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 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 edge for a distance up to as much as 0.1 inch or even more. Each face need not be a single planar uninterupted 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 opposite the last stage of the ultimate edge, may have a width as little as 0.0003 inch or even less as compared to the diameter of a beard hair which averages about 0.004 to 0.005 inch, while the thickness of the ultimate edge itself is generally less than 6000 Angstrom units and preferably less than 2500 Angstrom units. 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 coating 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 steel razor blade on a cutting edge of which there is a thin layer of certain gel material which is adherent to the underlying steel provides an easier shave as well as 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 making it possible to employ a shorter time for the beard-softening step. Tests of the cutting ability of the coated blades, off the face, under mechanically controlled conditions indicate that the force required to cut water-softened hair is greatly reduced by the present invention. This reduction in pull and ease of shave may be produced by using several successive shaves with the same coated blade edge, although it does not last indefinitely. Other important advantages are realized in the use of this invention, such as inhibition of the blade edges against chemical deterioration during shaving.

The layer of gel material may extend over the entire wedge faces back from the ultimate edge or even farther, or it may cover only the portion of the final facet immediately adjacent to the ultimate edge. It has been found that in some cases exceedingly thin layers of the order of 300 Angstrom units or less in thickness, so thin that their presence can be detected only with considerable difficulty, are recognizable effectively 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 an observed surface normal to the optical axis of the microscope) possess excellent shaving properties; the total number of fringes observed in the area extending back 0.002 inch from the ultimate edge of the blade averages 12 for these blades, indicating that the coating increases in thickness gradually from the ultimate edge to an average thickness of 2.4 microns at a distance of 0.002 inch. 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 by 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.

The preferred form of material is a stable soft gel which is adherent to the underlying steel surface. The word “gel” as used in the specification and claims means a structure that consists of a cross-linked polymer which has an insoluble infusible coherent three-dimensional network within which is contained fluid material of lower molecular weight. This structure is to be distinguished from a hard vitreous one. By the term “soft gel” is meant that the gel has a low shear resistance, either in its interior or at its surface or both, as distinguished from hard vitreous materials. By “stable” is meant that a blade cutting edge coated with the soft gel material will still possess superior shaving characteristics when stored under normal market conditions for a period of at least three months. Preferably the gel should be insoluble in water and conventional shaving soaps or cream and non-toxic. Such a composition is provided by curing in situ on the blade a selected organosilicon-containing polymer having a plurality of silylox groups, i.e., in which silicon is linked through oxygen to silicon or to other elements in the polymer framework, such as an organosiloxane, a silyl polycryst, or a modified organosiloxane in which a minor proportion of the silicon atoms have been replaced by atoms of another metal. 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 integral to the underlying steel 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 of 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.

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 forced 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 on 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 that the axe stops before it penetrates far into the wood. Heretofore, many efforts 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 flanks of the cutting edge throughout the shaving, but easily shears either within itself or at its interface with the hair. This shearing may be accompanied by expression of fluid from the material.

Certain criteria consistent with the foregoing theory, are required to obtain the benefits of the invention. The adhesion or bonding of the material to the facets adjacent the cutting edge must be great enough so that the film is not entirely removed from the facet surface adjacent the cutting edge during shaving, while the cohesion within the material or its adhesion to the hair must be 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. These criteria are met by a treated blade, leading to a great reduction in the pull on hairs and in the consequent discomfort in shaving. Inasmuch as the number of shaving forces 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), a relatively thick coating (10 microns at a distance of 0.005 to 0.006 inch from the ultimate edge) 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 on the metal a layer of polymeric gel less than 1 micrometer 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 0.002 to 0.005 inch 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 retain 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 behavior 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 2000 Angstrom units thick, as shown by the absence of any interference fringes.

