ABSTRACT

A cosmetic applicator includes bristles or tines with selectively changeable durometer to allow the relative flexibility or stiffness to be adjusted by the user. The bristles or tines are made directly from or incorporate within their structure piezoelectric ceramic fibers. The relative flexibility or stiffness of the piezoelectric fibers can be adjusted by subjecting the fibers to an electric current, or an electric or magnetic field, to cause the fibers to gain or lose flexibility. Stiffness or softness of the applicator can thus be adjusted to be suitable for different application operations such as depositing cosmetic product or combing and clump removal.
COSMETIC APPLICATOR HEAD WITH DYNAMICALLY ADJUSTABLE DURAMETER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention
[0002] The present invention relates generally to cosmetic applicators, and in particular, to a cosmetic applicator with a dynamically adjustable flexibility. The applicator includes piezoelectric fibers that are capable of changing durometer in response to a change in a supply of electricity or a change in an electric or magnetic field.

[0003] 2. Description of the Prior Art
[0004] Conventional cosmetic applicators such as mascara brushes have a set or fixed degree of flexibility or stiffness at a specified temperature that is dictated by the type of material (e.g., plastic or elastomer), the mass, geometry and durometer of the selected material, and the thickness of the structural member (e.g., the diameter of a mascara bristle or tine). Durometer is a measure of the hardness of a material. The parameters that establish the hardness of the applicator structures (e.g., the bristles, tines or other structures) of a conventional cosmetic applicator are, therefore, selected and established during the production engineering and manufacturing process. Once manufactured, there is little that an end-user can do to change the established durometer or hardness of an applicator.

[0005] The degree of hardness of a component of a cosmetic applicator may often have an effect on the application characteristics of a product formula, or on the effectiveness of a particular application process. Generally speaking, hardness is a property of the material used for making a component, while flexibility or stiffness is property of the material (including hardness) combined with the geometry of the component (i.e., the mass, structure, configuration and shape of the component). The hardness, or conversely, the softness, of a material used to make a component has a direct effect on determining the flexibility or stiffness of that component. The foregoing notwithstanding, the hardness of a material used in a component may also be referenced herein relative to stiffness of the component, or conversely referenced relative to the flexibility of the component. For example, it is believed that softer, more flexible bristles are better suited for depositing heavy loads of mascara product onto lashes, while stiffer, less flexible bristles are better suited for ‘doctoring’ the deposited mascara product, i.e., the stiffer less flexible bristle are better suited for combing through lashes to separate lashes, and remove clumps or excess mascara. See for example U.S. Pat. No. 6,481,445 to Miraglia. To accommodate this phenomena, users often deposit mascara product with a first applicator that has softer, more flexible bristles, and then ‘doctor’ the deposited mascara product with a brush applicator or comb-type applicator that has stiffer, less flexible bristles or tines. This is both inconvenient and more time consuming for the user.

[0006] Accordingly, there is a need for a cosmetic applicator that has bristles or tines capable of changing durometer from soft and relatively flexible for depositing operations, to relatively stiff and less flexible to better doctoring and clump removal operations after mascara is deposited.

BRIEF SUMMARY OF THE INVENTION

[0007] The applicator of the present invention includes bristles, tines or other applicator components with selectively changeable durometer to allow the relative flexibility or stiffness to be adjusted by the user. The bristles, tines or other applicator components are made directly from or incorporate within their structure piezoelectric ceramic fibers. The relative flexibility or stiffness of the piezoelectric fibers can be adjusted by subjecting the fibers to an electric current, or an electric or magnetic field, to cause the fibers to gain or lose flexibility in proportion to the strength of the current or field, and according to the polarity of the current or field. Selectively variable stiffness or hardness of an applicator can offer multiple ways to use the same applicator, and can yield different beneficial results based on desired application circumstances.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a cross-sectional elevation view of a first embodiment of the applicator of the present invention together with a container for containing product;
[0009] FIG. 2 is a more detailed elevation view of the first embodiment of the applicator shown in FIG. 1;
[0010] FIG. 3 is a perspective view of the first embodiment of the applicator shown in FIG. 2 during assembly of the applicator;
[0011] FIG. 4 is a side elevation view of the first embodiment of the applicator shown in FIG. 2 during assembly of the applicator;
[0012] FIG. 5 is a cross-sectional elevation view of a second embodiment of the applicator of the present invention together with a container for containing product;
[0013] FIG. 6 is a more detailed cross-sectional elevation view of a second embodiment of the applicator shown in FIG. 5;
[0014] FIG. 7 is an elevation view of the second embodiment of the applicator shown in FIG. 5;
[0015] FIG. 8 is a cross-sectional elevation view of a third embodiment of the applicator of the present invention together with a container for containing product; and
[0016] FIG. 9 is an elevation view of the third embodiment of the applicator shown in FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

