Description

Title of Invention: Temporary Antistiction Coating

Technical Field

The present invention relates to a copolymer comprising a hexafluoropropylene oxide moiety and a perfluoroalkylsulfonamide moiety. The present invention also relates to a method for synthesizing the copolymer, a copolymer obtainable by the method, a coating composition comprising the copolymer, a method for coating a substrate with the coating composition, a method for removing the coating composition, and a substrate that is at least partially coated with the coating composition.

Background Art

Particle generation and redeposition are important problems to for all conventional cutting processes. Particles and dust (between 0.1 and 5 μm) can be spread over the surface of the work piece during cutting process, especially in the case of laser-based technologies. Small particles are difficult to clean as the adhesion forces (such as capillary, electrostatic and Van der Waals forces) are strong compared to the force that can be applied by a wiping or rinsing device. Additionally, in conventional laser cutting, droplets of molten material are “soldered” to the surface of the work piece.

Until recently, the standard process for dicing semiconductor wafers was abrasive sawing, which has been optimized for this application over more than two decades. However, the demands of emerging types of semiconductor devices, such as those based on thin wafers and on compound semiconductors, can no longer be fulfilled by abrasive sawing.

Sliders and sliders containing magnetic heads are alumina-silicon carbide material typically manufactured by thin-film techniques such that several thousands of sliders or slider/head combinations are formed from a single substrate or wafer. The wafer is sliced into row bars, and each row bar is mounted to a mount bar by an adhesive. The slider features, including rails and transducing heads, are defined on the row bar, which is lapped smooth to form an air bearing surface for each slider on the bar. The bars are then diced into individual sliders for subsequent assembly into disc drives.

Dicing is accomplished by cutting the bar at predetermined locations between sliders using a diamond cutting blade. The cutting locations are called “dice lanes” and are of a predetermined width, matching the width of the cutting blade. The dicing operation creates compressive stresses in the material at the edge surfaces of the slider. These compressive stresses create undesirable ridges in the topography of the air bearing surface of the slider. More particularly,

the compressive stress propagates to form the undesirable ridges. Ridge formation at the edge of a slider due to dicing extends as much as 300 Angstroms (Å) (0.03 microns) in height above the slider surface with a width as much as 50 microns from the edge surface of the diced cut. These ridges adversely affect the flying characteristics of the slider, and contribute to increased head crashes, particularly as the ridge height approaches the fly height of the slider. In addition, debris from the dicing process becomes deposited on the surface of tiny sliders and makes the removal extremely difficult.

Because cleaning of debris on substrate surfaces is expensive and often difficult, the common approach is to keep the wafer clean by preventing the particles from attaching to the surface during the cutting step. The waterjet-guided laser has been an alternative to dicing and free-shape cutting of thin semiconductors, including those containing gallium arsenide (GaAs), and has been shown to have acceptably low levels of particle generation. The waterjet-guided laser features inherent rinsing by the waterjet and, thus, produces a much smaller amount of particles than any other laser process. The use of a waterjet during dicing is shown in Fig. 1, steps 110 and 120. Recently, particle-free dicing of wafers has been achieved by covering the whole workpiece with a well-controlled thin water film during the entire cutting process. However, this requires a continuous flow of water over the substrate, which may not be suitable for some applications.

Further, the water used in a waterjet-guided laser is a formulation containing surfactants and other chemicals such as polyethylene glycol (PEG) used as a coolant. Such chemicals can cause corrosion during the dicing process to the sensitive parts of the wafers such as the metal bond pad. Further, the jet force of the waterjet can deform, break, and/or crack the diced chips. The force of the water jet can also cause the diced chips from becoming detached or displaced from the dicing tape, which may lead to yield loss.

To overcome the above issues, sacrificial coatings have been developed. These are water soluble coatings which can be removed by cleaning with deionized water. However, water-soluble coatings are not compatible with the coolant that is typically used during the dicing process. Therefore, this decreases the effectiveness in particle trapping. In addition, water-based coatings can cause corrosion at sensitive parts of the wafer. Further, an additional drying step is required after water cleaning which requires heating/vacuum/air blowing/solvent drying techniques, which may decrease the efficiency of the process. In some cases when solvent drying is used, the solvent may not be compatible with the dicing tape, causing the diced particles to fall off, again making the process inefficient.

There is therefore a need to provide a copolymer coating of the substrate that overcomes or at least ameliorates, one or more of the disadvantages described above.

Summary

In an aspect, there is provided a copolymer comprising a hexafluoropropylene oxide moiety and a perfluoroalkylsulfonamide moiety.

In another aspect, there is provided a method for synthesizing the copolymer as defined above, comprising the step of contacting a first monomer comprising a hexafluoropropylene oxide moiety and a second monomer comprising a perfluoroalkylsulfonamide moiety.

In another aspect, there is provided a copolymer obtainable by contacting a first monomer comprising a hexafluoropropylene oxide moiety and a second monomer comprising a perfluoroalkylsulfonamide moiety.

In another aspect, there is provided a coating composition comprising the copolymer as defined above.

In another aspect, there is provided a substrate that is at least partially coated with the coating composition as defined above.

Advantageously, the copolymer and coating comprising the copolymer as defined above may facilitate precision coating and decoating of a substrate for temporary protection of substrates such as wafers, acting as an anti-stiction coating during dicing processes of substrates. This may advantageously overcome the issue of contamination of the wafers which may occur during conventional dicing processes.

Advantageously, the copolymer and the coating comprising the copolymer as defined above may provide a very thin (50 nm to 1.5 µm) but effective coating on substrates. Advantageously, the copolymer may comprise HFPO Methacrylate and MeFBSEA/MA. Advantageously, HFPO methacrylate may confer flexibility and conformability to the film, while MeFBSEA/MA may confer film forming properties and provide better corrosion protection to the coating. Further advantageously, the sulfonamide link of the MeFBSEA/MA may provide thermal stability and robustness to the polymer. Fluorochemical compounds may have properties such as oil/water repellency which may confer the advantageous properties such as corrosion resistance to the copolymer. In addition, by tuning the amount of MeFBSEA in the copolymer, it may be possible to advantageously tune the glass transition temperature to the copolymer.

More advantageously, the copolymer and coating comprising the copolymer as defined above may provide a coating having low surface energy, high flexibility, excellent conformability and efficient removability. Advantageously, the low surface energy may prevent particles/soil from sticking to the surface of the substrate. More advantageously, the coating may have good ahesion to the substrate, at least temporarily, for the duration of time it needs to protect the substrate. Further advantageously, the coating may form a soft film with excellent conformability, which may absorb the vibration during dicing and achive excellent coverage over the substrate. Further advantageously, the coating may have high heat stability, with a heat resistance of above 200 °C, and therefore may be able to withstand the heat that is produced during the dicing process.

Further advantageously, the copolymer and coating comprising the copolymer as defined above may be resistant to common hydrocarbon solvents used in the semiconductor and hard disk drive processes such as isopropyl alcohol (IPA) and other hydrocarbons, as well as other

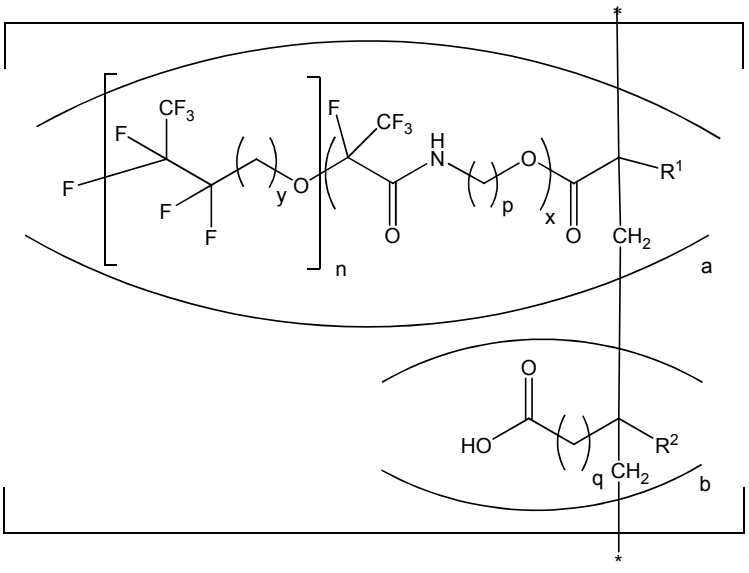
etching/cleaning/rinsing chemicals such as hydrogen fluoride, sulfuric acid and other alkalis. However, all chemicals used in the copolymer, the coating comprising the copolymer or processes as defined above are advantageously electronic grade, which means that they do not leave any residues, have acceptable limits for ionics, are silicone free, and are halide free. Further advantageously, the solvents used in the copolymer and coating comprising the copolymer, or any of the processes as defined above, may be non-flammable and environmenally friendly.

More advantageously, the coating composition may comprise a solvent. The solvent in the coating composition may have low surface tension. Advantageously, this may enable the coating to penetrate throughout the small features on the substrate, to ensure complete coverage of the substrate. Further, the low surface tension solvent may facilitate in wetting any surface of a complex substrate such as a wafer, thereby eliminating the need to add any surfactants, dispersing agents or leveling agents. Advantageously, the solvent may evaporate quickly, enabling the coated substrate to be ready for processing within a short period of time. This in turn may advantageously contribute to high throughput processing of the substrates such as wafers.

Advantageously, the coating as defined above may prevent bond pad corrosion, as it may prevent stringers or residues from becoming deposited on the top side of the substrate such as a wafer during back grinding processes. Further advantageously, the coating as defined above may prevent star cracks, dimples and dents from forming on the wafers during back grinding, and may advantageously protect against Burn marks and etchant seepage.

Further advantageously, the copolymer and coating comprising the copolymer as defined above may have advantages over conventional water-soluble sacrificial coatings, as fluoropolymers are water repellent and are more likely to remain on the surface until the completion of the process, even in the presence of water. Advantageously, this may facilitate increased trapping of the particles generated during the dicing process more effectively. In addition, the copolymer and coating comprising the copolymer as defined above may be able to protect the sensitive parts of the substrate from corrosion.