Very thick coatings of the same material, many times as thick as the 10 micron coating described above, did not extend 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 used. The organosilicon-containing polymer coating when uncured or under-cured has little or no adherence to the metal surface of the blade. It is believed that it is this lack of adherence to the metal surface which makes the uncured coating ineffective, as the coating will be wiped off the blade in the first few strokes of the shaving operation. When over-cured, the organosilicon-containing polymer coating strongly adheres to the metal surface of the blade but does not shear easily in the interior of the coating, nor at the interface with the hair, and it is believed that it is this high shear resistance which makes the over-cured coating ineffective.

Thus, between the uncured and over-cured 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 characterized chiefly by a network of alternate silicon and oxygen atoms in which most of the silicon atoms bear organic substituent groups attached through carbon-silicon bonds. They are their nature polymeric substances, existing as linear chains or cyclic polymers.

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 curing) affects primarily the physical properties. In general, in the case of an organosiloxane having specific alkyl substituent groups, the viscosity increases with 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 fluids; as the chain length of the siloxane increases, the viscosity of the fluid increases to the point where the material becomes a gum. As a fluid 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.
It will be seen that the proportion of structural units of an organosiloxane is governed by its composition; hence the average functionality is indicated by the average or empirical composition as well as by the structural formula. Thus the average compositions \((\text{CH}_3)_2\text{SiO}\) and \((\text{CH}_3)\text{HSiO}\) would correspond to organosiloxane polymers made from bifunctional units, such as a viscous liquid or soft gum or elastomer, whereas a composition \(\text{CH}_3\text{SiO}_2\) would correspond to a polymer made from units having an average functionality of three, and hence a thoroughly cross-linked siloxane resin. Since the composition \(\text{CH}_3\text{SiO}_3\) could equally well represent a polymer composed entirely of

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\begin{align*}
\text{CH}_3 & \quad -\text{O} & \quad -\text{O} & \quad -
\end{align*}
\]

units, or one composed of equal numbers of

\[
\begin{align*}
\text{CH}_3 & \quad -\text{O} & \quad -\text{Si} & \quad -
\end{align*}
\]

and

\[
\begin{align*}
\text{CH}_3 & \quad -\text{O} & \quad -\text{O} & \quad -
\end{align*}
\]

units, it follows that average composition is the conventional way of describing a given siloxane polymer. However, 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 steric 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 soft gel which is adherent to the steel.

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, essentially each silicon atom 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 soft gel, but a variety of other groups such as ethyl, n-propyl, i-propyl, n-butyl, n-amyI, vinyl, allyl or phenyl groups may be present provided they are limited to a proportion which is low enough not to interfere with curing to the desired soft gel which is adherent to the steel. 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-amyI 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 i-propyl groups, up to about 50% may be replaced by n-propyl or by n-amyI 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 i-propyl groups. It is also possible to replace a very small proportion of the methyl groups in dimethyl siloxane with vinyl or with allyI groups. These polymers may be cyclic or open-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 average composition \((RR'-\text{Si}-\text{O})_n\) in which \(R\) and \(R'\) are hydrogen or organic groups as specified above and in which \(n\) may have an average value up to 5000 or even more.

We have found that polymers having low values of \(n\) are difficult to use for a variety of reasons. When their boiling points are too low, they volatilize and fail to cure in situ. When they have no condensable end groups such as trimethylsiloxy groups and are of low molecular weight, they do not form the desired soft gel even when they do not volatilize. 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 di-methyl 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 itself not an initially liquid organosiloxane but which is converted to a siloxane in place. For example, octamethyl cyclotetrasiloxane, \((\text{CH}_3)_2\text{Si}-\text{NH}_2\), when applied to a razor blade cutting edge and allowed to stand in the atmosphere for an extended period, hydrolyzes 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 composition \((\text{CH}_3)\text{H}_2\text{SiO}\) in which \(n\) has an average value as set forth above are particularly preferred, although liquid dimethyl siloxanes in which \(n\) averages as above are also quite effective. It will be understood that the compositions referred to are average compositions only and that any given linear polymer molecule need not be made up of a chain of all siloxane units of which are identical to each other. Indeed, mixtures of different polymer molecules may be employed, which mixtures have the average composition indicated above. For example, methyl hydrogen siloxane may be made up of a mixture of polymer molecules containing