[0017] A first embodiment of an applicator 1 according to the invention is shown generally in FIGS. 1-4. The applicator 1 may be free-standing, or as illustrated in FIG. 1, may be part of a product package that includes a container 50 containing a cosmetic product. As shown in FIG. 1, the applicator 1 includes an applicator head 2 connected to a handle 4 by a rod 4. The handle 6 includes a hollow shell portion 7 having sufficient dimensions to contain additional components of the applicator, and to fit comfortably in the user's hand or fingers. The applicator head 2 may be in the form of, for example, a twisted wire brush 3 or a molded applicator head 9 (see FIG. 5). The applicator head 2 may take on other forms, such as, for example, a wand, a spatula, a puff, a comb, or a roller (not shown). The applicator head 2 is adapted for applying any cosmetic product, such as, for example, mascara. The applicator head 2 may be a relatively flat, expanded surface, e.g., the spatula, or may be a surface with tines, ridges, bristles, clearances or other details suitable and adapted for facilitating the loading, depositing and doctoring of cosmetic product on an application target such as, for example, eyelashes, eyebrows, hair, skin, lips, nails, etc.
Importantly, the application head 2 includes a component or components comprised of at least one selectively reactive material, such as, for example a piezoelectric material, adapted to change at least one of shape, volume, rigidity and orientation of the applicator head or a portion thereof in response to a change in supplied stimulus, such as, for example, electric current. The selectively reactive material may comprise a component or a portion of a component. For example, as illustrated in FIG. 1, the piezoelectric material may comprise a fiber or fibers used as a brush bristle or bristles, e.g., gripped in a conventional twisted wire core. Alternatively, as illustrated for example in FIG. 5, the selectively reactive material may be incorporated into molding compounds such that the material can be integrally molded into components such as tines or other relief structures of molded applicator heads. As yet another alternative, selectively reactive materials such as fibers can be over molded with elastic materials to form, for example, tines with a piezoelectric core. For example, the piezoelectric fibers may be molded in place within the tines, or may be inserted in bores in the tines. Alternatively, the piezoelectric material may comprise a surface veneer or layer of the tines or other structure of the applicator structure.

As an example, a first embodiment of the applicator 1 includes an applicator head 2 that is of the twisted wire core variety and is shown at reference number 3 in FIGS. 1-2. Twisted wire brush 3 has a twisted wire core 12 with proximal end 14 and a distal end 22. As shown in FIG. 1, the proximal end 14 of the applicator head 2 is adapted to be mounted in a bore 16 on the rod 4 that is in turn connected to the handle 6. A lumina 42 may be provided in the rod 4 in axial alignment and fluid communication with the bore 16, extending from the bore 16 to the shelf 7 to accommodate a circuit, a circuit board or conductors between the handle 6 and the applicator head 2. The handle 6 may include a skirt 8 with internal threads 10 adapted to cooperatively engage corresponding external threads 51 on a neck 52 of a cosmetic composition container 50 such that the handle 6 serves as a cap for the container 50. When the handle 6 is secured on the neck 52 of the container 50 the applicator head 2 is immersed in cosmetic product stored in the container 50.

As illustrated in FIGS. 3 and 4, the twisted wire core 12 is initially formed from a U-shaped wire 13, i.e., a wire folded back on itself to form two legs, 15 and 17. The applicator head 3 further comprises a plurality of individual bristles 18 (illustrated schematically in FIGS. 1 and 2) trapped between the legs 15 and 17 when the legs 15 and 17 are twisted together to form the core 12. The plurality of bristles 18 trapped in the twisted wire core form a bristle array 20. The process for making such a brush is well known and described in more detail in prior art patents such as U.S. Pat. Nos. 6,481,445 to Minglia, 4,733,425 to Hartel et al. and 4,861,169 to Schrefl, each incorporated herein by reference in its entirety. By virtue of the process for making the applicator head, i.e., twisting the legs 15 and 17 to capture the bristles 18 in the core 12, the bristles 18 are fixed in the twisted wire core 12 such that each of the plurality of bristles 18 is in direct contact with immediately adjacent bristles 18 of the plurality of bristles.

In the first embodiment, all or at least some of the plurality of bristles 18 are made from a piezoelectric material, i.e., all or at least some of the plurality of bristles 18 are piezoelectric fibers 19. Electric current is supplied to the selectively reactive material, i.e., the piezoelectric fibers 19, via a circuit 11. The current may be an alternating or direct current, depending on the requirements of the particular selectively reactive material. If alternating current is used, it is believed that a ‘pulsing’ hardness or shape change can be achieved. The circuit 11 includes a power source 5, such as, for example, a battery 21, a capacitor (not shown) or a connection to an external electric grid (not shown). In general, the power source 5 is connected to the piezoelectric material via at least two conductors, a feed conductor 23 and a return conductor 24, in the form of wire leads or a printed circuit board or boards. A lumina 42 may be provided in the rod 4 in axial alignment and fluid communication with the bore 16, extending from the bore 16 to the shelf 7 to accommodate passage of the feed conductor 23 and a return conductor 24 from the handle 6 to the applicator head 2.