In another aspect, there is provided a method for coating a substrate with the coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

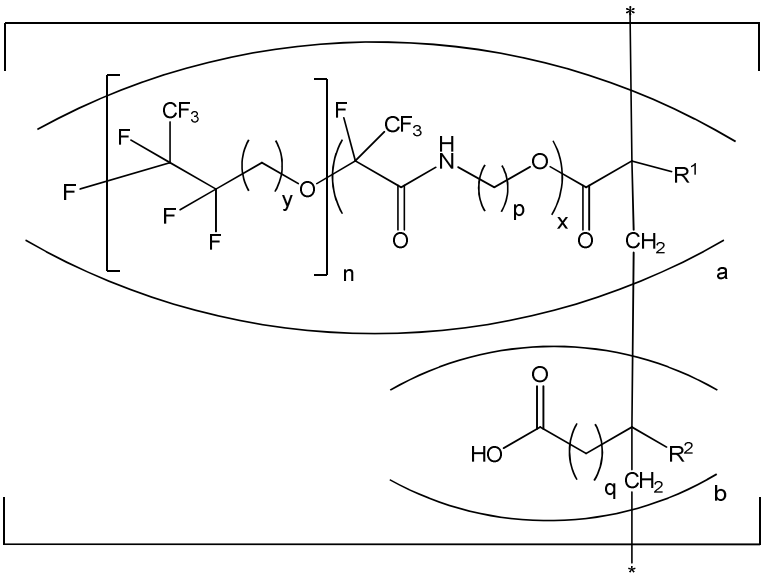
p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

comprising the step of applying the coating composition onto at least part of a substrate surface.

In another aspect, there is provided a method for removing a coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

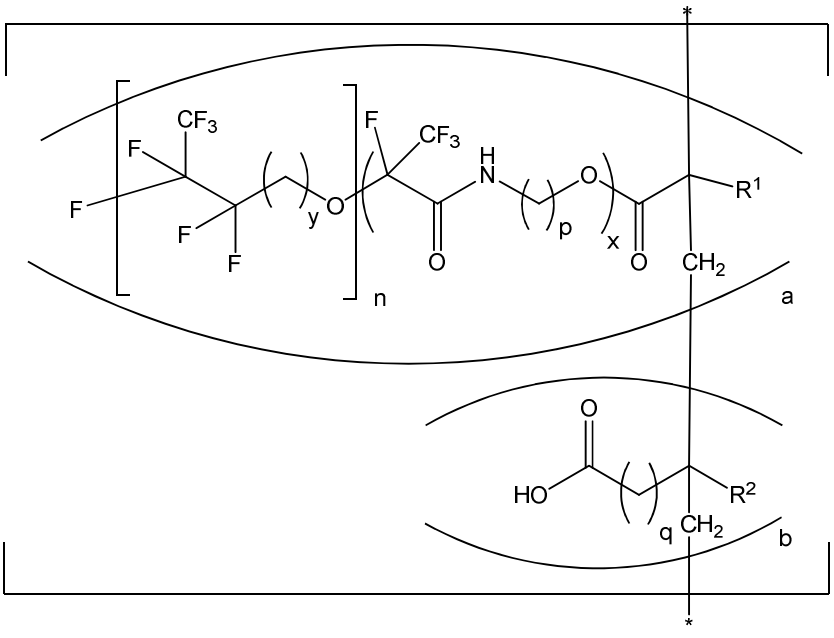
n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

from at least part of a substrate surface, comprising the step of applying a perfluoroalkyl ether to the coating composition.In another aspect, there is provided a method for coating and decoating a substrate with the coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

comprising the steps of:

i) applying the coating composition onto at least part of a substrate surface to coat the substrate surface;

ii) processing the substrate; and

iii) applying a perfluoroalkyl ether to the coating composition to decoat the substrate surface.

Further advantageously, the copolymer and coating comprising the copolymer may be easily and completely removed using a facile solvent wash technique. Advantageously, the coating may be removed using non-flammable and environmentally safe solvents, using a simple soaking technique and vapor rinsing with no sonication. Alternatively, the coating may be removed using a vapor degreaser technology.

Further advantageously, at the time of removing the copolymer and coating, the particles that may have been trapped on the coating during the dicing process may also be efficiently removed from the substrate, together with the coating. Advantageously the solvents used in the coating or decoating process may be compatible with the substrate, and may facilitate efficient removal of the coating without affecting the properties of the substrate. For example, the process for coating and decoating the copoylmer or coating comprising the copolymer as defined above may not cause the diced wafer to detach from the dicing tape.

Advantageously, the method for coating and decoating the substrate as defined above may be high thoroughput. Advantageously, a common dip coating technique with a robotic arm may facilitate the production of 150-180 wafers per hour with a single machine, facilitating a very efficient manufacturing process.

Definitions

The following words and terms used herein shall have the meaning indicated:

"Alkyl" as a group or part of a group refers to a straight or branched aliphatic hydrocarbon group, preferably a C_1–C_{50} alkyl, preferably a C_1–C_{12} alkyl, more preferably a C_1-C_{10} alkyl, most preferably C_1-C_6 unless otherwise noted. Examples of suitable straight and branched

C_1-C_6 alkyl substituents include methyl, ethyl, n-propyl, 2-propyl, n-butyl, sec-butyl, t-butyl, hexyl, and the like. The group may be a terminal group or a bridging group.

The word “substantially” does not exclude “completely” e.g. a composition which is “substantially free” from Y may be completely free from Y. Where necessary, the word “substantially” may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

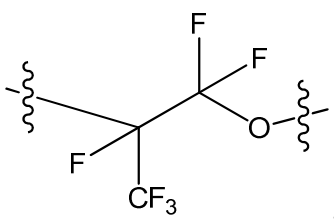
Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Certain embodiments may also be described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the disclosure. This includes the generic description of the embodiments with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

Detailed Disclosure of Optional Embodiments

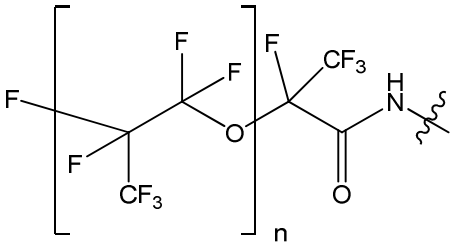
There is provided a copolymer comprising a hexafluoropropylene oxide moiety and a perfluoroalkylsulfonamide moiety.

The hexafluoropropylene oxide moiety refers to the following moiety:



The copolymer may comprise repeating units of the hexafluoropropylene oxide moiety and repeating units of the perfluoroalkylsulfonamide moiety.

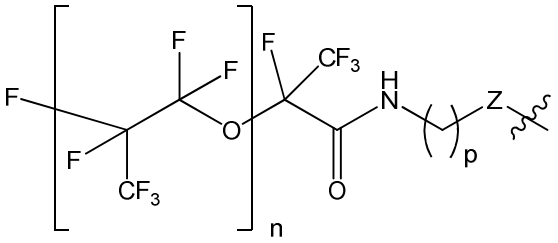
The hexafluropropylene oxide moiety may comprise the following structure:



wherein n may be an integer of at least one.

n may be an integer in the range of 1 to 15. n may be an integer in the range of 6 to 8.

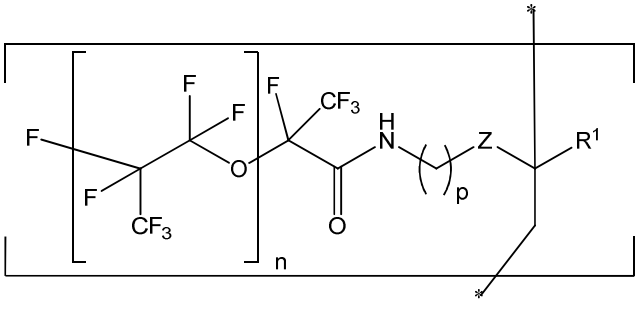
The hexafluoropropylene oxide moiety may comprise the following structure:



wherein p may be an integer in the range of 1 to 50, and

Z may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

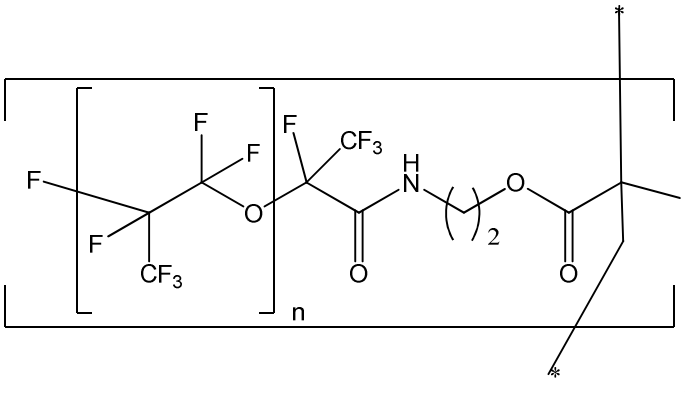
The repeating unit of the hexafluoropropylene oxide moiety may have the following structure:



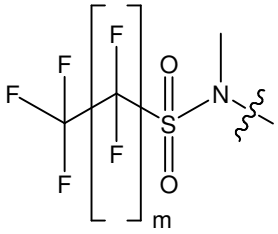
wherein R^1 may be hydrogen or alkyl.

wherein Z may be ester, p may be 2 and R^1 may be methyl.

The repeating unit of the hexafluoropropylene oxide moiety may have the following structure:

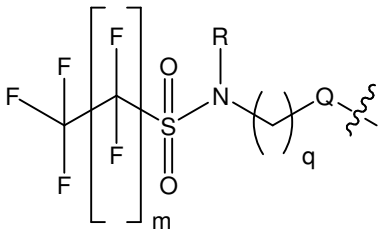


The perfluoroalkylsulfonamide moiety may comprise the following structure:



wherein m may be an integer in the range of 1 to 50.

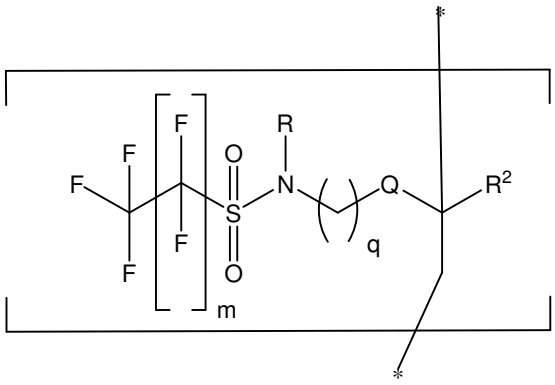
The perfluoroalkylsulfonamide moiety may comprise the following structure:



wherein q may be an integer in the range of 1 to 50, and

Q may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

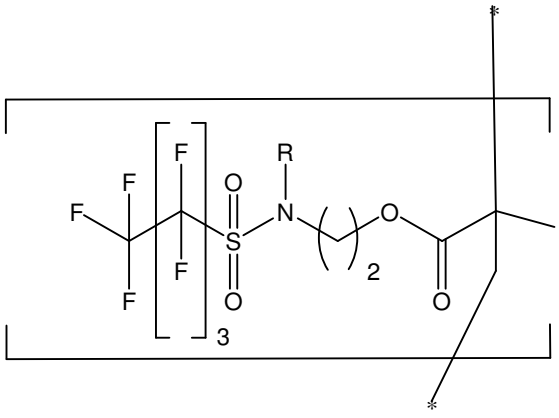
The repeating unit of the perfluoroalkylsulfonamide moiety may have the following structure:



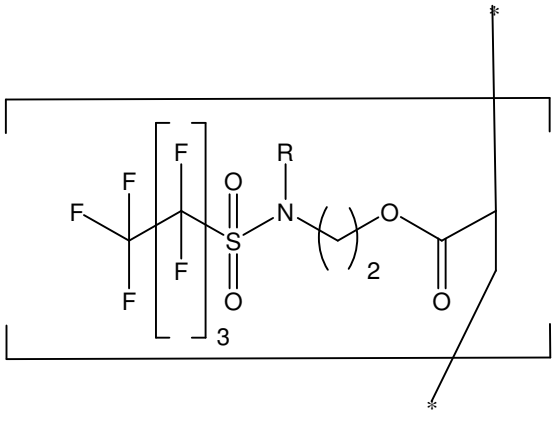
wherein R^2 may be hydrogen or alkyl.