\[
\begin{align*}
\text{CH}_3 & \quad -\text{Si} & \quad -\text{O} & \quad -
\end{align*}
\]

and

\[
\begin{align*}
\text{CH}_3 & \quad -\text{O} & \quad -\text{Si} & \quad -
\end{align*}
\]
groups and polymer molecules containing
\[ \text{Si-O-} \]

\[ \text{H} \]

It will also be clear that the optimum curing conditions for a polymer of the composition \((\text{CH}_3)_2\text{SiO} \) differ from those for a polymer of the composition \((\text{CH}_3)_2\text{HSiO} \) since Si—H bonds are known to oxidize more readily than methyl groups attached to silicon. Similarly, the curing conditions must depend upon the molecular weight of the siloxane composition, for if too high a temperature a volatile polymer of low molecular weight will evaporate before it can cure by oxidation.

The initially fluid or liquid polymer is preferably 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 fluid polymer, by spraying the fluid polymer onto the cutting edge, or by flowing the fluid polymer onto the edge from a capillary, or by stop- ping 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 fluid polymer must be partly cured in situ to a gel material.

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 speed for a longer period of time at a lower temperature, 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 over cure.

In the case of siloxane chains having the average composition \((\text{CH}_3)_2\text{SiO} \), 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 chloride, 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.

It is possible to determine readily when the liquid organosilicon-containing polymer has achieved the desired extent of cure by employing simple tests. In the case of liquid siloxanes having chains with an average composition \((\text{CH}_3)_2\text{SiO} \), 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. One of the best tests is, of course, to shave with treated and untreated blades and compare the results.

The following specific examples are illustrative of the nature of the present invention. In each example, except Example 8, the blades employed were all hardend, lacquered, standard carbon steel double-edge safety razor blades of 0.005-inch thickness (Gillette Blue Blades). The fringes reported were in all cases observed using white light.

### Example 1

An endless steel conveyor band provided with pairs of projecting nubs 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 nubs being arranged so that successive blades were spaced apart by somewhat less than ½ inch. The heater, a three-feet long generally rectangular mass of aluminum 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 blade individual blades being provided along the top and bottom of the heater, the temperature being controlled by thermocouples spaced in wells in the heater walls adjacent to 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 ½ 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 hydroxide siloxane having the average composition \((\text{CH}_3)_2\text{HSiO} \) and having a reduced specific viscosity of 0.08 as determined on an Ostwald-Dennon-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 soft gel material employed was a 12% by volume solution of the same organosiloxane in redistilled hexamethyldisiloxane as solvent, the solution also containing 1% by weight of dispersed finely divided molybdenum disulfide (Molykote Type GX, Alpha Molykote Corp.). The blades had on their cutting edges a coating of a soft gel material adherent to the steel. The coating exhibited no pattern of interference fringes, being less than 2000 angstroms thick in the zone extending 0.001 inch 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 hexamethyldisiloxane as solvent, the solution also containing 1% by weight of dispersed finely divided molybdenum disulfide (Molykote Type GX, Alpha Molykote Corp.). The blades had on their cutting edges a coating of a soft gel material adherent to the steel. The coating exhibited no pattern of interference fringes, being less than 2000 angstroms thick in the zone extending 0.001 inch from the ultimate edge.

Example 3
The procedure was the same as in Example 2 except that the molybdenum disulfide was replaced by finely divided silica (Godfrey L. Cabot, Inc., Cab-o-sil Fluffy 2491). The coating on the cutting edges was a soft gel structure adherent to the steel and displayed no interference fringes, being less than 2000 angstroms thick in the zone extending 0.001 inch back from the ultimate edge.