Preferably, to amplify and thereby increase the effectiveness of the change in durometer, the piezoelectric material, part or component is polarized. Piezoelectric material, parts or components may be polarized by applying a polarizing treatment (referred to as “poling”) to the piezoelectric ceramic material, part or component. The purpose of poling a piezoelectric material, part or component is to force an alignment of all of the individual dipole moments (pole vectors) inherent in the individual piezoelectric crystal structures within the material, part or component into a similar general direction or orientation. The piezoelectric material, part or component is exposed to an environment where a) the temperature is close to but below the material’s Curie point (temperature at which spontaneous polarization is lost in piezoelectric materials) and also b) electrodes are applied to the part, and a powerful direct current (DC) electric field is applied which forces the dipoles to align. Non-parallel dipoles exposed to this electrical field will experience a torque that causes them to be turned to a parallel configuration. The electric field is then removed, and the dipoles will remain almost completely aligned, with a minute amount of random direction in some dipoles. A reverse treatment is preferred for the cosmetic applicators discussed herein because it amplifies the change in the durometer of the material. For example, for a polarized material with a positive piezoelectric coefficient, also known as a piezoelectric modulus, if a voltage of the same polarity of the poling voltage is applied to the ceramic fibers in the direction of the poling voltage, the shape of tines or bristles will become dramatically softer and more pliable. The converse also works, for example, for a polarized material with a positive piezoelectric coefficient, if a voltage of the opposite polarity is applied, i.e., the shape or bristles will become dramatically stiffer and more rigid. Most piezoelectric materials have a positive piezoelectric coefficient; the material PZT is an example. There are some piezoelectric materials such as PVDF that have a negative piezoelectric coefficient, and will function, but in the inverse to the applied voltage and polarity discussed above. Also, it is possible to apply an AC (alternating current) voltage to the brush, which will cause the brush to stiffen and soften at a pulsing rate that matches the frequency of voltage that is applied.

The circuit 11 further includes a control 25 for selectively changing the power supplied to the piezoelectric fibers or material. The control may take the form of a simple bi-pole switch to selectively turn on or turn off the electric current. Alternatively, the control may be a potentiometer or rheostat to control resistance (this can also function as a position determining transducer for large changes in durometer). An indicator 26 such as a light emitting diode or an indicator
gauge may be provided to show that the device is working and may provide other information such as the state of charge of the power source. The power source 5 (e.g., the battery 21), the control 25 (the switch or rheostat), and the indicator 26 (the light or gauge) are preferably located on or in the handle 6, but may be located at any convenient place on the applicator. For example, the control may include a knob 54 at a closed end 53 of the handle 6 connected to a rheostat 55 that also serves to turn the power on and off.

In the embodiment shown in FIGS. 1-4, the circuit 11 within the twisted wire brush head 3 comprises a feed lead 28 connected to feed conductor 23 and a return lead 29 connected to return conductor 24. Feed lead 28 has an insulating jacket 31 covering most of its length. At each end of the feed lead 28 there is a clearance in the jacket 31 to allow the transmission of electric current. At a distal end 32 of the feed lead 28, a clearance in the insulating jacket 31 defines an exposed portion 34 of the feed lead that is adapted to contact the piezoelectric fibers 19 (bristles 18). At a proximal end 33 of the feed lead 28, a clearance in the insulating jacket 31 defines an exposed portion 35 of the feed lead 28 that is adapted to connect to the feed conductor 23 of the circuit 11, for example, by way of a butt connector 56. The return lead 29 may be formed from leg 15 of the U-shaped wire 13 of the twisted wire core 12. Alternatively, the return lead may be a separate structure. The wire of the twisted wire core 12 (i.e., legs 15 and 17 of the U-shaped wire 13) also has an insulating jacket 36 covering substantially all of its length. At the distal end 22 of the twisted wire core 12, a clearance 37 in the insulating jacket 36 defines an exposed portion 38 of the return lead 29. At the proximal end 14 of the twisted wire core 12, a clearance in the insulating jacket 36 on the leg 15 defines an exposed portion 30 adapted to connect to the return conductor 24, for example, by way of a butt connector 57. It will be understood that the feed lead 28 and feed conductor 23 may be integrally formed as a single, freestanding wire or as a single conductor on a printed circuit board, eliminating the need for butt connector 56. Similarly, the return lead 29 and return conductor 24 may be integrally formed as a single, freestanding wire or as a single conductor on a printed circuit board, eliminating the need for butt connector 57. Electric current is supplied, for example, from the battery 21 through the feed conductor 23 into the feed lead 28 through the exposed portion 35. The electric current is further transmitted through the feed lead 28 through the exposed portion 34 into the piezoelectric bristles 19. The current transmits through contacting adjacent piezoelectric bristles to exit into exposed portion 38 of the return lead 29 and continues through exposed portion 30 to transmit into return conductor 24, and through return conductor 24 to the battery, thus completing the circuit. When the electric current is applied to the piezoelectric bristles 19, the bristles 19 change at least one of shape, volume, rigidity or orientation.

In FIGS. 5-7, the applicator head 2 is an injection molded mascara brush that has a molded applicator head 9 preferably having tines 27 extending from a body 39. The tines 27 are adapted for loading, applying and doctoring a cosmetic such as, for example, mascara. The molded applicator head has a distal end 41 and, opposite the distal end 41, a proximal end 40 that is adapted to connect the molded applicator head 9 to a rod 4 (similar to that shown in FIG. 1). The rod 4 may be hollow to accommodate a feed conductor 23 and a return conductor 24. The conductors 23, 24 may be placed in a lumen 42 running along the axis of the rod 4, i.e., inside the hollow stem. Referring now to FIGS. 5-7, the molded brush head comprises two major components—an outer part 43 and an inner part 44. The outer part 43 includes portions of the exposed surfaces of the brush head, including the tines 27. The inner part 44 forms a backbone of the brush head, supporting the outer part 43, and is made of an electrical insulator material. The outer part 43 comprises piezoelectric material. The inner part 44 may be made from any suitable material or materials, such as, for example, any suitable plastic or ceramic that forms a good electrical insulator. The inner part 44 can be made by conventional, well known means for molding plastic. The outer part 43 is made from a piezoelectric material. The preferred method for making the outer part 43 is ceramic insert molding by ceramic injection molding (CIM), and from metal, the preferred method is metal injection molding (MIM). CIM and MIM are methods of powder injection molding. Extremely small (micro to nano scale) metal, ceramic or carbide powders are mixed into a binder and injected into the mold to form an initial shape. After the initial shape is made, the binders are chemically removed (e.g., with a solvent). The shape is then heated to a point where the powder material is sintered together without changing the initial shape. Alternatively, the molded brush head 9 may be manufactured by press molding, transfer molding, compression molding or other insert molding techniques, all of which are well known methods of molding. The outer part 43 can be overmolded onto the inner part 44.