Q may be ester, m may be 3, q may be 2 and R^2 may be hydrogen or methyl.

The repeating unit of the perfluoroalkylsulfonamide moiety may have the following structure:



or



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The weight ratio between the hexafluoropropylene oxide moiety and the perfluoroalkylsulfonamide moiety may be in the range of about 12:1 to about 1:1, about 12:1 to about 10:1, about 12:1 to about 7:1, about 12:1 to about 5:1, about 12:1 to about 2:1, about 10:1 to about 7:1, about 10:1 to about 5:1, about 10:1 to about 2:1, about 10:1 to about 1:1, about 7:1

to about 5:1, about 7:1 to about 2:1, about 7:1 to about 1:1, about 5:1 to about 2:1, about 5:1 to about 1:1 or about 2:1 to about 1:1.

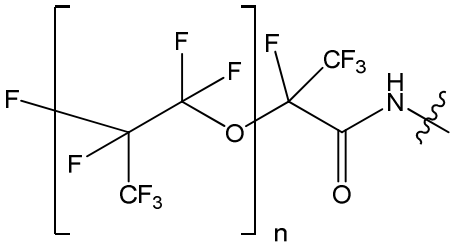
The weight ratio between the hexafluoropropylene oxide moiety and the perfluoroalkylsulfonamide moiety may be about 9:1.

The copolymer may be a linear copolymer, an alternating copolymer, a periodic copolymer, a statistical copolymer, a block copolymer, a stereoblock copolymer, a gradient copolymer or a random copolymer.

The copolymer may be a linear copolymer, a statistical copolymer and a block copolymer. The copolymer may be a random copolymer.

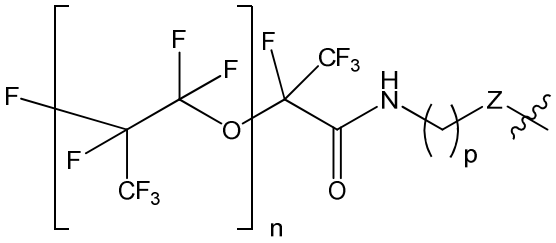
There is provided a method for synthesizing the polymer as defined above, comprising the step of contacting a first monomer comprising a hexafluoropropylene oxide moiety and a second monomer comprising a perfluoroalkylsulfonamide moiety.

The first monomer may comprise the following structure:



wherein n may be an integer of at least one.

The first monomer may comprise the following structure:



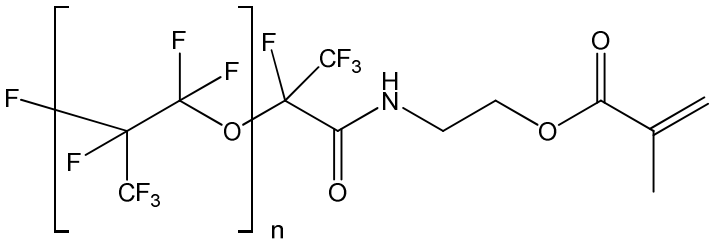
wherein p may be an integer in the range of 1 to 50, and

Z may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

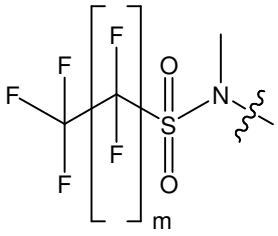
The first monomer may comprise a vinyl group.

p may be 2 and R^1 may be methyl.

The first monomer may have the following structure:

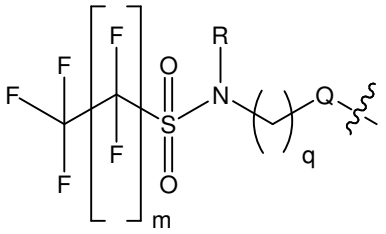


The second monomer may comprise the following structure:



wherein m may be an integer in the range of 1 to 50.

The second monomer may comprise the following structure:

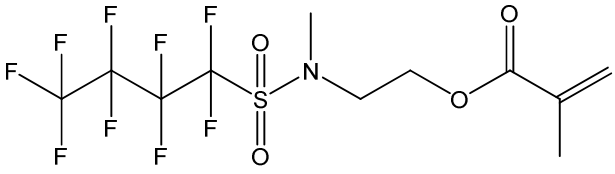


wherein q may be an integer in the range of 1 to 50, and

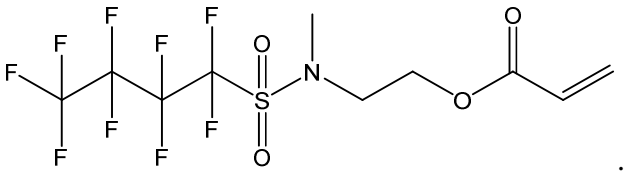
Q may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

The second monomer may comprise a vinyl group.

The second monomer may have the following structure:



or



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The first monomer and the second monomer may be contacted at a weight ratio in the range of about 12:1 to about 1:1, about 12:1 to about 10:1, about 12:1 to about 7:1, about 12:1 to about 5:1, about 12:1 to about 2:1, about 10:1 to about 7:1, about 10:1 to about 5:1, about 10:1 to about 2:1, about 10:1 to about 1:1, about 7:1 to about 5:1, about 7:1 to about 2:1, about 7:1 to about 1:1, about 5:1 to about 2:1, about 5:1 to about 1:1 or about 2:1 to about 1:1.

The first monomer and the second monomer may be contacted at a weight ratio of about 9:1.

The method may comprise the step of dissolving the first monomer and second monomer in a solvent.

The solvent may be 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane.

The polymerization may be performed at a temperature in the range of about 85 °C to about 90°C. 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane (Novec™ 7300) has a boiling point of 96°C, which may be suitable to facilitate smooth polymerization. Moreover, fluorinated solvents such as 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane may impart better properties of levelling and coverage due to its low surface tension.

The solvent may be degassed under nitrogen atmosphere.

The method may comprise the step of adding a polymerization initiator.

The polymerization initiator may be selected from the group consisting of benzoyl peroxide, 1,1'-azobis(cyclohexanecarbonitrile) and any mixture thereof.

The polymerization initiator may have a 10 hour half-life temperature of about 70°C to about 90°C. Benzoyl peroxide may have a 10 hour half-life temperature of about 72 °C and 1,1'-azobis(cyclohexanecarbonitrile) may have a 10 hour half-life temperature of about 88 °C. The by-product of the polymerization initiator may be easily removed without leaving any residue.

There is provided a copolymer obtainable by contacting a first monomer comprising a hexafluoropropylene oxide moiety and a second monomer comprising a perfluoroalkylsulfonamide moiety.

There is also provided a coating composition comprising the copolymer as defined above.

The coating composition may comprise a solvent. The solvent may be chosen to be a coating carrier that has a high boiling point, is non-flammable, has low surface tension, and has a good

rate of evaporation. Such a solvent may have favourable film/coating properties in terms of coverage, texture, being free of pin-holes and bubbles and not having an orange peel effect.

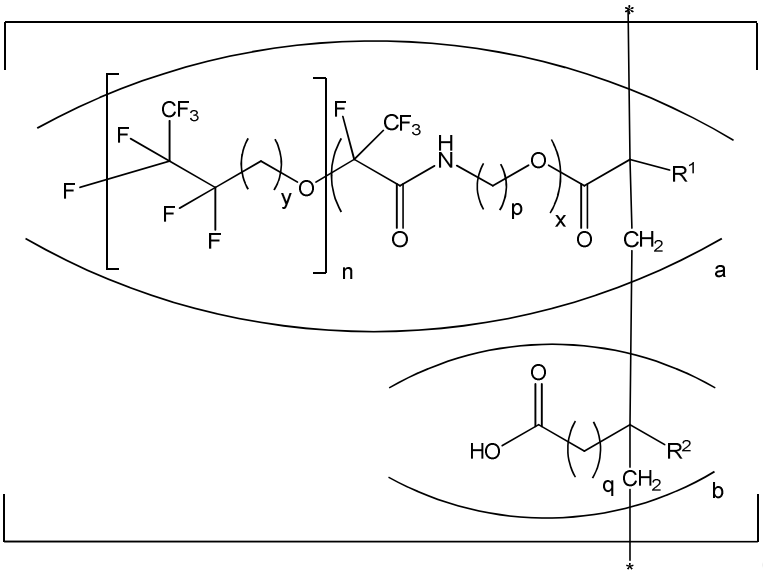
The solvent may have low surface tension. The solvent may be a perfluorinated solvent.

The solvent may be selected from the group consisting of 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane, ethyl nonafluoroisobutyl ether, and any mixture thereof.

The coating composition may comprise the copolymer in a range of about 0.2 wt% to about 10 wt%, about 0.2 wt% to about 0.5 wt%, about 0.2 wt% to about 1 wt%. about 0.2 wt% to about 2 wt%. about 0.2 wt% to about 5 wt%, about 0.5 wt% to about 1 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 5 wt%, about 0.5 wt% to about 10 wt%, about 1 wt% to about 2 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 10 wt%, about 2 wt% to about 5 wt%, about 2 wt% to about 10 wt%, or about 5 wt% to about 10 wt%.

The thickness of the coating composition may be in the range of about 50 nm to about 500 nm, about 50 nm to about 100 nm, about 50 nm to about 250 nm, about 100 nm to about 250 nm, about 100 nm to about 500 nm or about 250 nm to about 500 nm.

There is provided a method for coating a substrate with the coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

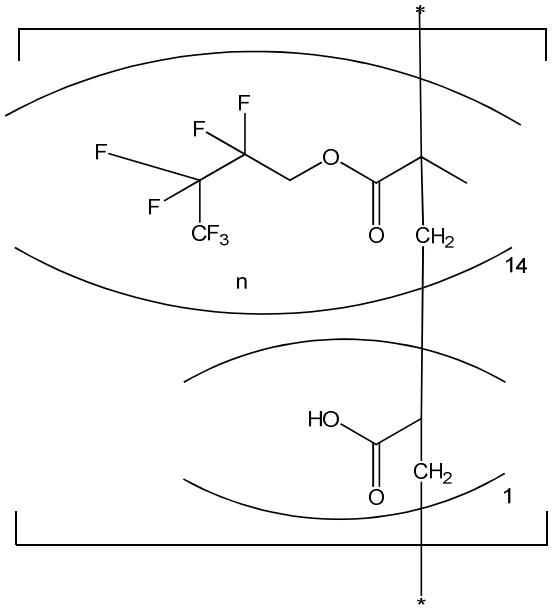
R^1 and R^2 are independently hydrogen or alkyl and

the a:b ratio is in the range of about 15:1 to about 1:1,

comprising the step of applying the coating composition onto at least part of a substrate surface.