Example 4
The procedure was generally the same as that described in Example 1. However, the coating composition 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 conveyer 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 soft gel coating adherent to the steel and displaying five interference fringes in the zone extending 0.001 inch from the ultimate edge.

Example 5
A high molecular weight dimethyl siloxane having the average composition \((\text{SiH}2)\text{SiO}2\) was prepared by catalytic isomerization and polymerization of the cyclic tetramer, the product having a reduced specific viscosity of 0.45. A solution of 60% by volume 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 soft gel on their cutting edges adherent to the steel and displaying four fringes in the zone within 0.001 inch from the ultimate edge.

Example 6
Ethyl hydrogen siloxane having the average composition \((\text{CH}2)\text{SiO}2\) and having a reduced specific viscosity of 0.05, determined as described in Example 1, was employed as the coating composition 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 \(\frac{3}{4}\) inch from the blade below it in the stack by a pair of \(\frac{3}{4}\) 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 (Theko 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 soft gel material adherent to the steel and displaying five fringes in the zone within 0.001 inch from the ultimate edge.

Example 7
A solution (50% by volume) of n-propyl hydrogen siloxane in xylene was employed as the coating composition and was applied to the blades as described in Example 6. The siloxane had the average composition \((\text{C}_3\text{H}_7)\text{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 soft gel structure on their cutting edges adherent to the steel and displaying three fringes in the zone extending 0.001 inch 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 composition a 12% by volume solution of the methyl hydrogen siloxane of Example 1 dissolved in redistilled hexamethyldisiloxane as solvent. The coating composition 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 soft gel adherent to the steel which exhibited three fringes in the zone extending 0.001 inch 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 had the average composition \(\text{R} \text{SiO}2\) 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 air oven as described in Example 7 where they remained for six minutes. After cooling in air the blades had a thin coating of soft gel material on their cutting edges adherent to the steel and displayed six interference fringes in the zone within 0.001 inch from the ultimate edge.

Example 10
There was used as the coating composition liquid ethyl methyl hydrogen siloxane having the average composition \(\text{R} \text{SiO}2\) 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 9. 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 soft gel material which exhibited six interference fringes in the zone extending 0.001 inch from the ultimate edge.
Liquid ethyl methyl siloxane having the average composition RRSiO in which 30% of the R groups were ethyl and 70% were methyl was employed as the coating composition without any solvent. The siloxane had a reduced specific viscosity of 0.09 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 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 soft gel structure on their cutting edges, but in this case displayed no interference fringes, being less than 2000 angstrom units thick in the zone within 0.001 inch from the ultimate edge.

Example 12
There was employed as the coating composition liquid n-butyl hydrogen siloxane having the average composition (C₄H₉)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 10 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 soft gel structure on their cutting edges and exhibited five fringes in the zone within 0.001 inch from the ultimate edge.

Example 13
There was employed as the coating composition 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 gel 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 0.001 inch of the ultimate edge.

Example 14
There was employed, as the coating composition, liquid phenyl methyl siloxane having the average composition 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 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 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 soft gel structure on their cutting edges adherent to the steel and displayed 12 fringes in the zone extending 0.001 inch from the ultimate edge.

Example 15
A solution (20% by volume) of modified methyl hydrogen siloxane in redistilled hexamethyl disiloxane solvent was employed as the coating composition. The methyl hydrogen siloxane had the average composition (CH₃)₂HSiO and the polymer chains were terminated with the group —OCH₂(CH₂)nOCH₃. This polymer had a reduced specific viscosity of 0.03 determined as in Example 12 above. The composition 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 soft gel structure on their cutting edges adherent to the steel and displayed 12 fringes in the zone extending 0.001 inch from the ultimate edge.