Ceramic and polymer parts or components for brushes that exhibit piezoelectric properties can also be created using additive manufacturing processes. Additive manufacturing includes any process of joining materials to make objects from three dimensional model data. This process is typically layer based, with each layer bound to the layer before it via sintering, melting, bonding (adhesive), aerosol jetting, inkjet technology, impact, and deposition of materials via energy waves and fields. Examples of these processes for additively manufacturing ceramics, metals, and polymers are SLS (Selective Laser Sintering), LENS (Laser Engineered Net Shaping), M3D (Maskless Mesoscale Materials Deposition), EFAB Technology, Ultrasonic Consolidation, SLA (Stereolithography), FDM (Fused Deposition Modeling), Direct Metal Deposition, and EBM (Electron Beam Melting) for examples. As with conventional manufacturing process such as MIM or CIM mentioned before, the additive manufactured parts or components are preferably also subjected to a polarizing treatment to align the dipole moments in the piezoelectric crystal structures in the material.

In the embodiment shown in FIGS. 5-7, there are two rows of tines 45 and 46 extending from one side of the brush head. However, it will be understood that any suitable number or arrangement of tines is possible. For example, in an alternative embodiment shown in FIGS. 8 and 9, explained in greater detail below, there are two rows of tines 145 and 146, each row extending from an opposite side of the brush head. The tines may be arranged in straight rows or curved rows, such as, for example, a row of tines that spirals around a longitudinal axis of the applicator head (not shown). The tines may be arranged in one or more arrays, i.e., groups of tines that are electrically, conductively connected to each other. For example, in the embodiment shown in FIG. 6, each of the two rows 45, 46 of tines may be an array of tines, 47, 48, respectively. Both tine arrays 47, 48 may be connected to the same circuit, or each tine array 47 and 48 may be connected to a separate circuit so that each tine array 47 and 48 can be
selectively and separately activated and set to a particular durometer. In this way, each tine array 47 and 48 may be selectively and individually set to the same durometer or a different durometer.

[0028] At the proximal end 40 of the applicator head 2, a reduced diameter portion defines a pin 49 dimensioned to be received in the bore 16 of the rod 4 to secure the applicator head 2 to the rod 4. The pin 49 can be secured in the bore 16 by any known means, such as, for example, adhering, friction fit, sonic welding, etc.

[0029] From proximal end 40 the outer part 43 extends along a lower side of the applicator head 2 to the distal end 41 where it wraps around the distal end and extends along the upper side back to the proximal end 40. The tines 27 are integrally formed with the portion of the outer part 43 that extends along the upper side of the applicator head 2. On the lower side of the applicator head 2 a portion of the outer part 43 of the body serves as the feed lead 28 while a portion of the outer part 43 on the upper side of the applicator head 2 serves as the return lead 29. The feed lead 28 is adapted to be connected to the feed conductor 23 by butt connector 56. Similarly, the return lead 29 is adapted to be connected to the return conductor 24 by butt connector 57. The electrical circuit from the power source 5 is completed by connecting the feed conductor 23 to the feed lead portion 28 of the outer part 43, and connecting the return conductor 24 to the return lead portion 29 of the outer part 43. In this way, electricity flows from the feed conductor 23 into the outer part 43 where it is applied to the tines 27. From the outer part 43 the current flows back to the return conductor 24 to complete a loop. The purpose of this loop is to run an amount of electrical current through the piezoelectric ceramic material of the tines 27 to effect the change in the material, such as, for example, changing the durometer of each tine. For example, a useful cosmetic applicator durometer could be selected to begin (static and without current) at 72 Shore D durometer. This would be the maximum stiffness of each brush tine as determined by the selection of the piezoelectric material in combination with the molded material of the applicator portion.

[0030] In FIGS. 8-9, the applicator head 2 is an injection molded mascara brush that has a molded applicator head 109 preferably having tines 127 extending from a body 139. The tines 127 are adapted for loading, applying and doctoring a cosmetic such as, for example, mascara. The molded applicator head has a distal end 141 and, opposite the distal end 141, a proximal end 140 that is adapted to connect the cosmetic applicator head 109 to a rod 4. The rod 4 may be hollow to accommodate a feed conductor 23 and a return conductor 24. The conductors 23, 24 may be placed in a lumen 42 running along the axis of the rod, i.e., inside the hollow stem. Referring now to FIG. 9, the molded brush head comprises two major components—an outer part 143 and an inner part 144. The outer part 143 includes portions of the exposed surfaces of the brush head, including the tines 127. The inner part 144 forms a backbone of the brush head, supporting the outer part 143, and is made of an electrical insulator material. The outer part 143 comprises piezoelectric material. The inner part 144 may be made from any suitable material or materials, such as, for example, any suitable plastic or ceramic that forms a good electrical insulator. The inner part 144 can be made by conventional, well known means for molding plastic. The outer part 143 is made from a piezoelectric material. The preferred method for making the outer part 143 is, from ceramic, insert molding by ceramic injection molding (CIM), and from metal, the preferred method is metal injection molding (MIM). CIM and MIM are methods of powder injection molding. Extremely small (micro to nano scale) metal, ceramic or carbide powders are mixed into a binder and injected into the mold to form an initial shape. After the initial shape is made, the binders are chemically removed (e.g., with a solvent). The shape is then heated to a point where the powder material is sintered together without changing the initial shape. Alternatively, the molded brush head 109 may be manufactured by press molding, transfer molding, compression molding or other insert molding techniques, all of which are well known methods of molding. The outer part 143 can be overmolded onto the inner part 144.

[0031] In the embodiment shown in FIGS. 8 and 9, there are two rows of tines 145 and 146, each row extending from an opposite side of the brush head. However, it will be understood that any suitable number or arrangement of tines is possible. For example, in an alternative embodiment shown in FIGS. 5 and 6, explained in greater detail above, there are two rows of tines 45 and 46, each row extending from the same side of the brush head. The tines may be arranged in straight rows or curved rows, such as, for example, a row of tines that spirals around a longitudinal axis of the applicator head (not shown). The tines may be arranged in one or more arrays, i.e., groups of tines that are electrically, conductively connected to each other. For example, in the embodiment shown in FIGS. 7 and 8, each of the two rows 145, 146 of tines may be an array of tines, 147, 148, respectively. Both tine arrays 147, 148 may be connected to the same circuit, or each tine array 147 and 148 may be connected to a separate circuit so that each tine array 147 and 148 can be selectively and separately activated and set to a particular durometer. In this way, each tine array 147 and 148 may be selectively and individually set to the same durometer or a different durometer.

[0032] At the proximal end 140 of the applicator head 2, a reduced diameter portion defines a pin 149 dimensioned to be received in the bore 16 of the rod 4 to secure the applicator head 2 to the rod 4. The pin 149 can be secured in the bore 16 by any known means, such as, for example, adhering, friction fit, sonic welding, etc.

[0033] From proximal end 140 the outer part 143 extends along a lower side of the applicator head 2 to the distal end 141 where it wraps around the distal end and extends along the upper side back to the proximal end 140. The tines 127 are integrally formed with the portion of the outer part 143 that extends along the lower and upper side of the applicator head 2. The outer part 143 of the body serves as both the feed lead 28 on the one side of the applicator head 2 and the return lead 29 on the opposite side of the applicator head. The feed lead 28 is adapted to be connected to the feed conductor 23. Similarly, the return lead 29 is adapted to be connected to the return conductor 24. The electrical circuit from the power source 5 is completed by connecting the feed conductor 23 to the feed lead portion 28 of the outer part 143, and connecting the return conductor 24 to the return lead portion 29 of the outer part 143. In this way, electricity flows from the feed conductor 23 into the outer part 143 where it is applied to the tines 27 on both sides of the applicator head 2. From the outer part 143 the current flows back to the return conductor 24 to complete a loop. The purpose of this loop is to run an amount of electrical current through the piezoelectric ceramic material of the tines 27 to effect the change in the material, such as, for example, changing the durometer of each tine. For example, a useful cosmetic applicator durometer could be.
selected to begin (static and without current) at 72 Shore D durometer. This would be the maximum stiffness of each brush time as determined by the selection of the piezoelectric material in combination with the molded material of the applicator portion.

[0034] As noted above, the control 25 may be in the form of a simple bipolar switch to selectively turn on or turn off the electric current. Alternatively, the control 25 may be a potentiometer or rheostat 55 to control resistance (this can also function as a position determining transducer for large changes in durometer). For example, as the control 25 in the form of a rheostat 55 is adjusted after the circuit is activated, and electric current is passed through the piezoelectric material in quantities selected according to the rheostat 55, the material softens respectively. Accordingly, the use may be made down to, for example, a durometer of 20 Shore A (very soft and flexible) more suitable for applicatory purposes. After applying cosmetic with the relative softer diameter, the rheostat could be re-adjusted by the user to, for example, yield a durometer of 72 Shore D to achieve a relatively stiffer applicatory more suitable for combing and separation of lashes. The higher durometer in the Shore D range would still allow the applicator to pass through a wiper and wipe effectively, but the ability to drop the durometer into the Shore A range can give specific abilities that a more rigid brush does not have (especially after being inundated in the mascara and then passed through the mascara wiper). For example, a stiffer brush may be able to lengthen and curl, but not volumize especially well. A softer brush may load and deposit more product and therefore volumize more effectively, but may yield more clumps or may not be able to "touch up" as well as a stiff brush can. Being able to selectively dial between durometers allows the user to approach conditional or progressively changing application situations with an inherent flexibility that a single conventional brush cannot provide. An example of this kind of flexibility would be to be able to adjust the brush to execute different steps in the application process. A first step could be volumizing and loading the lashes with mascara, which could benefit from a soft brush. The second step is to curl the lashes, which could benefit from a stiffer durometer, and the third step could be to separate the lashes with a very stiff durometer (which by itself would be very inefficient for loading the lashes in that it would pull most of what it loaded away because of its stiffness).