The compound having formula (I) may have y=1, x=0, n =1, q=0, R^1=methyl and R^2=hydrogen.

The copolymer having formula (I) may have repeating units of the following structure:



The coating composition comprising the copolymer having formula (I) may further comprise Novec™ 7200.

The applying step may be performed by dip coating, spin coating, brush coating, spray coating or airless spray dispensing.

When the coating composition is applied by dipping, the dwell time may be in the range of about 15 seconds to about 1.5 minutes, about 15 seconds to about 30 seconds, about 15 seconds to about 1 minute, about 30 seconds to about 1 minutes, about 30 seconds to about 1.5 minutes or about 1 minute to about 1.5 minutes.

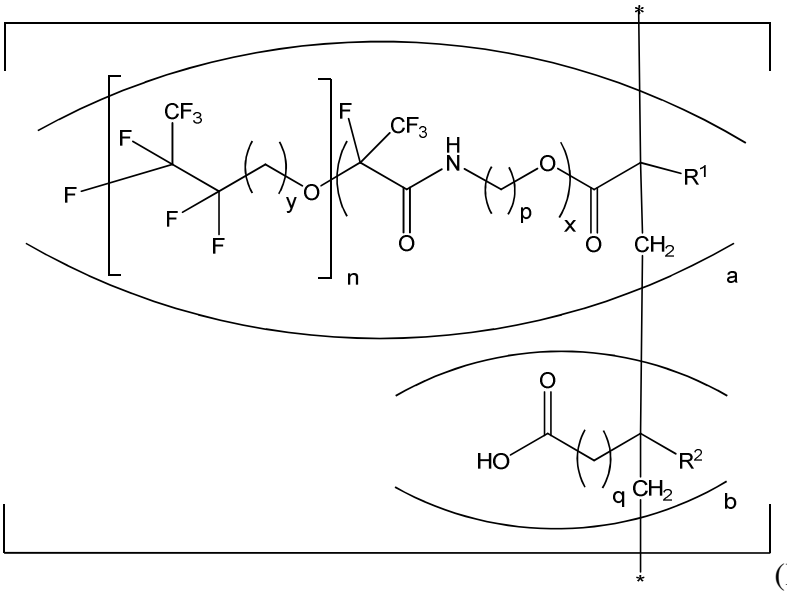
When the coating composition is applied by dipping, the pull speed may be in the range of about 5”/minute to about 25”/minute, about 5”/minute to about 10”/minute, about 5”/minute to about 12”/minute, about 5”/minute to about 15”/minute, about 5”/minute to about 20”/minute, about 10”/minute to about 12”/minute, about 10”/minute to about 15”/minute, about 10”/minute to about 17”/minute, about 10”/minute to about 20”/minute, about 10”/minute to about 22”/minute, about 12”/minute to about 15”/minute, about 12”/minute to about 17”/minute, about 12”/minute to about 20”/minute, about 12”/minute to about 22”/minute, about 12”/minute to about 25”/minute, about 15”/minute to about 17”/minute, about 15”/minute to about 20”/minute, about 15”/minute to about 22”/minute, about 15”/minute to about 25”/minute, about 17”/minute to about 20”/minute, about 17”/minute to about 22”/minute, about 17”/minute to about

25"/minute, about 20"/minute to about 22"/minute, about 20"/minute to about 25"/minute or about 22"/minute to about 25"/minute.

The method may comprise the step of drying the substrate coated with the coating composition at a temperature in the range of about 20 °C to about 70 °C, about 20 °C to about 50 °C, or about 50 °C to about 70 °C.

The method may comprise the step of drying the substrate coated with the coating composition for a duration in the range of about 1 minute to about 15 minutes, about 1 minute to about 5 minutes, about 1 minute to about 10 minutes, about 5 minutes to about 10 minutes, about 5 minutes to about 15 minutes, or about 10 minutes to about 15 minutes.

There is provided a method for removing a coating composition as defined above or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl and

the a:b ratio is in the range of about 15:1 to about 1:1,

from at least part of a substrate surface, comprising the step of applying a perfluoroalkyl ether to the coating composition.

The perfluoroalkyl ether may be methyl pefluorobutyl ether.

The perfluoroalkyl ether may be non-flammable, eco-friendly, have no volatile organic compounds, and may be efficiently removed without ultrasonication.

The application step may comprise dipping the substrate surface comprising the coating composition in the perfluoroalkyl ether.

The coating composition may be removed from the substrate surface within 10 minute of applying the perfluoroalkyl ether, more preferably within 5 minutes of applying the perfluoroalkyl ether.

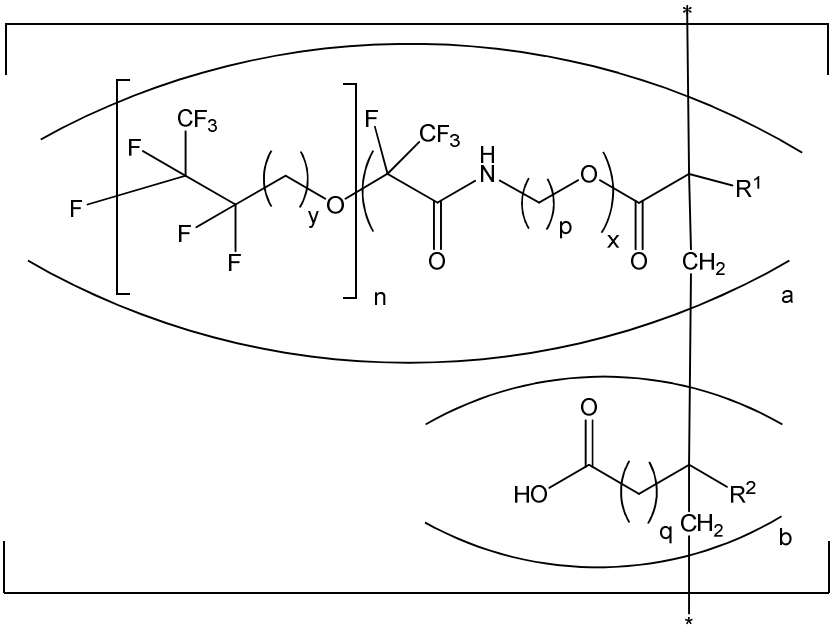
The step of dipping the substrate surface in the perfluoroalkyl ether may be performed at a temperature in the range of about 50 °C to about 65 °C, about 50 °C to about 55 °C, about 50 °C to about 60 °C, about 55 °C to about 60 °C, about 55 °C to about 65 °C, or about 60 °C to about 65°C.

The step of dipping the substrate surface in the perfluoroalkyl ether may be performed with a dwell time in the range of about 1 minute to about 7 minutes, about 1 minute to about 2 minutes, about 1 minute to about 5 minutes, about 2 minutes to about 5 minutes, about 2 minutes to about 7 minutes or about 5 minutes to about 7 minutes.

The step of dipping the substrate surface in the perfluoroalkyl ether may be performed with a drying time in the range of about 30 seconds to about 2 minute, about 30 seconds to about 1 minute or about 1 minute to about 2 minutes.

The method of decoating the coating composition may further comprise the step of rinsing the perfluoroalkyl ether off the substrate surface and drying the substrate surface.

There is provided a method for coating and decoating a substrate with the coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

comprising the steps of:

i) applying the coating composition onto at least part of a substrate surface to coat the substrate surface;

ii) processing the substrate; and

iii) applying a perfluoroalkyl ether to the coating composition to decoat the substrate surface.

The processing step may comprise lithography, taping, detaping, dicing, singulation, etching, bonding, debonding, baking, irradiation, grinding, thinning, cleaning and any combination thereof.

The step of applying the coating composition may be performed for a dwell time in the range of about 30 seconds to 1 minute, a pull speed in the range of about 6”/minute to about 20”/minute and a drying time of about 2 minutes.

The step of applying the perfluoroalkyl ether may be performed at a temperature in the range of about 55 °C to about 61 °C, a dwell time in the range of about 2 to 5 minutes and a drying time of about 1 minute.

The step of applying the perfluoroalkyl ether may not comprise a step of applying the perfluoroalkyl ether.

The method may be for temporarily protecting the substrate during the processing step.

The method may protect the substrate from corrosion during the processing step.

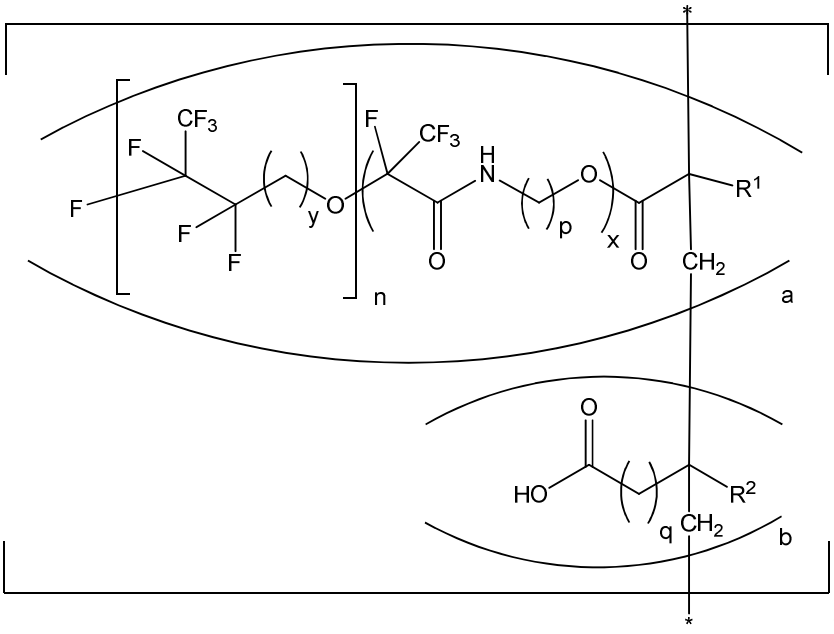
The processing step may be dicing, and the method may protect the substrate from debris that is formed during the dicing.

The method of coating and decoating may be performed so as to protect the substrate during the processing step. The method of coating and decoating may prevent debris or particles that are formed during the processing step from attaching to the substrate. Instead, the coating composition may act as a sacrificial coating such that any particles or debris that may be formed during the processing step may attach to the coating composition. The particles or debris attached to the coating composition may subsequently be removed during the decoating step. This in turn may ensure that the debris or particles do not attach to the substrate surface itself.

