiles comprise a pendant vinyl group.

9. The butyl rubber composition according to claim 6, wherein the at least one of a nitrogen based nucleophile and a phosphorus based nucleophile comprises a nucleophile selected from the group consisting of diphenylphosphinostyrene (DPPS),

allyldiphenylphosphine, diallylphenylphosphine, diphenylvinylphosphine, triallylphenylphosphine, N-vinyl caprolactam, N-vinyl phthalimide, 9-vinyl carbazole, N-[3-(dimethylamino)propyl]methacrylamide, diphenylvinylphosphin-methyl-N-vinylacetamide, N-allyl-N-butyl-2-propen-1-amine, 1-vinyl-2-pyrrolidone, 2-isopropenyl-2-oxazoline, 2-vinylpyrid-4-vinylpyridine, N-ethyl-2-vinylcarbazole, and mixtures thereof.

10. The butyl rubber composition according to claim 1, wherein:

the composition has an impermeability to oxygen, and the impermeability to oxygen is 15-25% greater than the impermeability of the butyl rubber without the self-assembled monolayer of organosilanes;

the composition, at a thickness of less than or equal to 0.51 mm, exhibits an optical transparency of at least 75% to a wavelength of 630 nm;

the composition is peroxide cured; and

the composition includes no additional fillers.

11. The butyl rubber composition according to claim 2, wherein:

the organotrichlorosilanes comprise trichloro(1H,1H,2H,2H-perfluorooctyl)silane (FOTS), n-octadecyltrichlorosilane (OTS), or a combination thereof;

the butyl rubber comprises repeating units derived from isobutylene, and repeating units derived from isoprene; and

the repeating units derived from the isoprene comprise the reaction product of halogenation of isoprenes, followed by reaction of the halogenated isoprenes and nucleophiles selected from the group consisting of diphenylphosphinostyrene (DPPS), allyldiphenylphosphine, diallylphenylphosphine, diphenylvinylphosphine, triallyiphenylphosphine, N-vinyl caprolactam, N-vinyl phthalimide, 9-vinyl carbazole, N-[3-(dimethylamino)propyl]methacrylamide, diphenylvinylphosphin-methyl-N-vinylacetamide, N-allyl-N-butyl-2-propen-1-amine, 1-vinyl-2-pyrrolidone, 2-isopropenyl-2-oxazoline, 2-vinylpyrid-4-vinylpyridine, N-ethyl-2-vinylcarbazole, and mixtures thereof.

12. A process for increasing the impermeability of butyl rubber to air, the process comprising:

treating a surface of the butyl rubber to provide a plurality of functional groups on the surface of the butyl rubber; and

reacting the functional groups with organosilanes to form a self-assembled monolayer of organosilanes on the surface of the butyl rubber to form a butyl rubber

composition having increased impermeability to air.

13. The process according to claim 12, wherein treating the surface of the butyl rubber comprises:

oxidizing the surface of the butyl rubber to provide a plurality of first functional groups on the surface of the butyl rubber;

reacting the first functional groups with a silicon halide to provide second functional groups on the surface of the butyl rubber; and

reacting the second functional groups with organotrichlorosilanes to form a self-assembled monolayer of organotrichlorosilanes on the surface of the butyl rubber.

14. The process according to claim 13, wherein:

the oxidizing comprises oxidizing the surface of the butyl rubber by an oxygen containing RF plasma; and

reacting the second functional groups with organotrichlorosilanes comprises depositing organotrichlorosilanes on the surface via physical vapour deposition (PVD).

15. *The process according to claim 14, wherein:*

the butyl rubber comprises repeating units derived from at least one isoolefin monomer and repeating units derived from at least one multiolefin monomer;

the silicon halide is a silicon tetrahalide; and

the organotrichlorosilanes comprise trichloro(1H,1H,2H,2H-perfluorooctyl)silane (FOTS), n-octadecyltrichlorosilane (OTS), or a combination thereof.

16. The process according to claim 13, wherein the process further comprises, prior to oxidizing the surface:

halogenating the butyl rubber to form an allylic halogen moiety; and

reacting the allylic halogen moiety with at least one of a nitrogen based nucleophile and a phosphorus based nucleophile to form a peroxide curable butyl rubber ionomer.

17. The process according to claim 16, wherein the nitrogen based nucleophiles and the phosphorus based nucleophiles comprise a pendant vinyl group.

18. The process according to claim 16, wherein:

reacting the allylic halogen moiety with at least one of a nitrogen based nucleophile and a phosphorus based nucleophile comprises admixing a peroxide curing agent with the halogenated butyl rubber and the at least one of the nitrogen based nucleophile and the phosphorus based nucleophile; and

the process further comprises curing the peroxide curable butyl rubber ionomer under suitable conditions for the peroxide curing agent.

19. The process according to claim 18, wherein:

the butyl rubber comprises repeating units derived from isobutylene, and repeating units derived from isoprene;

the silicon halide comprises $SiCl_4$;

the organotrichlorosilanes comprise trichloro(1H,1H,2H,2H-perfluorooctyl)silane (FOTS), n-octadecyltrichiorosilane (OTS), or a combination thereof;

the at least one of the nitrogen based nucleophile and the phosphorus based nucleophile comprise nucleophiles selected from the group consisting of diphenylphosphinostyrene (DPPS), allyldiphenylphosphine, diallylphenylphosphine, diphenylvinylphosphine, triallylphenylphosphine, N-vinyl caprolactam, N-vinyl phthalimide, 9-vinyl carbazole, N-[3-(dimethylamino)propyl]methacrylamide, diphenylvinylphosphin-methyl-N-vinylacetamide, N-allyl-N-butyl-2-propen-1-amine, 1-vinyl-2-pyrrolidone, 2-isopropenyl-2-oxazoline, 2-vinylpyrid-4-vinylpyridine, N-ethyl-2-vinylcarbazole, and mixtures thereof;

the composition, at a thickness of less than or equal to 0.51 mm, exhibits an optical transparency of at least 75% to a wavelength of 630 nm; and

the composition has an impermeability to oxygen, and the impermeability to oxygen is 15-25% greater than the impermeability of the butyl rubber without the self-assembled monolayer of organosilanes.

20. A process for increasing the impermeability of butyl rubber to air, the process comprising:

halogenating a butyl rubber comprising repeating units derived from at least one isoolefin monomer and repeating units derived from one or more multiolefin monomer to form an allylic halogen moiety;

reacting the allylic halogen moiety with at least one of a nitrogen based nucleophile having a pendant vinyl group and a phosphorus based nucleophile having a pendant vinyl group in the presence of a peroxide curing agent to form a peroxide curable butyl rubber ionomer;

curing the butyl rubber ionomer;

oxidizing a surface of the cured butyl rubber ionomer by an oxygen containing RF plasma to provide a plurality of functional groups on the surface of the butyl rubber;

treating the oxidized surface with an alcohol;

reacting the functional groups with silicon halide to form silicon-OH function groups on the surface of the butyl rubber; and

depositing organotrichlorosilanes on the surface via physical vapour deposition (PVD) to react the organotrichlorosilanes with the silicon-OH functional groups and form a self-assembled monolayer of organotrichlorosilanes on the surface of the butyl rubber.