[0035] While discussed in the context of piezoelectric materials above, other materials may be capable of providing selectively reactive changes in durometer, shape, volume or orientation. The term "selectively reactive material" as used herein means any material adapted to change structurally at least one of shape, volume, rigidity or orientation in response to application or removal of a quantity of energy. For example, the selectively reactive material may be a piezoelectric, ferroelectric or pyroelectric reactive material. See, for example, descriptions of selectively reactive materials in the book Solid State Physics: Advances in Research and Applications Volume 27, 1972 by Frederick Seitz, incorporated herein by reference in its entirety. Examples of materials that exhibit ferroelectric properties are certain nylons (e.g., Nylon 5,10), Polytrifluoroethylene, and Polyvinylidene Fluoride (PVDF), and Poly(methyl) methacrylate (PMMA). Examples of pyroelectric materials are those including polar crystals. The pyroelectric effect occurs when these crystals are heated or cooled, changing the polarity of the crystal, which creates a voltage across the crystal. Specific examples of materials that exhibit the pyroelectric effect are tourmaline, bone and tendon. The piezo materials used could have a positive piezoelectric coefficient (e.g., PZT) or a negative coefficient (e.g., PVDF).

[0036] Accordingly, in one embodiment, the applicator that is adapted for applying a cosmetic product, such as mascara, comprises a handle and an applicator portion extending from the handle. The applicator portion has an applicator structure including at least one selectively reactive material selected from a piezoelectric, ferroelectric or pyroelectric reactive material. The reactive material is adapted to change at least one of shape, volume, rigidity and orientation of the applicator structure in response to application or removal of an appropriate quantity of energy. Means for supplying or removing the quantity of energy are also provided, as well as control means for selectively controlling the quantity of energy supplied to or removed from the selectively reactive material. Preferably, the selectively reactive material is a piezoelectric material, and more preferably, the piezoelectric material is a ceramic-piezoelectric material.

[0037] In accordance with the invention, the applicator portion may comprise any applicator structure that is suitable for application of cosmetic products, such as, for example, a brush with bristles, a wand, a spatula, a puff, a comb, or a roller. As used herein, the term applicator structure can include the entire applicator portion as in any of the foregoing examples, or can refer to any part of the applicator portion, such as, for example, a tip of a molded brush, a bristle of a twisted wire brush, a surface of a spatula or roller, or a porous structure of a puff, in whole or in part. The applicator portion may have a surface or surfaces that are adapted for loading, transporting, applying, exfoliating, buffing, finishing and polishing. The surface may be enhanced with clearances, grooves, dipping, etc. to facilitate the loading, transport and application of cosmetic product.

[0038] The quantity of energy is selected from one of electrical, kinetic, thermal, magnetic or light energy. A ferromagnetic material has a permanent magnetic moment. The moment of a ferromagnetic material is present even in the absence of an external magnetic field affecting it (like a household magnet). The quantity of energy may be supplied, for example, as an alternating or direct current directly to the reactive material, or the energy may be supplied as an energy field, e.g., an electrical or magnetic field established via known circuits or components such as coils. When the piezo material is a light activated shape memory polymer (LASMP), optical energy may be provided in the form of light from an incandescent bulb, a laser, a light emitting diode (LED) or other suitable light source.

[0039] The piezoelectric material may be provided in the form of at least one fiber. The material may alternatively be provided in sheet-like form or as a laminate or bar stock, shapes that are very conducive to specifically directing how the materials will move and react to external forces placed upon them after durometer changes take place. The fibers involved can be any shape profile as well. This could be a bar, "C" or "U" shape, sigmoidal, tube, triangular or trilobal, square, any other polygon, etc.

[0040] The handle 6 may be attached to the applicator portion by a rod 4. The rod may be hollow, with a lumen 42 to provide an internal channel to run conductors, circuit, a circuit board or circuit boards between the handle and the appli-
The applicator head 2 may be selectively removable from the handle 6, at either end of the rod 4 or at the handle. The applicator head 2 may be removable so that it is replaceable. Or alternate applicator heads 2 may be provided with the handle 6 in a kit so that a single handle 6 can be used with, for example, a brush applicator portion, a spatula applicator portion, etc.

The control means 25 is selected from at least one of a switch, a potentiometer, a rheostat and an integrated circuit. The integrated circuit may be adapted to selectively provide the quantity of energy in continuous or pulsed mode, i.e., the current and frequency are controlled. The pulsed mode may be uniform or cyclical (this is continuous), gradual (increasing or decreasing), or syncopated (rhythmic, containing strong or weak accents and/or rests).

There are several different flexible ceramic configurations possible for an applicator. A mascara applicator is described herein, but other types of applicators and cosmetic surfaces such as brushes, wands, spatulas, puffs, combs, exfoliating, depilatory, buffing, finishing, or polishing surfaces for example, could incorporate the reactive material in any number of ways. For example, a spatula could have at least one surface made from a sheet of reactive material. The material could be so arranged as to cause the spatula to "cup" or flatten, or display a degree of change in stiffness or flexibility in response to the changes in current.

For mascara application, the applicators can be constructed much like a conventional twisted wire brush, i.e., they may be composed of multiple extruded fibers that are twisted conventionally along an axis into a brush. A power source and circuits are added to effect the change. If fibers are used, the brush can be purely piezoelectric (e.g., ceramic) fibers, or a mix of piezoelectric and conventional fibers for specific effects. The electricity to the piezoelectric material of the extruded fibers can be achieved by attaching one of the two wires from the handle or stem to the distal end of the mascara brush, with the other wire attached to the base of the wire embedded within the handle or stem.