Example 16
There was used as the coating composition liquid methyl hydrogen siloxane having the average composition (CH₃)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 and removed and cooled in air at about 50° F. until the blades had reached a temperature of about 95° F. The finished blades had a thin layer of soft gel structure on their cutting edges adherent to the steel, but in this case displayed no interference fringes, being less than 2000 angstrom units thick in the zone within 0.001 inch from the ultimate edge.

Example 17
There was employed as the coating composition liquid dimethyl silyl polyester of ethylene glycol having the average composition (CH₃)₂SiO(OC₂H₄OCH₂)OCH₃ 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 soft gel structure on their cutting edges but in this case displayed no interference fringes, being less than 2000 angstrom units thick in the zone within 0.001 inch from the ultimate edge.

Example 18
There was employed as the coating composition a modified liquid dimethyl siloxane in which a portion of the silicon atoms were substituted by tin atoms, having the average composition (CH₃)₂SiO(CH₃)₂SnO, with the atomic ratio of silicon to tin about 19 to 1. This liquid polymer had a reduced specific viscosity of 0.01 as determined in Example 12. 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 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 soft gel structure, but in this case displayed no interference fringes, being less than 2000 angstrom units thick in the zone within 0.001 inch from the ultimate edge.

Example 19
There was employed as the coating composition liquid vinyl methyl siloxane having the average composition 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 soft gel material on their cutting edges adherent to the steel, but in
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Example 20

There was employed as the coating composition liquid allyl methyl silicone having the average composition RRSSO, in which 0.5% of the R groups were allyl and 99.5% were methyl. The silicone 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 soft gel on their cutting edges adherent to the steel and displaying ten fringes in the zone within 0.001 inch from the ultimate edge.

Example 21

There was employed as the coating composition liquid n-amy1 methyl silicone having the average composition RRSSO, in which 50% of the R groups were amyl and 50% were methyl. The silicone 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 were washed with cold water and dried. The material on their cutting edges adherent to the steel and displayed six fringes in the zone within 0.001 inch from the ultimate edge.

Example 22

There was employed as the coating composition liquid isopropyl methyl hydrogen silicone having the average composition RRSSO in which 30% of the R groups were isopropyl and 70% were hydrogen. The silicone had a reduced specific viscosity of 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 soft gel material on their cutting edges adherent to the steel and displayed six fringes in the zone within 0.001 inch 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 half its width covered in the width of the 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 may be used in real-type razors.

This application is a continuation-in-part of our co-pending application Serial No. 776,203, filed November 25, 1958, now abandoned.

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 suggest themselves to persons skilled in the art.

What is claimed is:

1. A safety razor blade having on its cutting edge an adherent stable gel coating consisting essentially of a partially cured organosilicon-containing polymer.

2. A safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosilicon-containing polymer.

3. A steel safety razor blade having on its cutting edge an adherent gel coating consisting essentially of a partially cured organosiloxane.

4. A steel safety razor blade having on its cutting edge an adherent gel coating consisting essentially of a cured organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a portion of the substituent groups being selected from the class consisting of hydrogen and methyl groups and the remainder being selected from the class consisting of methyl, ethyl, n-propyl, i-propyl, n-butyl, n-amyl, vinyl, allyl and phenyl groups, said i-propyl, n-amyl, vinyl, allyl and phenyl groups being present only when another of said substituent groups other than hydrogen is also present, so that the silicone is curable to a gel adherent to the steel.

5. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured dimethyl sily1 polyester of ethylene glycol.

6. A safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosiloxane which is incapable of complete removal by carbon tetrachloride at room temperature, said organosiloxane having prior to curing the composition defined in claim 4.

7. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two methyl groups.

8. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a portion of said substituent groups being hydrogen atoms and the remainder being methyl groups.

9. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, approximately one-half of the total substituent groups being hydrogen atoms and the remainder being methyl groups.

10. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a minor proportion of silicon atoms has been replaced with atoms of tin.

11. A steel safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured sily1 polyester.

12. A safety razor blade having on its cutting edge an adherent soft gel coating consisting essentially of a cured tin-containing organosiloxane, said organosiloxane being initially composed of molecules in which a minor proportion of silicon atoms has been replaced with atoms of tin.