There is provided a substrate that is at least partially coated with the coating composition as defined above.

The substrate may be selected from the group consisting of metal, glass, aluminium coupon, silicon wafer and printed circuit board.

There is also provided a system for coating and decoating a substrate with the coating composition as defined above, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

the system comprising:

i) a device for applying the coating composition onto at least part of a substrate surface to coat the substrate surface; and

ii) a device for applying a perfluoroalkyl ether to the coating composition to decoat the substrate surface.

The device for applying the coating composition and the device for applying the perfluoroalkyl ether may be located adjacent to each other.

The device for applying the coating composition and the device for applying the perfluoroalkyl ether may each individually comprise a dip coater tank comprising a robotic arm for dipping the substrate.

The robotic arm may comprise a servomotor for applying the coating composition or for applying the perfluoroalkyl ether. Since the substrate may be sensitive to vigorous vibrations, it may be necessary to minimize vibrations during the application process.

The dip coater tank may further comprise an ultrasonic vapor degreaser.

The system may not use any cooling oil.

The system may further comprise a reservoir tank, wherein the coating composition is fed back into the reservoir tank.

The system may be automated.

Brief Description of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1

[Fig. 1] is a schematic representation showing a conventional water-jet dicing process and the coating of sacrificial coatings and its decoating process.

Fig. 2

[Fig. 2] is a schematic representation of the process for coating and decoating a wafer with a sacrificial coating.

Fig. 3

[Fig. 3] is a differential scanning calorimetry spectrum of the polymer SGL-3051.

Fig. 4

[Fig. 4] is a thermogravimetric analysis spectrum of the polymer SGL-3051.

Fig. 5

[Fig. 5] is a series of images showing the contact angle of water (A) before coating, (B) after coating and (C) after decoating of SGL-3051 on the surface of a polished Aluminium media substrate.

Fig. 6

[Fig. 6] refers to graphs showing TOF-SIMS analysis after decoating of SGL-3051.

Fig. 7

[Fig. 7] refers to scanning electron microscopy (SEM) images of (A) row bar before dicing, (B) row bar after dicing, (C) row bar after decoating with 3M Novec™ 71IPA, (D) row bar coated with 5% SGL-3051 before dicing, (E) row bar coated with 5% SGL-3051 after dicing, and (F)

row bar coated with 5% SGL-3051 after decoating with 3M Novec™ 71IPA. Each image was taken in duplicate from two different samples.

Fig. 8

[Fig. 8] refers to images of a metal bond pad (A) uncoated then cleaned with hydrogen fluoride (HF), and (B) coated with 3M Novec™ 1901, cleaned with HF then decoated with 3M Novec™ 71IPA.

Detailed Description of Drawings

Fig. 1

[Fig. 1] shows a conventional water-jet dicing process and the coating of sacrificial coatings and its decoating process. In the conventional water-jet dicing process depicted by steps 110 and 120, a saw 111 is used to dice substrate 112. Substrate 112 may be a wafer. In the process, silicon dust 113 is produced. In step 110, the slower the cutting speed, the more silicon dust is produced. In step 120, water jet nozzle 121 is used to clean away the silicon dust 113 using high pressure water. Steps 130, 140 and 150 depict the use of sacrificial coatings. Coating step 130 shows the substrate 112 being immersed in to the coating solution 132. The substrate 112 is then sawed during the substrate sawing step 140. Finally, during the decoating step 150, the stripping of the coating 151 results in the production of decoating vapour 152.

Examples

Non-limiting examples of the invention will be further described in greater detail by reference to specific Examples, which should not be construed as in any way limiting the scope of the invention.

Example 1: Materials and Methods

The reagents used are as outlined in Table 1 below.

HFPO Methacrylate, MeFBSEA and MeFBSEMA were procured from 3M Company of St. Paul, Minnesota of the United States of America.

Initiators Luperox A75 and Vazo88 were purchased from Sigma-Aldrich of St. Louis, Missouri of the United States of America.

Novec 7200, 71IPA and Novec 7300 were purchased from Electronics Markets Materials Division 3M Company of St. Paul, Minnesota of the United States of America.

Table 1. Reagents used in the coating

Compound	CAS #	Source	Formula/Structure
HFPO	301205-80-1	3M Company,	$C3F_7O[CF(CF_3)CF_2O]nCF(CF_3)CONHCH_2$

Methacrylate (HFPOMA)		St Paul, Minnesota USA	$CH_2OOCC(CH_3)=CH_2$ Mol. Wt. 1344
MeFBSEA (C4-acrylate)	67584-55-8	3M Company, St Paul, Minnesota USA	$C_4F_9SO_2N(CH_3)CH_2CH_2OOCCH=CH_2$
MeFBSEMA (C4-methacrylate)	67584-59-2	3M Company, St Paul, Minnesota USA	$C_4F_9SO_2N(CH_3)CH_2CH_2OOCC(CH3)=CH2$
Luperox A75	94-36-0	Sigma-Aldrich, St Louis, Missouri, USA	Benzoyl Peroxide
Vazo 88	2094-98-6	Sigma-Aldrich, St. Louis, Missouri, USA	1,1′-Azobis(cyclohexanecarbonitrile)
Novec 7300	132182-92-4	3M Company, St Paul, Minnesota USA	Pentane, 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-
Novec 7200	163702-06-5 163702-05-4	3M Company, St Paul, Minnesota USA	Ethyl nonafluoroisobutyl ether Ethyl nonafluorobutyl ether
Novec 1901	NA	3M Company, St Paul, Minnesota USA	Copolymer of heptafluorobutylmethacrylate and acrylic acid

Analyses

FTIR: FTIR was performed using the Thermo Nicolet AVATAR Diamond ATR on the polymer samples to know when the polymerization reaction was complete. One drop of the solution from the reaction flask was dispensed on the detector for the FTIR and the solvent was evaporated using a heat gun. FTIR was performed and the disappearance of the acrylate double bond peak at 1640$cm^{-1}$was monitored.Contact Angle:.Contact Angle measurements were done on coated wafers was to determine the consistency and coverage of the coating on wafers. This was done using the Sessile drop method with a Rame-Haart goniometer. A drop of water (5 microliter) was dispensed on the surface of the coated or uncoated substrate and the angle of the drop with respect to the surface was measured.

Thermal Gravimetric Analysis (TGA)-Differential Scanning Calorimetry (DSC): These analyses were done to investigate the polymer's thermal characteristics.

TGA was performed on the polymer to determine the thermal stability. This was done at a temperature ranging from room temperature to 600°C at 10°C/minute under N_2 flow. A TA TGA Q5000IR set up was used with the following parameters:

Temperature Range and Heating Rate:	25°C-600°C at 10°C/min
Description of Test Method:	1: Select gas 2 2: Equilibrate at 25.00 °C 3: Isothermal for 2.00 min 4: Mark end of cycle 1 5: Ramp 10.00 °C/min to 600.00 °C 6: Mark end of cycle 2
Purge Gas & Flow Rate:	Air at 25mL/min
Pre-analysis Purge Time:	2 min

DSC was performed to determine the glass transition temperature of the polymer. This was done at a temperature ranging from -60°C to 200°C at 5°C/min under N_2 flow. A TA DSC Q2000 set up was used with the following parameters:

Temperature Range and Heating Rate:	-90°C-300°C at 10°C/min
Description of Test Method:	1: Equilibrate at -90.00 °C 2: Isothermal for 1.00 min 3: Mark end of cycle 1 4: Ramp 10.00 °C/min to 300.00 °C 5: Mark end of cycle 2 6: Equilibrate at -90.00 °C 7: Isothermal for 1.00 min 8: Mark end of cycle 3 9: Ramp 10.00 °C/min to 300.00 °C 10: Mark end of cycle 4
Purge Gas Flow Rate:	Nitrogen at 50mL/min

TOF-SIMS (After removal) was used to determine the coating residue.

Example 2: Formulations

Components of the formulations are described in Table 2.

Table 2. Formulations

Name	**HFPOMA (g)**	**MeFBSEA (C4-acrylate) (g)**	**MeFBSEMA (C4-methacrylate) (g)**	**Ratio HFPO:C4**
SGL 3051	90	10	-	9:1

SGL 3053	90	-	10	9:1
HFPO Homopolymer	100	-	-	-
MeFBSEA Homopolymer	-	100	-	-
MeFBSEMA Homopolymer	-	-	100	-
MeFBSEA-HFPOMA	20	80	-	1:4

MeFBSEA-HFPOMA was found to be too brittle and did not have the desired properties. It was therefore not tested further.

Example 3: Coating-Decoating Procedure

The coating stock solutions for the formulations in Table 2were synthesized using solution polymerization technique. The monomers as outlined in Table 2 were dissolved in Novec™ 7300 to form a 20 w/v% solution. The solution was degassed and placed under N_2 atmosphere. To this, the initiator (either Luperox A75 or Vazo88) was added. The solution was stirred at 85 to 90 °C for 3 hours. The complete conversion of monomers (completion of polymerization) was confirmed by the disappearance of 1640 cm^{-1} acrylate peak using FTIR. The solution was filtered to provide the coating solution with 20% solid content.

The copolymerization of the HFPOMA and C_4-acrylate/methacrylate were carried out smoothly using different initiators including peroxy intiators and azo initiators. A slight increase in viscosity was observed during the polymerization. The solution after polymerization was slightly hazy which was further filtered using a 0.2 micron syringe filter to provide a clear coating solution.

For the coating application, the above stock solution was diluted using Novec™ 7200 to the respective concentrations as described below. Typically the SGL-3051 was used as a 5 wt/vol% stock solution, whereby the 20 w/v% solution as outlined above was diluted to 5 wt/vol% with Novec™ 7200.

A general schematic of the coating and decoating process is shown in Fig. 2. In Fig. 2, incoming wafer 200 is subjected to coating process 210. The coating process 210 comprises the step 211 of dipping the wafer 200 into a 3M Novec™ coating, the step 212 of removing the wafer 200 from the coating and step 213 of drying at room temperature. After the coating process 210, the wafer 200 can be processed by the user in step 220 and then subjected to decoating process 230. The decoating process 230 comprises the step 231 of dipping the processed wafer 200 into a 3M Novec™ fluid, the step 232 of removing the wafer 200 from the 3M Novec™ fluid and the step 233 of rinsing the vapour and drying. Finally, the wafer 200 can be subsequently processed in step 240.

Coating application

The coating was done on wafers using dip and airless spray dispensing technique. After dipping with a dwelling time of 30 seconds, the wafer was withdrawn at a constant speed of 12"/minute. The wafer substrate was dried under ambient conditions or at 60 °C for 2 minutes.

Spraying was done using Musashi CV-10 robotic airless dispenser using standardized procedure.