The applicator could consist of one or more flexible ceramic rows or arrays of lines, teeth, threaded surfaces, or other geometries conducive to application. These wires or teeth could be microns in length and/or width up to 30 mm in length. The applicator could have conventional plastic lines that do not change durometer which are embedded in flexible ceramic surfaces that will allow the wires to "float" as the durometer is changed by the addition of energy. The flexible surfaces are the foundation that the rigid wires are supported in. When energy is added, the foundation can become softer or harder allowing the wires to function independently when acted upon. This foundation material could be a constant thickness or density across the area that the wires are placed, or it could gradually increase, decrease, or otherwise have a changing condition that would allow the wires to have different levels of mobility.

The applicator can be fully composed of flexible ceramic material, or be a hybrid containing conventional materials (thermoset and/or thermoplastic polymers and elastomers, metals, etc.) mixed with flexible ceramic components. This hybrid could be created by bi-injection (plastic and piezoelectric ceramic), insert molding (plastic around a piezoelectric ceramic part), or by assembly (a plastic tube within the piezoelectric ceramics or piezoelectric ceramics with a plastic tube or clearance). Additional plastics and elastomers that can be used could be polyolefins, fluoropolymers, and vinyls as well.

The durometer range that can be applied could be any range within the Shore A Durometer range (softer), the Shore D Durometer range (harder), the Rockwell Hardness region of measurement (hardest) or any durometer emulation across any combination of the previously mentioned ranges. Examples of “hardness” are: Shore hardness applies to softer or more flexible plastics, rubbers and elastomers; and Rockwell Hardness applies to measuring “harder” plastics such as Nylons, Acetal (Delrin), Polystyrene (PS), or Polycarbonate (PC).

When the selectively reactive material is, for example, piezoelectric material, it functions either by the piezoelectric effect or via the inverse piezoelectric effect. The piezoelectric effect is where the materials of the applicator are subject to expansion and compression that causes the material to become polarized, and generate voltages of opposite polarity; any energy generated is proportionate to the mechanical force applied to the material. Voltage is created by a change in the dipole movement by mechanical energy applied to the material.

The inverse piezoelectric effect occurs when the applicator material is subject to an electrical field, and the material actually expands or contracts based on the field’s polarity, and this effect is also proportionate to the strength of the electrical field. For the best mode (inverse piezoelectric effect) we would apply a voltage of the same polarity as the polarizing voltage of the material (this is the voltage applied to the “insert” ceramic (for example) material to make it piezoelectric) to the material. When this voltage is applied to a mascara brush fiber, its length will increase and the diameter of the fiber will narrow accordingly. If the same voltage is applied but with the opposite polarity, the brush fiber will shorten, and the diameter of the fiber will expand (broaden or bulge) with the change. In short, electrical energy is converted into mechanical energy that manipulates the mascara brush. An interesting aspect of this application could be to apply an alternating voltage to the fibers, which would cause them to expand and contract, or increase and decrease durometer cyclically at the frequency of the voltage that we would apply. This is basically how piezoelectric motors work, but in this case we are applying it to mascara brush fibers.

The piezoelectric material may have a defined natural frequency that is determined by its shape and size. This frequency is how the material naturally tends to oscillate, and this frequency can be changed by electrical current (voltage changes vibration amplitude). The selectively reactive material could comprise any crystalline material that represent any of the thirty two crystal classes. Twenty-one of these crystal classes (crystalline geometric point groups) have direct piezoelectric effects and would represent what is likely the composition of the best types of materials for this purpose. The 21 crystal classes are 1, 2, m, c, c2, mm2, 4, 4, 422, 4 mm, 42 m, 3, 32, 3 m, 6, 6, 622, 6 mm, 62 m, 23, 43 m and 432.

The selectively reactive material incorporated in the bristles, tines or other structure can be affected by either a sustained electric field, or a pulsed field that can create direct and inverse piezoelectricity to create an oscillating effect in the durometer change.
Some suggested selectively reactive materials that would be suitable for the present invention include:

Naturally occurring materials: Bone, Enamel, Dentin, Wood (piezoelectric texture), Silk, Topaz, Quartz, Cane Sugar, Berlinitic, Rochelle Salt, Tourmaline-Group materials.

Synthetically materials: Langasite (La₃Ga₃Si(O14)) and Gallium Orthophosphate (GaPO₄) (both are synthetic quartz crystals)

Ceramics: Barium Titanate (BaTiO3); Lead Titanate (PbTiO3); Lead Zirconate Titanate (PbZrTiO3) aka PZT; Potassium Niobate (K NbO3); Lithium Niobate (Li NbO3); Lithium Tantalate (Li TaO3); Sodium Tungstate (Na2WO3); Ba2NaNb5O5; Pb2K4Nb5O15; Sodium Potassium Niobate (NaK Nb); Bismuth Ferrite (BiFeO3); Sodium Niobate (Na NbO3)

Polymers: Polyvinylidene Fluoride (PVDF)

There are several possible methods/configurations to manipulate the applicator. For example, the durometer/flexibility of the brush can be adjusted by a simple single or bi-pole switch (on/off), or multiple poles and/or multiple throw switches with several different current settings. Alternatively, the durometer/flexibility of the brush can be adjusted by a potentiometer or rheostat, or digitally by an integrated circuit. An integrated circuit or other suitable electronic control could be used to manipulate the durometer, including in a pulse, pattern or program of energy delivery that would cause the durometer to change as a frequency. This pulse could have consistent frequency intervals, could increase or decrease over time (gradiual), or be synchronized (rhythmic stresses and/or rests). This pulsing frequency will not function as a free standing “vibration” (only the flexibility is changing) but the effects of the durometer change will be apparent when contact by the bines, tips, or bristles contact the eyelashes, ad the force of the eyelashes effects movement on the dynamically changing flexibility of the mascara brush. The changes would be proportional to the measurement of the material’s electric dipole moment (a measure of the system’s overall state of polarity).