13. A steel safety razor blade having on its cutting edge an adherent coating consisting essentially of an organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a minor proportion of the total substituent groups being methyl groups, at least a portion of said coating being cured in situ to a stable soft gel adherent to the steel.
14. A steel safety razor blade having on its cutting edge an adherent coating consisting essentially of an organosiloxane, said organosiloxane being initially composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a minor proportion of the total substituent groups being allyl groups and the remainder being methyl groups, said coating being cured at least partly in situ to a stable soft gel adherent to the steel.

15. The method of treating a safety razor blade which comprises applying to its cutting edge a coating consisting essentially of an organosilicon-containing polymeric material and partly curing said coating to a gel adherent to said blade.

16. The method of treating a safety razor blade which comprises applying to its cutting edge a coating consisting essentially of an organosilicon-containing polymeric material and partly curing said coating to a gel adherent to said blade.

17. The method of treating a steel safety razor blade which comprises heating said blade to an elevated temperature not over 340°F, and applying to its cutting edge a coating consisting essentially of an organosilicon-containing polymeric material and curing it to a soft gel adherent to said blade.

18. The method of treating a safety razor blade which comprises applying to its cutting edge a coating composition consisting essentially of an organosiloxane composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a portion of the substituent groups being selected from the class consisting of hydrogen and methyl groups and the remainder being selected from the class consisting of methyl, ethyl, n-propyl, i-propyl, n-butyl, n-amyl, vinyl, allyl and phenyl groups, said i-propyl, n-amyl, vinyl, allyl and phenyl groups being present only when another of said substituent groups other than hydrogen is also present, and partially curing said coating to a gel adherent to said blade.

19. The method of treating a steel safety razor blade which comprises applying to its cutting edge a liquid coating composition consisting essentially of an organosiloxane composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, a portion of said substituent groups being hydrogen atoms and the remainder being methyl groups, and air-curing said coating at an elevated temperature to a soft gel which is adherent to said blade and incapable of complete removal by carbon tetrachloride at room temperature.

20. In the method of manufacturing a steel safety razor blade which comprises perforating a strip of high carbon steel, hardening said strip, sharpening at least one longitudinal margin of said strip to provide a cutting edge, and parting said strip into individual blades, in combination, the step which comprises curing on said cutting edge a coating of an organosilicon-containing polymeric material to a stable adherent soft gel which facilitates shaving.

21. In the method of manufacturing a steel safety razor blade which comprises providing a strip of high carbon steel, hardening said strip and sharpening at least one longitudinal margin of said strip to provide a cutting edge, the step which comprises applying to said cutting edge and curing a coating of an organosilicon-containing material to form a polymeric soft gel adherent to the steel, which gel facilitates shaving.

22. In the method of manufacturing a steel safety razor blade which comprises providing a strip of high carbon steel, hardening said strip, sharpening at least one longitudinal margin of said strip to provide a cutting edge, and parting said strip into individual blades, in combination, the step of forming in situ on said cutting edge a coating of organosiloxane material and curing said coating to a stable soft gel adherent to the steel, which gel facilitates shaving.

23. The method of treating a safety razor blade which comprises applying to its cutting edge a liquid coating composition consisting essentially of an organosiloxane composed of molecules containing a chain of alternating silicon and oxygen atoms, each silicon atom within the chain having bonded to it two substituent groups, approximately one-half of the total substituent groups being hydrogen atoms and the remainder being methyl groups, and curing said coating in hot air at a temperature of 285°–340°F for two to fifteen minutes.

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CERTIFICATE OF CORRECTION

Patent No. 2,937,976

Leon E. Granahan et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 57, for "means" read -- meant --; column 14, line 4, after "adherent" insert -- soft --.

Signed and sealed this 18th day of October 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents