

PATENT SPECIFICATION

NO DRAWINGS

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COMPLETE SPECIFICATION

Razor Blades

We, THE GILLETTE COMPANY, a Corporation organized under the laws of the State of Delaware, United States of America, of Gillette Park, Boston, State of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to single- or double-edge safety razor blades and pertains more specifically to a safety razor blade with a coated cutting edge, having the characteristic of shaving hair much more easily than blades heretofore known and to a method of producing such blades.

Conventional steel safety razor blades to which the present invention may be applied to produce improved blades are from 0.003 to 0.015 inch (say 75 to 375 microns) thick and have wedge-shaped cutting edges, the included solid angle of which is greater than 14° and less than 35°. The faces or sides of some such cutting edges extend back from the ultimate edge for a distance up to as much as 2.5 millimeters or even more. Each face need not be a single planar uninterrupted continuous surface or "facet", but may consist of two or more "facets" formed by successive grinding or honing operations and intersecting each other along zones generally parallel to the ultimate edge. The final facet, i.e. the facet immediately adjacent the ultimate edge, may have a width as little as 7.5 microns or even less as compared to the diameter of a beard hair which averages about 100 to 125 microns, while the thickness of the ultimate edge itself is generally less than 0.6 micron and preferably less than 0.25 micron. The steel of which the blade edge is composed may be either carbon steel or hardenable stainless steel. In either case it is hardened by a suitable heat-

treating process. There is a limit to the extent to which the blade subsequently may be heated since excessive reheating will lead to loss of hardness. As a general rule the hardened blade edges cannot be subjected to a temperature above about 400° F. for more than five minutes without risk that some objectionable tempering or softening of the steel will occur. However, the invention may also be applied to blades having cutting edges of (or coated with) metals or metal alloys other than steel or stainless steel.

As is well known, such conventional steel razor blades despite their sharpness cannot be employed for shaving a dry beard without excessive discomfort and pain, and it is as a practical matter necessary to employ with them a beard-softening agent such as water and/or a shaving cream or soap. The pain and irritation produced by shaving dry are due to the excessive force required to draw the cutting edge of the blade through the unsoftened beard hairs, which force is transmitted to the nerves in the skin adjacent the hair follicles from which the beard hairs extend, and, as is well known, the irritation produced by excessive pulling of these hairs may continue for a considerable period of time after the pulling has ceased. Although a variety of materials have been applied both to the cutting edges of blades and to the beard hair in an effort to reduce the pull, the only materials which have been found commercially useful are those which soften the beard hair itself.

Applicants have discovered that a safety razor blade adherent to a cutting edge of which there is a layer of a suitable organosilicon-containing polymer provides an easier shave with a remarkable reduction in pull; i.e., reduction in the force required to cut or sever the beard hairs, making it less important to soften the beard as completely as is customary, therefore

[Price 4s. 6d.]

making it possible to employ a shorter time for the beard-softening step.

While there may be other methods which could be adopted for demonstrating improved shaving ability we wish it to be understood that statements in the appended claims that the coating on the blade edge is of such a character that the blade provides an easier shave mean that in the aggregate blades having such a coating give more comfortable shaves with less pull than do like blades untreated, as determined by statistical methods from the expressed preferences of numerous individuals, each shaving himself with a treated and also with an untreated blade under similar and appropriate conditions. The reduction in pull and easier shave may persist during several successive shaves with the same coated blade edge, although it does not last indefinitely.

The layer of polymer material need not extend over the entire wedge faces of the cutting edge. It has been found that in some cases exceedingly thin layers of the order of 0.03 microns or less in thickness are recognisably effective during the first facial shave with the blade. There is no precise upper limit on the thickness of the layer of material, and it has been found that thicknesses very many times as great as the above-mentioned order of thickness are satisfactory in some cases. The thickness need not be and usually is not uniform throughout the extent of the layer, but tapers off at the margins.

Razor blades of the present invention which exhibit a pattern of spectral interference fringes (when examined at a magnification of several hundred diameters using vertical illumination with white light and with the observed surface normal to the optical axis of the microscope) possess excellent shaving properties. In the case of certain blades of the present invention possessing excellent shaving properties the total number of fringes observed in the area extending back 50 microns from the ultimate edge of the blades averaged 12, indicating that the coating increased in thickness gradually from the ultimate edge to an average thickness of 2.4 microns at a distance of 50 microns. In arriving at these values, a refractive index of 1.5 and a half-wave length for white light of 3000 Angstroms were used.

It has also been found that by using monochromatic illumination, for example the yellow line of sodium or the green line of mercury, it is possible to observe many more fringes, depending on the thickness and contour of the film.

According to the invention there is provided a safety razor blade having on a cutting edge thereof a coating of an organosilicon-containing polymer which has been so cured *in situ* that the blade provides an easier shave as herein defined. More specifically, there is provided a safety razor blade having on a cutting edge thereof a coating of an organo-

silicon-containing polymer which has been cured *in situ* to form a gel as herein defined adherent to the said cutting edge so that the blade provides an easier shave as herein defined.

The word "gel" as used in the specification and claims means a stable gel having a low shear resistance, either in its interior or at its surface or both, and having a structure that consists of a cross-linked polymer which has an insoluble infusible coherent three-dimensional network within which is contained liquid material of lower molecular weight. This structure is to be distinguished from a hard vitreous one. By "stable" is meant that a blade cutting edge coated with the gel material will still possess superior shaving characteristics when stored under normal market conditions for a period of at least three months. The gel should be insoluble in water and conventional shaving soaps or creams and be non-toxic. Such a material is preferably provided by curing *in situ* on the blade a selected organosilicon-containing polymer having a plurality of siloxy groups, i.e., a polymer in which silicon is linked through oxygen to silicon or to other elements in the polymer framework, such as an organosiloxane, a silyl polyester, or a modified organosiloxane in which a small proportion of the silicon atoms have been replaced by atoms of another metal. For example, 1 silicon atom is replaced by 1 atom of tin. The curing serves to provide a cross-linked structure in which a proportion of silicon atoms in the polymer chains are cross-linked and in which the polymer is adherent to the underlying blade. The curing is preferably carried out by heating in hot air, called "air-curing", although prolonged exposure at room temperature to radiation such as from radium is also effective. It is not essential that all the curing be done *in situ*, since the organosilicon-containing polymer may be partly cured in advance and the cure completed *in situ* on the blade to the desired gel state.

While the theory of operation of the present invention may not be fully understood and applicants do not wish to be bound by the following explanation, it is believed that the reduced pull in shaving results mainly from a shearing of the organosilicon-containing polymer during cutting. The total force required to cut hair involves at least two components. One is the force needed to push the ultimate cutting edge through the hair, and the other is the force needed to overcome the friction caused by the pinching and adhesion of partially severed hair of the flanks of the wedge-shaped cutting edge. The latter is believed to be the major component of the total force required to sever the hair. For example, in the case of an axe cutting into the side of a tree, the pinching friction on the flanks of the cutting edge becomes so great

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that the axe stops before it penetrates far into the wood. Heretofore, many efforts to improve shaving have been directed to perfecting the cutting edge and to softening the hairs to be cut. Shaving soaps and creams, until applied long enough to soften the beard by wetting it, have little effect in reducing the total force needed to sever hair. The present invention is believed to reduce that force in a novel manner by interposing between the blade and the hair a material which adheres firmly to the faces of the cutting edge throughout the shaving, but has a low shear resistance either in its interior or at its surface or both. Shearing may be accompanied by expression of liquid from the material.

The adhesion or bonding of the material to the facets of the cutting edge should be great enough so that the film is not entirely removed from the facet surface during shaving. The cohesion within the material or its adhesion to the hair should be less than its adhesion or bonding to the metal surface, permitting the material to shear without being completely removed from the metal. The force required to cause such shearing should be small enough that the total force required to cut hair with a treated blade is less than that required with an untreated blade. The material should have sufficient compressive strength so that gross contact between hair and metal does not occur. A treated blade leads to a great reduction in the pull on hairs and in the consequent discomfort in shaving. Inasmuch as the number of shaves during which the effect of the material persists is limited to several shaves, it is believed that attrition of some of the material occurs during use.

The extent to which the coating shears depends upon the state of cure. In the case of methyl hydrogen siloxane (such as is used in Example 1 below), when a relatively thick coating (10 microns at a distance of 125 to 150 microns from the ultimate edge) is cured for a short time, the top portion of the coating usually remains liquid, and is removed when the blade is first used, leaving on the surface of the metal a layer of polymeric gel less than 1 micron thick which is still effective to produce the greatly improved shaving characteristics of the present invention for at least one shave.

When the same type of coating is cured for a somewhat longer time, the entire mass of the coating becomes a gel; however, it is still soft and weak enough that during the first shave this upper portion is pushed away from the underlying thin (less than 2 microns) layer in the zone extending back about 50 to 125 microns from the ultimate edge. The remaining thin layer, which is strongly adherent to the underlying metal, remains effective for a number of shaves.

The 10 micron thick coating may be cured

for a still longer time, until the entire mass of the coating becomes a stiffer material, and still retains its effectiveness.

When a film of the same material and thickness is cured to a still greater extent, it becomes a hard glassy coating which may exhibit occasional abrupt fractures. A blade having such a coating is no better than an untreated blade in shaving quality and may be worse.

Blades bearing a very thin initial coating, of the order of 1 to 2 microns thick, of the same material exhibit much the same behaviour as the cure is progressively increased, except that the residual film left next to the metal after removal of the overlying liquid or very soft gel may be less than 0.2 micron thick, as shown by the absence of any interference fringes.

Very thick coatings of the same material, many times as thick as the 10 microns coating described above, should not be cured beyond the point (described above) at which the upper portion of the coating is pushed away during the first use of the blade.

The useful range of curing is wide but not unlimited and will depend on the particular organosilicon-containing polymer employed in the present invention; in the case of methyl hydrogen siloxane, the range is fairly wide but by no means unlimited. Undercuring as well as overcuring produces coatings which do not improve the shaving properties of the blades. The organosilicon-containing polymer coating when uncured or undercured has little or no adherence to the surface of the blade. It is believed that it is this lack of adequate adherence to the surface which makes the undercured coating ineffective, as the coating will be wiped off the blade in the first few strokes of the shaving operation. When overcured, the organosilicon-containing polymer coating strongly adheres to the surface of the blade but does not shear easily and it is believed that it is this high shear resistance which makes the overcured coating ineffective. Thus, between the undercured and overcured conditions, there exists a region of effective cures which impart to the blade the remarkable shaving properties never previously achieved.

The organosilicon-containing polymers useful in this invention include the organosiloxanes. These are chemical compounds characterised chiefly by chains of alternate silicon and oxygen atoms in which most of the silicon atoms bear organic substituent groups attached through carbon-silicon bonds. They are by their nature polymeric substances, existing as linear chains or cyclic polymer chains.

The nature of the individual substituent groups affects the chemical as well as the physical properties of the organosiloxane, while the length of the chains and the number of cross-links (the result of some form of

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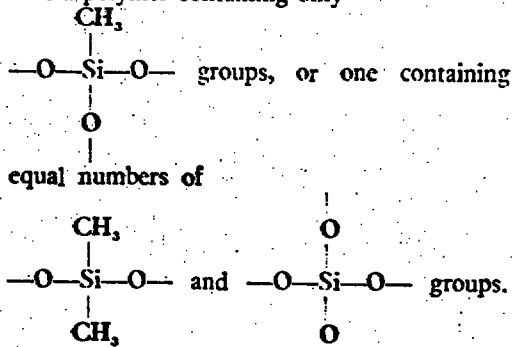
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curing) affect primarily the physical properties. In general, in the case of an organosiloxane having specific alkyl substituent groups, the viscosity increases with the chain length. When a large proportion of the substituent groups are hydrogen atoms, the organosiloxane is readily cured or cross-linked by an oxidation reaction; when the substituent groups are aromatic, such as phenyl groups, they are very much less subject to oxidation.

When little or no cross-linking is present, dimethyl siloxanes are liquids; as the chain length of the siloxane increases, the viscosity of the liquid increases to the point where the material becomes a gum. As a liquid dimethyl siloxane is cured or cross-linked it becomes a gel, and as the extent of cross-linking increases it becomes progressively harder and more brittle until it loses its gel character and becomes an increasingly hard and inflexible rosin-like material.

The average functionality of the units of an organosiloxane polymer is indicated by the average formula as well as by the structural formula. Thus the average unit formulae $(CH_3)_2SiO$ and $(CH_3)_3HSiO$ would correspond to organosiloxane polymers made from bifunctional units, such as a viscous liquid or soft gum or elastomer, whereas an average unit formula $CH_3SiO_{1.5}$ would correspond to a polymer made from units having an average functionality of three, and hence a thoroughly cross-linked siloxane resin. The average unit formula $CH_3SiO_{1.5}$ could equally well represent a polymer containing only



The average unit formula is a convenient way of describing a given siloxane polymer, but it will be obvious to those skilled in the art that very high proportions of trifunctional and tetrafunctional units, even though they be compensated by equivalent numbers of monofunctional units, may cause stereochemical interference with the condensation process, so that the curing characteristics of the polymer are changed. For this practical reason, in each organosiloxane system, indeed in each organosilicon-containing polymeric system, the substitution of trifunctional (or tetrafunctional) plus equivalent monofunctional units must be limited to a minor proportion so that it does not interfere

with curing to the desired gel which is adherent to the blade.

The organosiloxanes employed for cross-linking on the blade may be generally defined having in mind the qualifications of the preceding paragraphs, as initially liquid polymers composed of molecules containing a chain of alternating silicon and oxygen atoms, each of a substantial number of silicon atoms within the chain having bonded to it two substituent groups. A substantial number of these groups should be either methyl groups or hydrogen atoms in order to permit curing to the desired gel, but a variety of other groups such as ethyl, n-propyl, iso-propyl, n-butyl, n-amyl, vinyl, allyl or phenyl groups may be present provided that they are limited to a proportion which is low enough not to interfere with curing to the desired gel which is adherent to the blade. When all of the substituent groups are hydrogen, the liquid polymer tends to overcure to the undesired hard glassy condition. The minimum as well as the maximum proportion of hydrogen atoms which may be replaced by the other substituent groups varies depending upon the nature of the other substituent group present. From about 40% to 100% of the hydrogen atoms may be replaced by methyl groups, but only about 40% to 80% of the hydrogen atoms may be replaced by ethyl groups, and only about 40% to 50% by n-propyl or by n-butyl groups. Even though organosiloxanes having higher proportions of hydrogen atoms than those stated above can be applied to blades to give the results of the present invention for a short time after cure, we have found that such organosiloxanes tend to overcure during storage for the normal period between production and consumer use; hence such organosiloxanes can be used only under special conditions, as for example by applying them to the blade edge immediately before use. Phenyl groups, isopropyl groups, vinyl groups, allyl groups, and n-amyl groups can be present in the molecule only when some additional substituent group other than hydrogen alone is also present.

In the case of dimethyl siloxane, up to about 15% of the methyl groups may be replaced by phenyl groups, up to about 30% may be replaced by isopropyl groups, up to about 50% may be replaced by n-propyl or by n-amyl groups, and up to about 70% may be replaced by ethyl groups without destroying the effectiveness of the material, while in the case of methyl hydrogen siloxane up to about 40% of the methyl groups present may be replaced by phenyl groups, and up to about 60% of the methyl groups may be replaced by iso-propyl groups. It is also possible to replace a very small proportion of the methyl groups in dimethyl siloxane with vinyl or with allyl groups.

These polymers may be cyclic or open-



of

chain in nature, in which latter case the terminal groups at each end of the polymer chains are usually hydroxyl groups or aliphatic or aromatic groups.

The desired organosiloxanes may also be defined as initially liquid polymers having structures with the general formula $[RR'-Si-O]_n$, in which R and R' are each hydrogen or an organic group as specified above and in which n has an average value up to 5000 or even more.

We have found that most polymers having low values of n are difficult to use for a variety of reasons. When their boiling points are too low, they volatilise and fail to cure *in situ*. When they have non-condensable end groups such as trimethylsiloxy groups and are of low molecular weight, they do not form the desired gel even when they do not volatilise. In both cases, however, the presence of a very small proportion of higher polymeric material in the composition may result in a satisfactory coating. Low molecular weight materials having condensable end groups, i.e., hydroxyl groups, are more useful than equally low molecular weight materials having non-condensable end groups. In the case of linear dimethyl siloxanes with terminal hydroxyl groups or of cyclic dimethyl siloxanes in which rupture of the ring produces condensable end groups, a polymer having a value of n of the order of 7 or more is easy to use. It is preferable to avoid difficulties by using much higher molecular weight materials.

It will be understood that it is also possible to apply to the cutting edge of the blade a material which is not initially a liquid organosiloxane but which is converted to a siloxane in place. For example, octamethyl cyclotetrasilazane, $[(CH_3)_2Si-NH]_4$, when applied to a razor blade cutting edge and allowed to stand in the atmosphere for an extended period, hydrolyses to form a liquid siloxane which can then be cured in the usual manner.

Best results are obtained with those organosiloxanes in which R is methyl and R' is hydrogen or methyl. Of these the liquid methyl hydrogen siloxanes having the average formula $[(CH_3)_2HSiO]_n$, in which n has an average value set forth above are particularly preferred, although liquid dimethyl siloxanes in which n has an average value as above are also quite effective. It will be understood that the formulae referred to are average formulae only and neglect the contribution made by end groups in the case of non-cyclic materials. Any given linear polymer molecule need not be made up of a chain of units all of which are identical to each other and mixtures of different polymer molecules may be employed, which mixtures have the average general formula indicated above. For example, methyl hydrogen siloxane may be made up of a mixture of polymer molecules composed of

$\begin{array}{c} CH_3 \\ | \\ -Si-O- \end{array}$ units and polymer molecules 65

$\begin{array}{c} CH_3 \\ | \\ H \\ | \\ -Si-O- \end{array}$ composed of units, as well as polymer molecules

$\begin{array}{c} H \\ | \\ CH_3 \\ | \\ -Si-O- \end{array}$ composed of units. Also, this material may con-

tain polymer molecules each of which includes two or all three types of unit. Such co-polymers may be prepared by co-hydrolysis of combinations of dimethyldichlorosilane, methyldichlorosilane, and dichlorosilane. 70

It will also be clear that the optimum curing conditions for a polymer of the unit formula $(CH_3)_2SiO$ differ from those for a polymer of the unit formula $(CH_3)_2HSiO$ since Si-H bonds are known to oxidise more readily than methyl groups attached to silicon. Similarly, the curing conditions must depend upon the molecular weight of the siloxane polymer, for at too high a temperature a volatile polymer of low molecular weight will evaporate before it can cure by oxidation. 75

The initially liquid polymer may be applied directly to clean faces of the safety razor blade edge in any suitable manner; for example, by dipping or immersing the blade edge in the polymer, by spraying the polymer onto the cutting edge, or by flowing the polymer onto the edge from a capillary, or by stropping it on. It is desirable, in order to obtain optimum adhesion or bonding of the polymer to the underlying metal of the blade, that all foreign material such as organic greases and oils are removed from the blade faces before the liquid polymer is applied. This may be accomplished, for example, by washing the blade with a volatile solvent such as benzene, trichloroethylene, or carbon tetrachloride and drying. It may be desirable to thin or dilute the polymer by the addition of a suitable inert volatile organic solvent or diluent such as carbon tetrachloride, hexamethyl disiloxane, or 1,4-dioxane in order to facilitate application of the polymer to the sharpened edge of the razor blade. After a cutting edge of the blade is coated and any solvent or diluent has been evaporated, the polymer must be sufficiently 85

When the cure is carried out by heating the coated blade in a hot air oven, the range of time and temperature required will also depend upon the volume of air in the oven and its circulation rate as well as upon the size, 90
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mass and geometry of the individual blades and of the coating and the total number present in the oven at any one time, all of which factors affect the rate of heat transfer to the coating and the rapidity at which it is heated.

If the cure is insufficient, so that the organosilicon-containing polymer remains essentially a liquid, it is not substantially more effective than other liquids, for example lubricating oils, and it fails to enhance the apparent sharpness of the blade and fails to reduce the pull. If the cure is continued too long, it also fails to produce the desired results, and under some circumstances an overcure may even result in a blade inferior to the original uncoated blade, particularly when the coating is initially relatively thick. It may be desirable in some cases to cool the heated blade rapidly in a stream of air to prevent overcure.

In the case of siloxane chains having the average unit formula $(CH_3)_2HSiO$, an effective cure may be accomplished by heating the blade in the presence of air at 300° F. for about fifteen minutes. In general, heating at 285°—340° F. for two to fifteen minutes in the presence of air is preferred. An effective cure may also be achieved by heating the blade coated with the liquid polymer for a longer period of time at a lower temperature, for example for a period of about two and a half hours at 200° F., or for a shorter period of time at a higher temperature, as for example for about twenty seconds at 400° F. It may be desirable to include additives which may be either chemically inert or chemically active as in Examples 2 and 3.

The time and temperature required for the desired extent of cure may be reduced by employing in conjunction with the liquid polymer composition suitable known catalysts. Examples of such catalysts are choline dicarbonate, ammonium hydroxide, piperidine, dibutyl tin dilaurate, tin laurate, and zinc naphthenate. The minimum cure required for any given liquid organosilicon-containing polymer starting material will also vary depending upon its chain length, lower temperatures and shorter times being required for starting materials of longer chain lengths.

In the case of liquid siloxanes having chains with the average unit formula $(CH_3)_2HSiO$, if the material is completely removed by wiping with a felt or cloth or if it dissolves completely in carbon tetrachloride at room temperature, the cure is less than the minimum required.

The following specific examples are illustrative of the nature of the present invention. In each example, except Example 8, the blades employed were all hardened, lacquered, standard carbon steel double-edge safety razor blades of 0.005 inch (125 microns) thickness available commercially under the designation of "Gillette Blue Blades" the word "Gillette" being a Registered Trade Mark. The fringes reported were in all cases observed using white

light. In each of the examples the treated blades were found by actual shave tests to have remarkably improved shaving characteristics as compared with like blades untreated.

EXAMPLE 1

An endless steel conveyor band provided with pairs of projecting nibs for holding blades in position on its upper horizontal face with their edges parallel to the direction of advance was mounted so that it advanced the blades continuously into, through and out of an elongated heater. The band width was less than half the width of the blades and approximately 0.05 inch thick, the nibs being arranged so that successive blades were spaced apart by somewhat less than $\frac{1}{8}$ inch. The heater, a three-foot long generally rectangular mass of aluminium weighing many times as much as an equal length of band and blades, had a longitudinal internal central passage only slightly greater in cross section than the band with the blades carried by it. Electrical resistance strip heaters were provided along the top and bottom of the heater, the temperature being controlled by thermocouples seated in wells in the heater walls adjacent the passage. The speed of the band was adjusted so that each blade required three minutes to pass through the heater, which was maintained at 320° F.

The blades to be treated were washed with trichloroethylene, dried and mounted on the advancing conveyor band and were carried through an applicator station spaced approximately $3\frac{1}{2}$ feet in advance of the entrance to the heater. At the applicator station both cutting edges of each blade were advanced longitudinally through laterally open narrow channels supplied with a 12% by volume solution in carbon tetrachloride of methyl hydrogen siloxane having the average unit formula $(CH_3)_2HSiO$ and having a reduced specific viscosity of 0.08 as determined on an Ostwald-Cannon-Fenske Viscometer ASTM Series 50 (which viscometer is described in the appendix to ASTM Tentative Method D-445-46-T) using 5 ml. of a xylene solution containing 10 g. of the siloxane per 100 ml. of solution at 27° C. Each cutting edge thus acquired a coating of the solution. As the blades continued to advance toward the heater, the carbon tetrachloride evaporated. After a single passage through the heater, the blades were allowed to cool in air. The blades had on the cutting edges a coating of a gel which was adherent to the underlying steel and which exhibited a pattern of seven interference fringes in the zone extending back 25 microns from the ultimate edge.

EXAMPLE 2

The procedure was the same as in Example 1 except that the coating material employed was a 12% by volume solution of the same

organosiloxane in redistilled hexamethyl-disiloxane as solvent, the solution also containing 1% by weight of dispersed finely divided molybdenum disulphide supplied under the designation "Molykote Type GX" by Alpha Molykote Corp., the word "Molykote" being a Registered Trade Mark. The blades had on their cutting edges a coating of a gel material adherent to the steel. The coating exhibited no pattern of interference fringes, being less than 0.2 micron thick in the zone extending 25 microns from the ultimate edge.

EXAMPLE 3

The procedure was the same as in Example 2 except that the molybdenum disulphide was replaced by finely divided silica (Godfrey L. Cabot, Inc., Cab-o-sil Fluffy 2491). The coating on the cutting edges was a gel adherent to the steel and displayed no interference fringes, being less than 0.2 micron thick in the zone extending 25 microns back from the ultimate edge.

EXAMPLE 4

The procedure was generally the same as that described in Example 1. However, the coating material consisted of a mixture of one part by volume of the methyl hydrogen siloxane of Example 1 dissolved in one part by volume of 1,4-dioxane, to which solution there was added, with thorough stirring, an equal volume of a mixture consisting of 50% by volume of a 44% by weight aqueous solution of choline bicarbonate and 50% by volume of 1,4-dioxane. The mixture was allowed to stand 15 minutes at room temperature before being applied to the blades. In addition, the speed of the band conveyor was increased so that each blade required only 9.5 seconds to pass through the heater. Each blade was found to have on its cutting edges a gel coating adherent to the underlying steel and displayed five interference fringes in the zone extending 25 microns from the ultimate edge.

EXAMPLE 5

A high molecular weight dimethyl siloxane composed essentially of units of the formula $(CH_3)_2SiO$ was prepared by catalytic isomerisation and polymerisation of the cyclic tetramer, the product having a reduced specific viscosity of 0.4, determined as described in Example 1 (except that the solution contained 5 g. of the siloxane per 100 ml. of solution instead of 10 g.). A 12% by volume solution of this siloxane in carbon tetrachloride was employed as the coating composition in a procedure like that described in Example 1 except that the conveyor band was stopped so that each blade remained in the heater for thirty minutes. The treated blades had a thin layer of gel on their cutting edges adherent to the steel and displaying four fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 6

Ethyl hydrogen siloxane having the average unit formula $(C_2H_5)HSiO$ and having a reduced specific viscosity of 0.03, determined as described in Example 1, was employed as the coating material without any solvent. A stack of approximately 50 blades, previously washed with trichloroethylene and dried and arranged with their flat sides in contact and with their edges aligned, was dipped manually in a pool of the liquid siloxane so that each sharpened edge along its entire length barely touched the liquid surface. The blades were then mounted on pairs of steel spindles, each blade being spaced $\frac{1}{16}$ inch from the blade below it in the stack by a pair of $\frac{3}{16}$ inch diameter washers so as to ensure uniform heating. A holder carrying seven such pairs of spindles with their stacks of blades arranged so that the edges of successive stacks were about $\frac{1}{4}$ inch apart and having a total loaded weight of approximately 650 g. was placed in a hot air oven (Thelco No. 18-A-D-9, Precision Scientific Co.) set at 320° F. and allowed to remain for twenty minutes after which the blades were removed and allowed to cool in air. Each blade had on its cutting edges a thin layer of gel material adherent to the steel and displaying five fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 7

A solution (50% by volume) of n-propyl hydrogen siloxane in xylene was employed as the coating material and was applied to the blades as described in Example 6. The siloxane had the average unit formula $(C_3H_7)HSiO$ and a reduced specific viscosity of 0.03, determined as described in Example 1 above, except that the xylene solution contained 20 g. of siloxane in 100 ml. of solution.

The blades on their spindles were placed in a hot air oven (Blue M Model OV-50, Blue M Electric Co.) set at 320° F. and allowed to remain 2½ hours, then were cooled in air. The finished blades had a thin layer of gel on their cutting edges adherent to the steel and displaying three fringes in the zone extending 25 microns from the ultimate edge; the fringes in this case were all grouped in the rear portion of the zone, no fringes at all appearing in the first quarter of the zone adjacent the ultimate edge.

EXAMPLE 8

There was used as the coating material a 12% by volume solution of the methyl hydrogen siloxane of Example 1 dissolved in redistilled hexamethyl disiloxane as solvent. The coating material was applied to stainless steel double-edge safety razor blades purchased on the open market following the procedure described in Example 1. The blades had on the cutting edges a coating of gel adherent to the steel which exhibited three fringes in the zone extending 25 microns from the ultimate edge.

EXAMPLE 9

Liquid ethyl methyl hydrogen siloxane without solvent was applied to the blade edges as described in Example 6. The siloxane was composed of units of the formula RRSiO in which 13% of the R groups were ethyl, 40% were methyl and 47% were hydrogen, and had a reduced specific viscosity of 0.06 determined as described in Example 1.