Alternatively, the durometer could be changed by magnetism (electromagnetic field)—introducing a magnetic field, and/or reversing polarity can be methods to change the flexibility of the applicator.

Power can be supplied to the applicator using batteries, solar power, kinetic power (from a piezo effect by bending, vibration, agitation, etc. of piezo based materials), or from other suitable sources, such as a connection to a commercial power grid.

Cosmetic applicators are often created as a matrix of several different applicator surfaces; whether they are tines, bristles, discs, etc., and for these shapes, different dermatometers of material may be selected within a predicted range. To create effective applicators for more customer specific needs (ethnographic, genetic, application specific like volumizing or curling, etc.), a manufacturer would be required to produce many different levels of flexibility in the applicator components. Offering too many levels of choice reduces manufacturing efficiency, and may lead to consumer confusion as to what is best for a particular need. The present invention provides the consumer flexibility in terms of selecting a particular dermatometer brush, while limiting the number of variations a manufacturer must produce. The present applicator allows manipulation by the user of the durometer of cosmetic applicators that is dynamic and interactive. The user can choose an appropriate setting and either stay with this setting, or change settings depending on changing needs throughout the course of a day, over multiple applications, the life of the product, etc. In terms of manufacturing, only one version is produced, because the device is infinitely customizable in the hands of the consumer.

Being able to change the durometer of a cosmetic applicator allows for a consumer-specific customizable application. For example, a mascara brush can be adjusted to lengthen and separate at a stiffer durometer setting, and volumize and load the lashes with mascara at a lower durometer setting. Other benefits could include different levels of skin care from skin exfoliation at high durometer settings to skin conditioning and finishing at low durometer settings.

The method to dynamically adjust durometer on a cosmetic applicator may be used for cosmetic/treatment/ pharmaceutical packages such as mascaras, eye liner, eye shadow, lip gloss, treatments, hair care, sun protection/fanning, foundations, concealers, hand or body creams, nail polish, exfoliants and skin care applications.

It is understood that various modifications and changes in the specific form and construction of the various parts can be made without departing from the scope of the following claims.

What is claimed is:

1. An applicator adapted for applying a cosmetic product, such as mascara, on a part of a human body, the applicator comprising:
   a. handle;
   an applicator head extending from the handle, the applicator head having an element including at least one selectively reactive material adapted to change at least one of shape, volume, rigidity and orientation of the applicator structure in response to application or removal of a quantity of energy;
   a power source for supplying the quantity of energy to the selectively reactive material; and
   control means for selectively controlling the application of the quantity of energy to the selectively reactive material.

2. The applicator of claim 1 wherein the selectively reactive material is a piezoelectric material.

3. The applicator of claim 2 wherein the piezoelectric material is a ceramic-piezoelectric material.

4. The applicator of claim 1 wherein the applicator portion includes at least one of a brush, a wand, a spatula, a puff, a comb, and a roller.

5. The applicator of claim 1 wherein the applicator surface includes at least one of a surface adapted for loading, transporting, applying, exfoliating, buffering, finishing and polishing.

6. The applicator of claim 1 wherein the quantity of energy is selected from one of electric, magnetic or light energy.

7. The applicator of claim 6 wherein the quantity of energy is supplied as an energy field.

8. The applicator of claim 1 wherein the quantity of energy is electric energy supplied as direct or alternating current to the selectively reactive material through a circuit.

9. The applicator of claim 2 wherein the piezoelectric material is provided in the form of at least one fiber.

10. The applicator of claim 1 wherein the handle is attached to the applicator portion by a stem.

11. The applicator of claim 1 wherein the applicator portion is selectively removable from the handle.
12. The applicator of claim 1 wherein the applicator portion is selectively replaceable.

13. The applicator of claim 1 wherein the control means is selected from at least one of a switch, a potentiometer, a rheostat and an integrated circuit.

14. The applicator of claim 13 wherein the integrated circuit is adapted to selectively provide the quantity of energy in continuous or pulsed mode.

15. The applicator of claim 14 wherein the pulsed mode is uniform or syncopated.

16. The applicator of claim 1 wherein the selectively reactive material is polarized.

17. The applicator of claim 2 wherein the piezoelectric material is polarized.

18. The applicator of claim 3 wherein the ceramic-piezoelectric material is polarized.

19. An applicator adapted for applying a cosmetic product, the applicator comprising:

   a handle;
   an applicator head extending from the handle, the applicator portion having an element including at least one piezoelectric material adapted to change at least one of shape, volume, rigidity and orientation of the applicator structure in response to a change in an energy input selected from one of electric current, magnetic field and light;
   means for supplying the energy input; and
   control means for selectively controlling the energy input.

20. The applicator of claim 19 wherein the at least one piezoelectric material is polarized.

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