For spray coating, the following parameters were used:

Height of sprayer from wafer = 1"
Width of spray stream = 2"
Air nozzle pressure = 0.15mPa
Valve nozzle Pressure = 0.18mPa
Pressure at Coating syringe/reservoir = 0.13mPa.
Dispensing speed = 100mm/sec

For dip coating, wafers were stored in a cassette, and the whole cassette was dipped inside the dip tank. Each cassette holds 12 or 25 wafers. The following parameters were used:

Dipping speed = 20"/min
Dwell time = 30 sec.
Withdrawal speed = 6-20"/min
Druing time = 2 min.

After coating, the wafer was dried at room temperature for 10 minutes.

Coating removal

Novec™ 71IPA was used as a standard to remove the coating using a dipping or vapour degreasing technique. Vapor degreasing was performed without Ultrasonics. The wafers were soaked in Novec™ 71IPA for 5 to 10 minutes, with 1 minute vapour rinse and drying.

Decoating was done using soaking and vapor rinse. A vapor degreaser was used to do this. Soaking was done at 55°C, which is the boiling point of Novec 71IPA, for 5 minutes and then vapor rinse was performed for 1 minute.

Due to the high content of HFPOMA, the coating provided excellent conformability and water resistance. The coating formulated using the peroxy initiator was found to leave residue after cleaning. So it was confirmed that the carboxylic acid residue left by the peroxy initiator after the polymerization was the cause for the residue.

EGC Novec™ 1700 and 1702 were also tested, but the coating was very difficult to remove and cannot be removed completely. As both these coatings contain free carboxylic acid groups which facilitated the bonding of the coatings to the substrate, it is believed that the presence of

the carboxylic acid groups in the coating may render it difficult to remove the coatings from the substrate.

Example 4: Coating Properties

Differential scanning calorimetry

Fig. 3 shows the differential scanning calorimetry (DSC) curve for polymer SGL-3051, which shows a small T_g peak around -40°C. This means that the coating material is very flexible and conformable.

Thermogravimetric analysis

Fig. 4 shows the thermogravimetric analysis (TGA) for polymer SGL-3051, which shows excellent thermal stability as the bulk decomposition only starts well above 200 °C.

Contact angle measurements

Static water and hexadecane contact angle measurements were used to monitor the coating and decoating of the polymer on polished Aluminum media substrates. Fig. 5 shows the contact angle of SGL-3051 using water, and Table 3 summarises the contact angle measurements of SGL-3051 using water and hexadecane. The uncoated surface gave a very small contact angle showing complete wetting characteristics. After coating, the contact angle became greater than 110°, showing that the coating imparted repellency to the surface. After removal of coating, the contact angle was returned to be the same as that of an uncoated surface. Efficient removability was therefore observed using Novec™ 71IPA, as indicated by the contact angle measurements summarized in Table 3.

Table 3. Contact angle measurements of SGL-3051

	Before coating (Fig. 5A)	**After coating (Fig. 5B)**	**After decoating (Fig. 5C)**
H_2O (mean)	33.3°	111.0°	31.7°
C_{16} (mean)	18°	62.2°	14.5°

TOF-SIMS analysis

TOF-SIMS was carried out on the plate after the decoating process of SGL-3051, as shown in Fig. 6. Excellent removability of the coating was observed. In the top chart, the first bar refers to the coated sample and the rest refer to the decoated sample at different points.

Example 5: Application – Wafer Dicing

Row bar for sliders were glued onto a carrier before dicing. This carrier was coated with a 5% solution of polymer SGL-3051 by a dip coating method at a withdrawal speed of 10”/min. This

row bar was diced using a saw with a water jet as coolant. After dicing, the coating which had some debris on the surface was removed using Novec™ 71 IPA. Scanning electron microscopy (SEM) photographs in Fig. 7 show excellent removability of the debris.

Figures 7A to 7F show the different stages of the row bar dicing. Each image was taken in duplicate from two different samples. Figure 7A shows the row bar before dicing. The results are summarised in Table 4.

Table 4. Observations during dicing

Figure	Stage	Operation	Result
7A	Bare row bar	Before dicing	Clean. After the Micro Lithography process.
7B	Bare row bar after dicing	After dicing	Heavy debris found
7C	Cleaning with Novec™ 71IPA	Ultrasonication and vapor degreasing using Novec™ 71IPA	Heavy particles are removed. But lighter particles are adhered on to sliders. Unacceptable.
7D	Coated with SGL-3051	By dip coating technique	Excellent coverage over the fine features
7E	Diced after coating	Dicing done using diamond saw with coolant	Debris accumulated over the coated surface of sliders
7F	Cleaned	Cleaned using Novec™ 71IPA	~ 100% removal of debris and SGL-3051 coating achieved

Example 6: 3M Novec™ 1901

Metal bond pad corrosion

Metal Bond pad corrosion has been a long lasting issue on wafers due to fluoride ion contamination. The results in Fig. 8 were obtained using 3M Novec™ 1901 Electronic Grade Coating which was decoated using 3M Novec™ 71IPA Engineered Fluid. Typically after bonding, the substrate is coated, and then subjected to pre-grinding. This is followed by conventional grinding, Taiko grinding, wet etching, detaping then decoating. Coating was done using a dip coater. The wafer was then staged and subjected to cleaning using HF (hydrogen fluoride) comparing both coated and uncoated wafers. HF is typically used to remove any loose particles on the surface of the wafer. Comparing Fig. 8A and 8B, it can be observed that the uncoated wafers exhibited corrosion at the bond pad areas 810 compared to 3M Novec™ 1901 coated bond pad which did not exhibit corrosion at the bond pad areas 820.This shows that the coating is able to protect sensitive bond pads from corrosion during such cleaning processes.

Example 7: Thickness Measurements

The thickness of the coating is important for the end user. The purpose of the coating is to protect the wafers from corrosion, but at the same time, the coating should not interfere with the

other processes intended by the end user, such as analyses including conductivity test, magnetic imaging and focused ion beam (FIB). Accordingly, thinner coatings would prevent interference of the coating with these analyses, while protecting the wafer from corrosion.

The thickness of various 3M Novec™ Electronic Grade Coatings as well as SGL-3051 was measured using Nanosurf AFM. Measurements were done by taking cross-section depth profiling and subtracting the coated and uncoated area. It was shown that it is possible to tune the thickness of the coating to obtain a coating thickness in the range of 50-500 nm for 3M Novec™ 27002, 3M Novec™ 2701, 3M Novec™ 1700 and 3M Novec™ 1702, and a thickness in the range of 2 µm to 10 µm for SGL-3051 using the dip coating technique and adjusting the pull speed, as shown in Table 6. The process can be customized based on the desired use.

Table 6. Thickness measurements

Liquid	**Before Coating**	**Thickness (nm)**
3M Novec™ 27002	20”/min pull speed	72
3M Novec™ 2701	12”/min pull speed	205
3M Novec™ 1700	12”/min pull speed	340
3M Novec™ 1702	12”/min pull speed	6-8
SGL-3051	20”/min pull speed	2000-10,000

Example 8: Automated Coating and De-Coating

The coating-decoating process may be automated by employing a system comprising a device for applying the coating composition and a device for decoating the composition. The two devices may be located side-by-side, comprising a simple dip coater tank and a robotic arm for dipping the substrate into the coating or the decoating solvent. A servomotor may be used in the robotic arm to facilitate vibrationless movement. The device for decoating the composition may comprise an ultrasonic vapour degreaser. An additional reservoir tank may be used to store the coating composition in an idle state. This may prevent excess solvent evaporation whereby the coating polymer (% solid content) and the thickness of the deposited coating may be consistently controlled.

Industrial Applicability

The polymer and coatings comprising the polymer may be useful as temporary protection against debris build-up during semiconductor wafer dicing processes. The polymer and coatings comprising the polymer may be useful in protecting hard disk drive media substrates during transportation from a plating/polishing facility to the final sputtering and assembly facility. The polymer and coating comprising the polymer may be useful as a temporary thin layer coating for corrosion protection. The polymer and coating comprising the polymer may also be useful as an anti-stiction coating, a conformal coating for printed circuit board protection or as a coating for facilitating mold release. The effective removal of the coating by 3M ultrasonication/vapor degreasing technology may also be useful in facilitating efficient coating and decoating processes.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

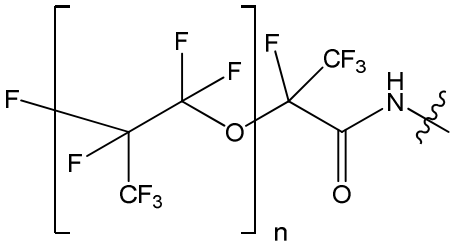
Claims

1. A copolymer comprising a hexafluoropropylene oxide moiety

   and a perfluoroalkylsulfonamide moiety.

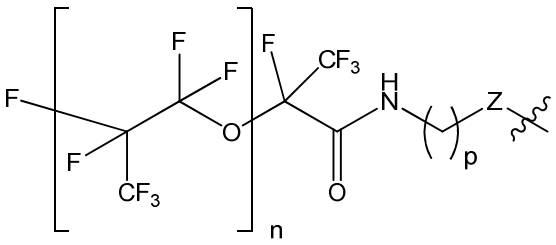
2. The copolymer according to claim 1, comprising repeating units of the hexafluoropropylene oxide moiety and repeating units of the perfluoroalkylsulfonamide moiety.

3. The copolymer according to claim 1 or 2, wherein the hexafluropropylene oxide moiety comprises the following structure:



   wherein n is an integer of at least one.

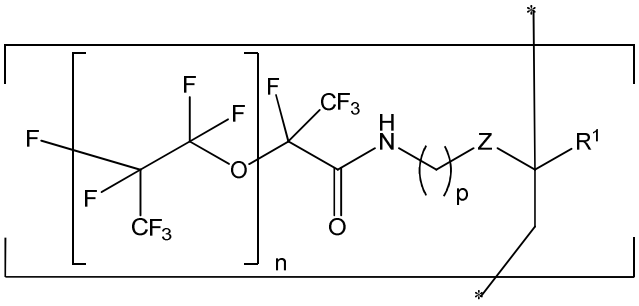
4. The copolymer according to claim 3, wherein the hexafluoropropylene oxide moiety comprises the following structure:



   wherein p is an integer in the range of 1 to 50, and

   Z is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

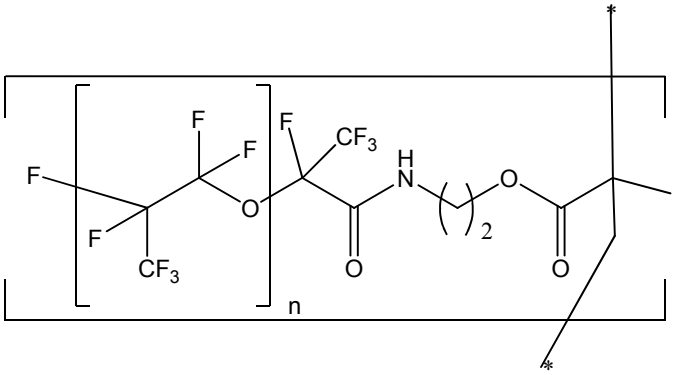
5. The copolymer according to any one of claims 2 to 4, wherein the repeating unit of the hexafluoropropylene oxide moiety has the following structure:



wherein R^1 is hydrogen or alkyl.