The blades, after coating of their edges, were stacked on spindles and placed in a hot oven as described in Example 7 where they remained for six minutes. After cooling in air the blades had a thin coating of gel material on their cutting edges adherent to the steel and displaying six interference fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 10

There was used as the coating material liquid ethyl methyl hydrogen siloxane composed of units of the formula RRSiO in which 29% of the R groups were ethyl, 23% were methyl and 48% were hydrogen. It had a reduced specific viscosity of 0.02 determined as described in Example 7. The composition was applied to the blade edges manually, as described in Example 6, and the blades stacked on spindles were placed in an oven as described in Example 7 where they remained for 10 minutes, after which they were cooled in air at room temperature. The finished blades carried on their cutting edges an adherent coating of gel material which exhibited six interference fringes in the zone extending 25 microns from the ultimate edge.

EXAMPLE 11

Liquid ethyl methyl siloxane composed of units of the formula RRSiO in which 30% of the R groups were ethyl and 70% were methyl was employed as the coating material without any solvent. The siloxane had a reduced specific viscosity of 0.09 determined as described in Example 7. The siloxane was applied to the blade edges manually as described in Example 6, and the blades stacked on spindles were placed in an oven as described in Example 7 where they were allowed to remain for five hours, after which they were cooled in air at room temperature. The resultant blades carried a layer of adherent polymeric material in the form of a gel on their cutting edges, but in this case displayed no interference fringes, the layer being less than 0.2 micron thick in the zone within 25 microns from the ultimate edge.

EXAMPLE 12

There was employed as the coating material liquid n-butyl hydrogen siloxane having the average unit formula $(\text{C}_4\text{H}_9)_2\text{HSiO}$. The siloxane had a reduced specific viscosity of 0.14 determined as described in Example 1 (except that the xylene solution contained 2 g. of

siloxane per 100 ml. of solution instead of 10 g.). The material was applied to the blade edges as described in Example 6, and the blades were allowed to remain in the oven as described in Example 7 for twenty-four hours, after which they were cooled in air. The resultant blades carried a layer of adherent polymeric material in the form of a gel on their cutting edges and exhibited five fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 13

There was employed as the coating material liquid methyl hydrogen siloxane having a reduced specific viscosity of 0.08 determined as described in Example 1. The material was applied to the blade edges and cured as described in Example 6, except that the oven was maintained at 332°F . instead of 320°F . and the blades were allowed to remain in it for only three minutes.

After cooling in air, the coated blades were then extracted for 21 hours with benzene at reflux temperature in a Soxhlet extractor. During the extraction a portion of the material on the cutting edges was dissolved and carried away by the benzene. The benzene-extracted blades were then dried in air at room temperature and were found to exhibit five fringes in the zone within 25 microns of the ultimate edge.

EXAMPLE 14

There was employed, as the coating material liquid phenyl methyl siloxane composed of units of the formula RRSiO , in which 15% of the R groups were phenyl and 85% were methyl. The siloxane had a reduced specific viscosity of 0.02 as determined in Example 1. The siloxane was applied to the blade edges manually as described in Example 6, and the blades stacked on spindles were placed in an oven as described in Example 7, where they were allowed to remain for 30 minutes, after which they were cooled in air at room temperature. The resultant blades carried a layer of adherent polymeric material in the form of a gel on their cutting edges adherent to the steel and displayed 12 fringes in the zone extending 25 microns from the ultimate edge.

EXAMPLE 15

A solution (20% by volume) of a modified methyl hydrogen siloxane in redistilled hexamethyl disiloxane solvent was employed as the coating material. The methyl hydrogen siloxane had an average unit formula $(\text{CH}_3)_2\text{HSiO}$ and the polymer chains were terminated with groups of the formula $-\text{OCH}(\text{CF}_3)\text{CF}_3\text{H}$. This polymer had a reduced specific viscosity of 0.03 determined as in Example 12 above. The polymer was applied to the blade edges as described in Example 6, and the blades stacked on spindles were placed in an oven as described in Example 7, where they were allowed to remain for 10 minutes, after which

they were cooled in air at room temperature. The resultant blades had a layer of gel on their cutting edges adherent to the steel and displayed 12 fringes in the zone extending 25 microns from the ultimate edge.

EXAMPLE 16

There was used as the coating material liquid methyl hydrogen siloxane having the average unit formula $(CH_3)_2HSiO$ with a reduced specific viscosity of 0.08 determined as described in Example 1. A stack of approximately 1000 blades previously washed in trichloroethylene and dried and arranged with their flat sides in contact and with their edges aligned was placed in a hot air oven (Blue M Model OV-50, Blue M Electric Co.) set at 340° F. where they were allowed to remain for 26 minutes, at which time the blade edges had reached 320° F. The blade stack was removed from the oven for about 30 seconds, during which time the edges were sprayed with the siloxane described above. The coated blades were then replaced in the same oven for 10 minutes longer and then removed and cooled in air at about 50° F. until the blades reached a temperature of about 95° F. The finished blades had a thin layer of gel on their cutting edges adherent to the steel, but in this case displayed no interference fringes, the layer being less than 0.2 micron thick in the zone within 25 microns from the ultimate edge.

EXAMPLE 17

There was employed as the coating material liquid dimethyl silyl polyester of ethylene glycol having the average unit formula $(CH_3)_2SiOCH_2CH_2O$ and having a reduced specific viscosity of 0.008 determined as described in Example 1. The material was applied to the blade edges as described in Example 6, and the blades were allowed to remain in the oven as described in Example 7 for two hours, after which they were cooled in air at room temperature. The resultant blades carried a layer of adherent polymeric material in the form of a gel on their cutting edges but in this case displayed no interference fringes, the layer being less than 0.2 micron thick in the zone within 25 microns from the ultimate edge.

EXAMPLE 18

There was employed as the coating material a modified liquid dimethyl siloxane in which a portion of the silicon atoms were replaced by tin atoms, the siloxane being composed essentially of units of the formulae $(CH_3)_2SiO$ and $(CH_3)_2SnO$, with the atomic ratio of silicon to tin about 19 to 1. This liquor polymer had a reduced specific viscosity of 0.01 as determined in Example 12. The polymer was applied to the blade edges manually as described in Example 6, and the blades stacked on spindles were placed in an oven as described in Example 7, where they were allowed

to remain for two hours, after which they were cooled in air at room temperature. The resultant blades carried a layer of adherent polymeric material in the form of a gel, but in this case displayed no interference fringes, the layer being less than 0.2 micron thick in the zone within 25 microns from the ultimate edge.

EXAMPLE 19

There was employed as the coating material liquid vinyl methyl siloxane composed of units of the formula $RRSiO$, in which 0.5% of the R groups were vinyl and 99.5% were methyl. The siloxane had a reduced specific viscosity of 0.009 as determined in Example 5. The material was applied to the blade edges and cured as described in Example 7 except that the blades remained in the oven for 75 minutes. After cooling in air at room temperature, the blades had a thin coating of gel material on their cutting edges adherent to the steel, but in this case displayed no interference fringes, the coating being less than 0.2 micron thick in the zone within 25 microns from the ultimate edge.

EXAMPLE 20

There was employed as the coating material liquid allyl methyl siloxane composed of units of the formula $RRSiO$, in which 0.5% of the R groups were allyl and 99.5% were methyl. The siloxane had a reduced specific viscosity of 0.106 as determined in Example 5. The material was applied to the blade edges and cured as described in Example 1 except that the speed of the band was adjusted so that each blade required 2 minutes to pass through the heater. The treated blades had a thin layer of gel on their cutting edges adherent to the steel and displaying ten fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 21

There was employed as the coating material liquid n-amyl methyl siloxane composed of units of the formula $RRSiO$, in which 50% of the R groups were amyl and 50% were methyl. The siloxane had a reduced specific viscosity of 0.015 as determined in Example 1. The material was applied to blade edges and cured as described in Example 7 except that the blades remained in the oven for 3 hours. After cooling in air at room temperature the blades had a thin coating of gel material on their cutting edges adherent to the steel and displayed six fringes in the zone within 25 microns from the ultimate edge.

EXAMPLE 22

There was employed as the coating material liquid isopropyl methyl hydrogen siloxane composed of units of the formula $RRSiO$ in which 30% of the R groups were isopropyl, 20% were methyl and 50% were hydrogen. The siloxane had a reduced specific viscosity of

50 edge.
55 liquid
60

0.06 as determined in Example 1. The material was applied to the blade edges and cured as described in Example 7 except that the blades remained in the oven for 30 minutes. After cooling in air at room temperature the blades had a thin coating of gel material on their cutting edges adherent to the steel and displayed six fringes in the zone within 25 microns from the ultimate edge.

The coating may be applied as a step during the manufacture of the blades; for example a thin strip of high carbon steel in the "as rolled" condition, having a little more than the width desired in the finished razor blades, may be subjected to a perforating or notching operation, after which it is hardened; then one or both longitudinal margins of the strip are sharpened. After the sharpening step the coating of the present invention may be applied to the sharpened edges and cured, following which individual blades may be severed from the strip by a parting operation. If desired, of course, the coating of the present invention may be applied after the parting operation. It will be understood that the term "blades" is intended to include the very long, flexible, ribbon-like blades which can be used in reel-type razors.

Although specific embodiments of the invention have been described herein, it is not intended to limit the invention solely thereto, but to include all of the variations and modifications which fall within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. A safety razor blade having on a cutting edge thereof a coating of an organosilicon-containing polymer which has been so cured *in situ* that the blade provides an easier shave as herein defined.

2. A safety razor blade having on a cutting edge thereof a coating of an organosilicon-containing polymer which has been cured *in situ* to form a gel as herein defined adherent to the said cutting edge so that the blade provides an easier shave as herein defined.

3. A safety razor blade according to Claim 1 or 2 in which the organosilicon-containing polymer consists essentially of a plurality of organosiloxy groups.

4. A safety razor blade according to Claim 3 in which the coating results from curing of a polymer composed of a chain of alternating silicon and oxygen atoms with two substituents bonded to each of a substantial number of said silicon atoms, a portion of the substituents being hydrogen or methyl, and the remainder of the substituents being methyl, ethyl, n-propyl, isopropyl, n-butyl, n-amyl, vinyl, allyl or phenyl, but said isopropyl, n-amyl, vinyl, allyl or phenyl substituents being present only when some substituent other than hydrogen is also present.

5. A safety razor blade according to Claim

4 in which the substituents are hydrogen and methyl.

6. A safety razor blade according to Claim 5 in which about one-half of the total substituents are hydrogen and the remainder are methyl.

7. A safety razor blade according to Claim 6 in which the hydrogen- and methyl-substituted polymer has been cured in hot air at a temperature of 285°—340° F. for 2 to 15 minutes.

8. A safety razor blade according to Claim 4 in which the polymer has a minor proportion of allyl or vinyl substituents and the remainder methyl substituents.

9. A safety razor blade according to Claim 1 or 2 in which the coating results from the curing of a silyl polyester.

10. A safety razor blade according to Claim 9 in which the silyl polyester is a dimethyl silyl polyester of ethylene glycol.

11. A safety razor blade according to Claim 1 or 2 in which the coating results from the curing of a polymer comprising a chain of alternating silicon and oxygen atoms, a small proportion of the silicon atoms of the polymer being replaced by another metal.

12. A safety razor blade according to Claim 11 in which approximately one silicon atom in twenty is replaced by an atom of tin.

13. A safety razor blade according to Claim 12 in which each silicon and tin atom has bonded to it two methyl substituents.

14. A safety razor blade according to any one of the preceding claims in which the coating tapers in thickness toward its margins.

15. A safety razor blade according to any one of the preceding claims in which the blade is made of steel.

16. Coated safety razor blades substantially as set forth herein.

17. A method of treating a safety razor blade to facilitate shaving therewith which comprises providing on a cutting edge thereof a coating of an organosilicon-containing polymer and then so curing said material that the blade provides an easier shave as herein defined.

18. A method of treating a safety razor blade to facilitate shaving therewith which comprises providing on a cutting edge thereof a coating of an organosilicon-containing polymer and then air-curing said material at an elevated temperature to form a gel as herein defined adherent to the said cutting edge so that the blade provides an easier shave as herein defined.