6. The copolymer according to any one of claims 3 to 5, wherein Z is ester, p is 2 and R^1 is methyl.

7. The copolymer according to any one of claims 2 to 6, wherein the repeating unit of the hexafluoropropylene oxide moiety has the following structure:



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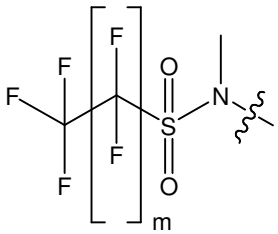
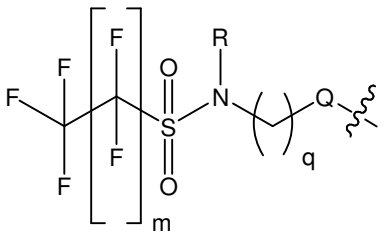
8. The copolymer according any one of the preceding claims, wherein the perfluoroalkylsulfonamide moiety comprises the following structure:



wherein m is an integer in the range of 1 to 50.

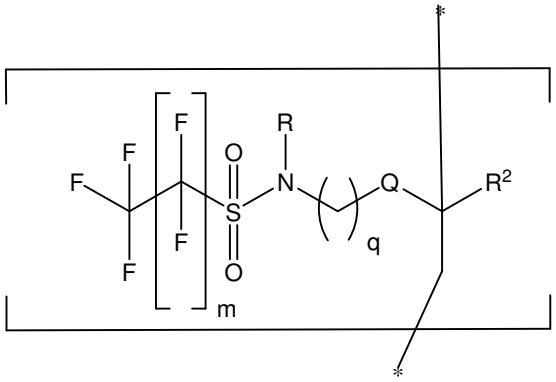
9. The copolymer according to claim 8, wherein the perfluoroalkylsulfonamide moiety comprises the following structure:



wherein q is an integer in the range of 1 to 50, and

Q is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

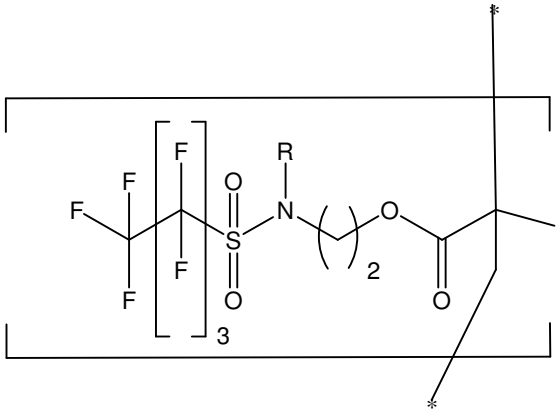
10. The copolymer according to claim 8 or 9, wherein the repeating unit of the perfluoroalkylsulfonamide moiety has the following structure:



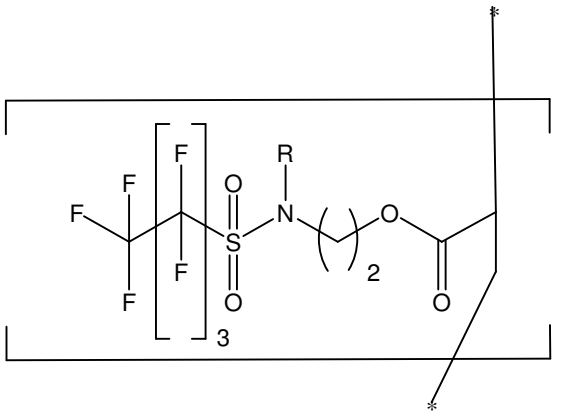
wherein R^2 is hydrogen or alkyl.

11. The copolymer according to any one of claim 8 to 10, wherein Q is ester, m is 3, q is 2 and R^2 is hydrogen or methyl.

12. The copolymer according to any one of claims 2 to 11, wherein the repeating unit of the perfluoroalkylsulfonamide moiety has the following structure:



or



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13. The copolymer according to any one of the preceding claims, wherein the weight ratio between the hexafluoropropylene oxide moiety and the perfluoroalkylsulfonamide moiety is in the range of about 12:1 to about 1:1.

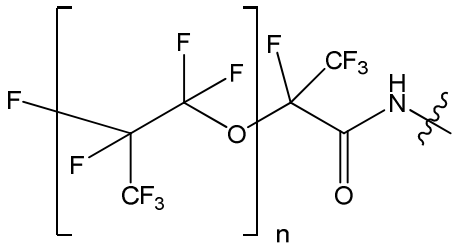
14. The copolymer according to claim 13, wherein the weight ratio between the hexafluoropropylene oxide moiety and the perfluoroalkylsulfonamide moiety is about 9:1.

15. The copolymer of any one of the preceding claims, wherein the copolymer is a linear copolymer, an alternating copolymer, a periodic copolymer, a statistical copolymer, a block copolymer, a stereoblock copolymer, a gradient copolymer or a random copolymer.

16. A method for synthesizing the copolymer according to any one of claims 1 to 15, comprising the step of contacting a first monomer comprising a hexafluoropropylene oxide moiety

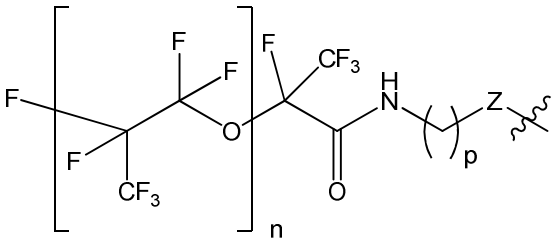
and a second monomer comprising a perfluoroalkylsulfonamide moiety.

17. The method according to claim 16, wherein the first monomer comprises the following structure:



wherein n is an integer of at least one.

18. The method according to claim 17, wherein the first monomer comprises the following structure:



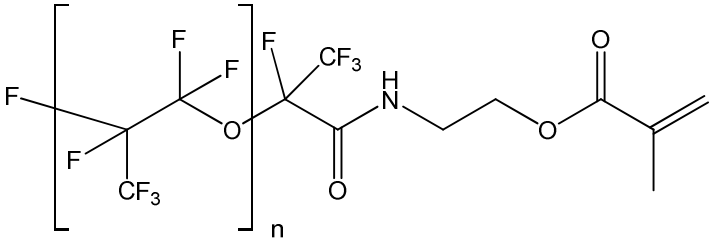
wherein p is an integer in the range of 1 to 50, and

Z is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

19. The method according to any one of claims 16 to 18, wherein the first monomer comprises a vinyl group.

20. The method according to any one of claims 16 to 19, wherein p is 2 and R^1 is methyl.

21. The method according to any one of claims 16 to 20, wherein the first monomer has the following structure:



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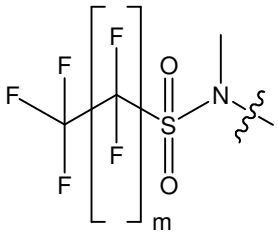
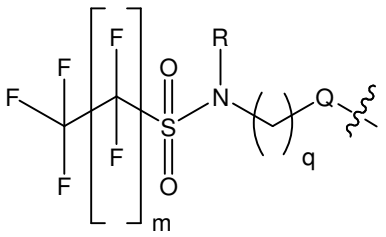
22. The method according any one claims 16 to 21, wherein the second monomer comprises the following structure:



wherein m is an integer in the range of 1 to 50.

23. The method according to claim 22, wherein the second monomer comprises the following structure:

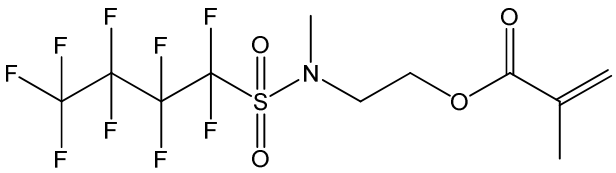


wherein q is an integer in the range of 1 to 50, and

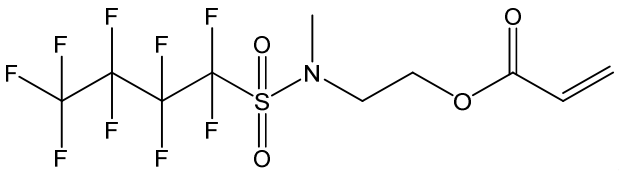
Q is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

24. The method according to any one of claims 16 to 23, wherein the second monomer comprises a vinyl group.

25. The method according to any one of claims 16 to 24, wherein the second monomer has the following structure:



or



.

26. The method according to any one of claims 16 to 25, wherein the first monomer and the second monomer are contacted at a weight ratio in the range of about 12:1 to about 1:1.

27. The method according to claim 26, wherein the first monomer and the second monomer are contacted at a weight ratio of about 9:1.

28. The method according to any one of claims 16 to 27, comprising the step of dissolving the first monomer and second monomer in a solvent.

29. The method according to claim 28, wherein the solvent is 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane.

30. The method according to claim 28 or 29, wherein the solvent is degassed under nitrogen atmosphere.

31. The method according to any one of claims 16 to 30, comprising the step of adding a polymerization initiator.

32. The method according to claim 31, wherein the polymerization initiator is selected from the group consisting of benzoyl peroxide, 1,1'-azobis(cyclohexanecarbonitrile) and any mixture thereof.

33. A copolymer obtainable by contacting a first monomer comprising a hexafluoropropylene oxide moiety and a second monomer comprising a perfluoroalkylsulfonamide moiety.

34. A coating composition comprising the copolymer according to any one of claims 1 to 15 or 33.

35. The coating composition according to claim 34, comprising a solvent.

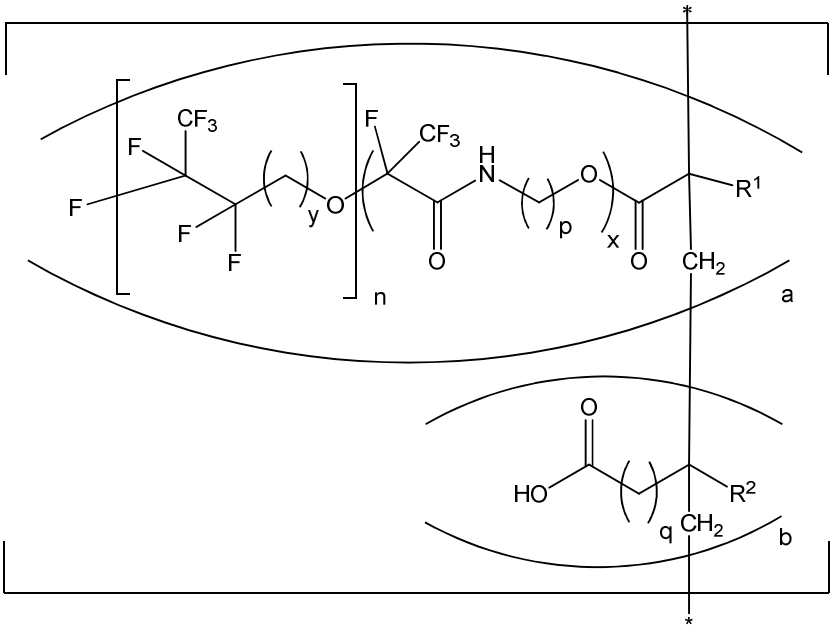
36. The coating composition of claim 35, wherein the solvent is a perfluorinated solvent.