19. A method according to Claim 17 or 18 in which the blade is treated to an elevated temperature prior to the application of the coating thereto.

20. A method according to any one of Claims 17 to 19 in which the coating material provided at the cutting edge is a polymer composed of a chain of alternating silicon and





0.06 as determined in Example 1. The material was applied to the blade edges and cured as described in Example 7 except that the blades remained in the oven for 30 minutes. After cooling in air at room temperature the blades had a thin coating of gel material on their cutting edges adherent to the steel and displayed six fringes in the zone within 25 microns from the ultimate edge.

The coating may be applied as a step during the manufacture of the blades; for example a thin strip of high carbon steel in the "as rolled" condition, having a little more than the width desired in the finished razor blades, may be subjected to a perforating or notching operation, after which it is hardened; then one or both longitudinal margins of the strip are sharpened. After the sharpening step the coating of the present invention may be applied to the sharpened edges and cured, following which individual blades may be severed from the strip by a parting operation. If desired, of course, the coating of the present invention may be applied after the parting operation. It will be understood that the term "blades" is intended to include the very long, flexible, ribbon-like blades which can be used in reel-type razors.

Although specific embodiments of the invention have been described herein, it is not intended to limit the invention solely thereto, but to include all of the variations and modifications which fall within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. A safety razor blade having on a cutting edge thereof a coating of an organosilicon-containing polymer which has been so cured *in situ* that the blade provides an easier shave as herein defined.

2. A safety razor blade having on a cutting edge thereof a coating of an organosilicon-containing polymer which has been cured *in situ* to form a gel as herein defined adherent to the said cutting edge so that the blade provides an easier shave as herein defined.

3. A safety razor blade according to Claim 1 or 2 in which the organosilicon-containing polymer consists essentially of a plurality of organosiloxy groups.

4. A safety razor blade according to Claim 3 in which the coating results from curing of a polymer composed of a chain of alternating silicon and oxygen atoms with two substituents bonded to each of a substantial number of said silicon atoms, a portion of the substituents being hydrogen or methyl, and the remainder of the substituents being methyl, ethyl, n-propyl, isopropyl, n-butyl, n-amyl, vinyl, allyl or phenyl, but said isopropyl, n-amyl, vinyl, allyl or phenyl substituents being present only when some substituent other than hydrogen is also present.

5. A safety razor blade according to Claim

4 in which the substituents are hydrogen and methyl.

6. A safety razor blade according to Claim 5 in which about one-half of the total substituents are hydrogen and the remainder are methyl.

7. A safety razor blade according to Claim 6 in which the hydrogen- and methyl-substituted polymer has been cured in hot air at a temperature of 285°—340° F. for 2 to 15 minutes.

8. A safety razor blade according to Claim 4 in which the polymer has a minor proportion of allyl or vinyl substituents and the remainder methyl substituents.

9. A safety razor blade according to Claim 1 or 2 in which the coating results from the curing of a silyl polyester.

10. A safety razor blade according to Claim 9 in which the silyl polyester is a dimethyl silyl polyester of ethylene glycol.

11. A safety razor blade according to Claim 1 or 2 in which the coating results from the curing of a polymer comprising a chain of alternating silicon and oxygen atoms, a small proportion of the silicon atoms of the polymer being replaced by another metal.

12. A safety razor blade according to Claim 11 in which approximately one silicon atom in twenty is replaced by an atom of tin.

13. A safety razor blade according to Claim 12 in which each silicon and tin atom has bonded to it two methyl substituents.

14. A safety razor blade according to any one of the preceding claims in which the coating tapers in thickness toward its margins.

15. A safety razor blade according to any one of the preceding claims in which the blade is made of steel.

16. Coated safety razor blades substantially as set forth herein.

17. A method of treating a safety razor blade to facilitate shaving therewith which comprises providing on a cutting edge thereof a coating of an organosilicon-containing polymer and then so curing said material that the blade provides an easier shave as herein defined.

18. A method of treating a safety razor blade to facilitate shaving therewith which comprises providing on a cutting edge thereof a coating of an organosilicon-containing polymer and then air-curing said material at an elevated temperature to form a gel as herein defined adherent to the said cutting edge so that the blade provides an easier shave as herein defined.

19. A method according to Claim 17 or 18 in which the blade is treated to an elevated temperature prior to the application of the coating thereto.

20. A method according to any one of Claims 17 to 19 in which the coating material provided at the cutting edge is a polymer composed of a chain of alternating silicon and



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5 oxygen atoms with two substituents bonded
to each of a substantial number of said
silicon atoms, a portion of the substituents
being hydrogen or methyl, and the remainder
of the substituents being methyl, ethyl, n-
propyl, iso-propyl, n-butyl, n-amyl, vinyl, allyl,
or phenyl, but said iso-propyl, n-amyl, vinyl,
allyl or phenyl substituents being present only
when some substituent other than hydrogen
is also present.

10 21. A method according to Claim 20 in
which the substituents in the polymeric
material are hydrogen and methyl.

15 22. A method according to Claim 21 in
which about one-half of the total substituents
are hydrogen and the remainder are methyl.

20 23. A method according to Claim 22 in
which the hydrogen- and methyl-substituted
polymeric material is cured in hot air at a
temperature of 285°—340° F. for 2 to 15
minutes.

25 24. A method according to any one of
Claims 17 to 23 in which the coating is pro-
vided on the cutting edge of a steel blade
after hardening thereof.

25. A method according to any one of
Claims 17 to 24 in which foreign material is
removed from the cutting edge, e.g. by
washing the blade with a volatile solvent, be-
fore application of the coating to said edge.

30 26. A method according to any one of
Claims 17 to 25 in which the coating and
curing steps are performed as part of a
sequence of operations also including harden-
ing the strip of high carbon steel, sharpening
at least one longitudinal margin thereof, and
parting the strip into individual blades.

35 27. The methods of coating safety razor
blades substantially as set forth in the
examples.

40 28. Coated safety razor blades whenever
prepared by a method according to any one of
Claims 17 to 27.

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