37. The coating composition according to claim 35 or 36, wherein the solvent is selected from the group consisting of 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)-pentane, ethyl nonafluoroisobutyl ether, and any mixture thereof.

38. The coating composition according to any one of claims 34 to 37, wherein the coating composition comprises the copolymer in a range of about 0.2 wt% to about 10 wt%.

39. The coating composition according to any one of claims 34 to 38, wherein the thickness of the coating composition is in the range of about 50 nm to about 500 nm.

40. A method for coating a substrate with the coating composition according to any one of claims 34 to 39, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

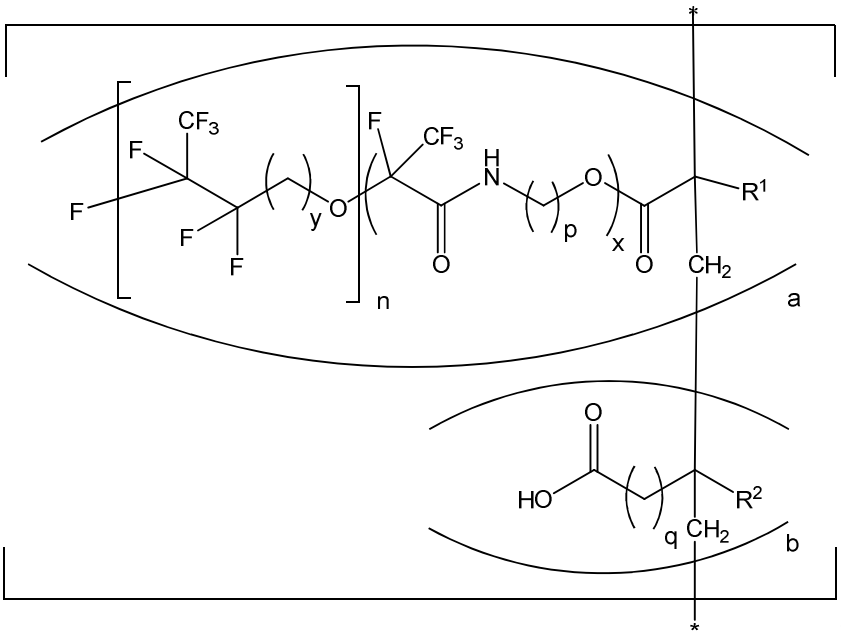
comprising the step of applying the coating composition onto at least part of a substrate surface.

41. The method according to claim 40, wherein the applying step is performed by dip coating, spin coating, brush coating, spray coating or airless spray dispensing.

42. The method according to claim 41, wherein when the coating composition is applied by dipping, the dwell time is in the range of about 15 seconds to about 45 seconds, and the pull speed is in the range of about 10"/minute to about 25"/minute.

43. The method according to any one of claims 40 to 42, comprising the step of drying the substrate coated with the coating composition at a temperature in the range of about 20 °C to about 70 °C for a duration in the range of about 1 minute to about 15 minutes.

44. A method for removing a coating composition according to any one of claims 34 to 39 or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

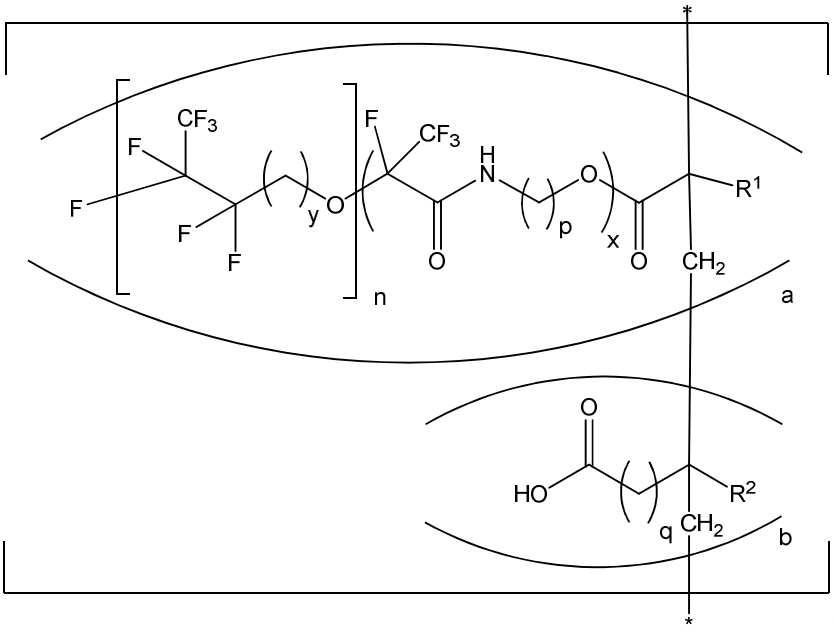
from at least part of a substrate surface, comprising the step of applying a perfluoroalkyl ether to the coating composition.

45. The method according to claim 44, wherein the perfluoroalkyl ether is methyl pefluorobutyl ether.

46. The method according to claim 44 or 45, wherein the application step comprises dipping the substrate surface comprising the coating composition in the perfluoroalkyl ether.

47. The method according to any one of claims 44 to 46, further comprising the step of rinsing the perfluoroalkyl ether off the substrate surface and drying the substrate surface.

48. A method for coating and decoating a substrate with the coating composition according to any one of claims 34 to 39, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

comprising the steps of:

i) applying the coating composition onto at least part of a substrate surface to coat the substrate surface;

ii) processing the substrate; and

iii) applying a perfluoroalkyl ether to the coating composition to decoat the substrate surface.

49. The method according to claim 48, wherein the processing step comprises lithography, taping, detaping, dicing, singulation, etching, bonding, debonding, baking, irradiation, grinding, thinning, cleaning and any combination thereof.

50. The method according to claim 48 or 49, wherein the step of applying the coating composition is performed for a dwell time in the range of about 15 seconds to about 1.5 minutes, a pull speed in the range of about 5”/minute to about 23”/minute and a drying time in the range of about 1 minute to about 3 minutes.

51. The method according to any one of claims 48 to 50, wherein the step of applying the perfluoroalkyl ether is performed at a temperature in the range of about 50 °C to about 65 °C, a dwell time in the range of about 1 minute to about 7 minutes and a drying time in the range of about 30 seconds to about 2 minutes.

52. The method according to claim 51, wherein no sonication is applied during the step of applying the perfluoroalkyl ether.

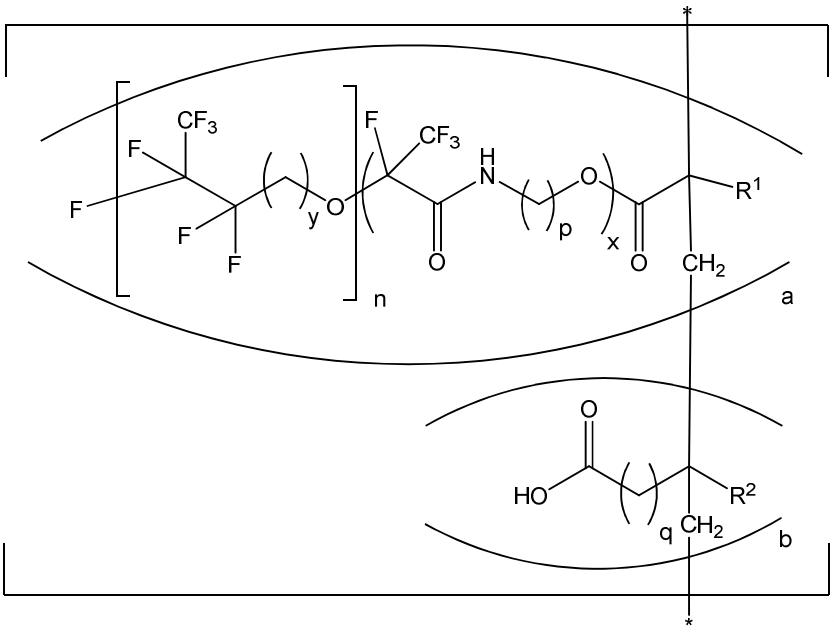
53. The method according to any one of claims 48 to 52, wherein the method is for temporarily protecting the substrate during the processing step.

54. The method according to claim 53, wherein the method protects the substrate from corrosion during the processing step.

55. The method according to claim 53, wherein the processing step is dicing, and the method protects the substrate from debris that is formed during the dicing.

56. A substrate that is at least partially coated with the coating composition according to any one of claims 34 to 39.

57. A system for coating and decoating a substrate with the coating composition according to any one of claims 34 to 39, or a coating composition comprising a copolymer having repeating units of the following formula (I):



(I)

wherein y and x are independently 0 or 1,

n is an integer of at least one,

p and q are independently an integer in the range of 1 to 50,

R^1 and R^2 are independently hydrogen or alkyl, and

the a:b ratio is in the range of about 15:1 to about 1:1,

the system comprising:

iii) a device for applying the coating composition onto at least part of a substrate surface to coat the substrate surface;

iv) an device for applying a perfluoroalkyl ether to the coating composition to decoat the substrate surface.

58. The system according to claim 57, wherein the device for applying the coating composition and the device for applying the perfluoroalkyl ether are located adjacent to each other.

59. The system according to claim 57 or 58, wherein the device for applying the coating composition and the device for applying the perfluoroalkyl ether each individually comprises a tank comprising a robotic arm for dipping the substrate.

60. The system according to claim 59, wherein the robotic arm comprises a servomotor for applying the coating composition or for applying the perfluoroalkyl ether.

61. The system according to any of claims 59 or 60, wherein the tank for applying the perfluoroalkyl ether further comprises an ultrasonic vapor degreaser.

62. The system according to claim 57 or 57, wherein no cooling oil is used.

63. The system according to any one of claims 57 to 62, further comprising a reservoir tank, wherein the coating composition is fed back into the reservoir tank.

64. The system according to any one of claims 57 to 63, wherein the system is automated.