US 20100059383A1

(19) United States

(12) **Patent Application Publication**

Duerig et al.

(10) **Pub. No.: US 2010/0059383 A1**

(43) **Pub. Date: Mar. 11, 2010**

(54) **DEVICE AND METHOD FOR PATTERNING A SURFACE OF A POLYMER LAYER**

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(21) Appl. No.: **12/375,417**

(22) PCT Filed: **Jul. 18, 2007**

(86) PCT No.: **PCT/IB2007/052869**

§ 371 (c)(1), (2), (4) Date: **Nov. 23, 2009**

(30) **Foreign Application Priority Data**

Jul. 28, 2006 (EP) 06118094.9

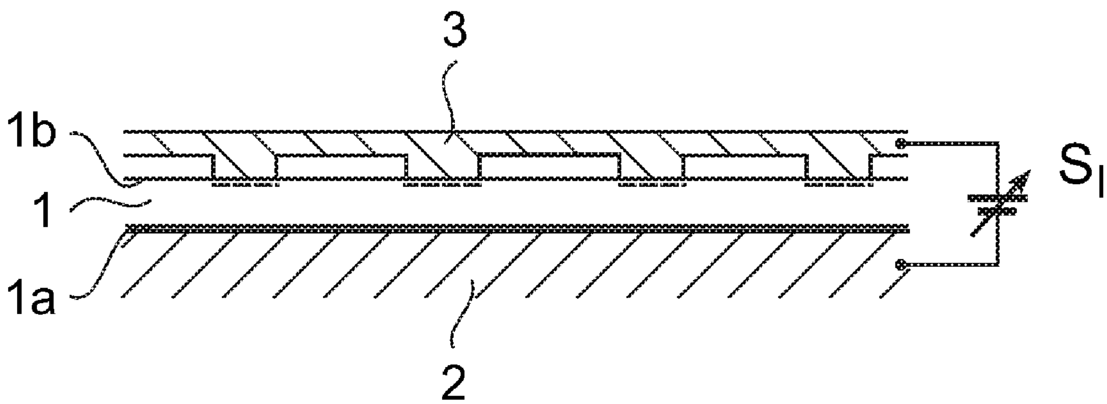
Publication Classification

(51) **Int. Cl.**
C25D 1/00 (2006.01)

(52) **U.S. Cl.** .... **205/76**; 204/224 R

(57) **ABSTRACT**

The present invention relates to a device for forming topographic features on a surface of a polymer layer comprising: a polymer layer (**1**); a substrate (**2**) comprising a conductor, a first surface (**1***a*) of the polymer layer (**1**) being provided on the substrate (**2**); and at least one electrode (**3**) which, when the device is in use, interacts with a second surface (**1***b*) of the polymer layer (**1**), wherein, when in use, the device is operable to apply a first electrical potential (P**1**) to the at least one electrode (**3**) relative to the substrate (**2**), thereby to cause a protrusion (**4**) to be formed on the second surface (**1***b*) of the polymer layer (**1**).



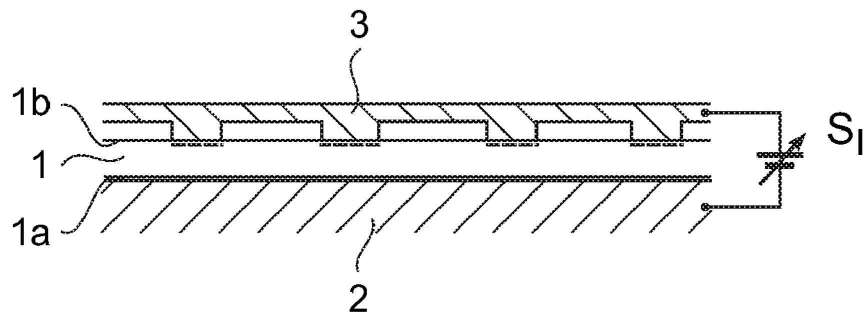


Fig. 1A

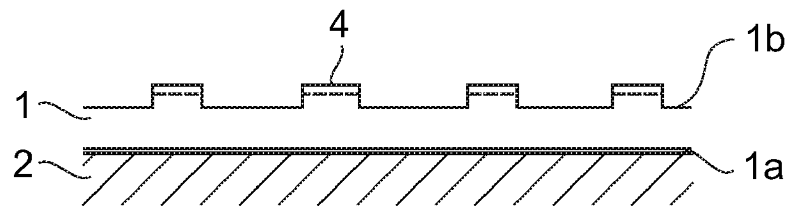


Fig. 1B

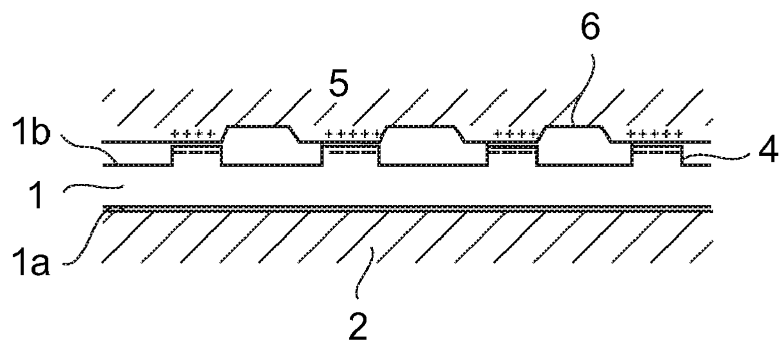


Fig. 2

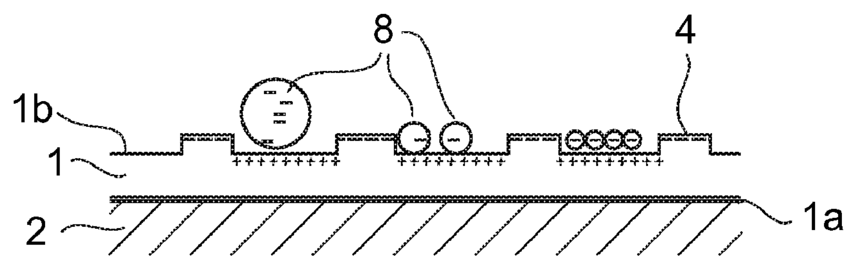


Fig. 3A

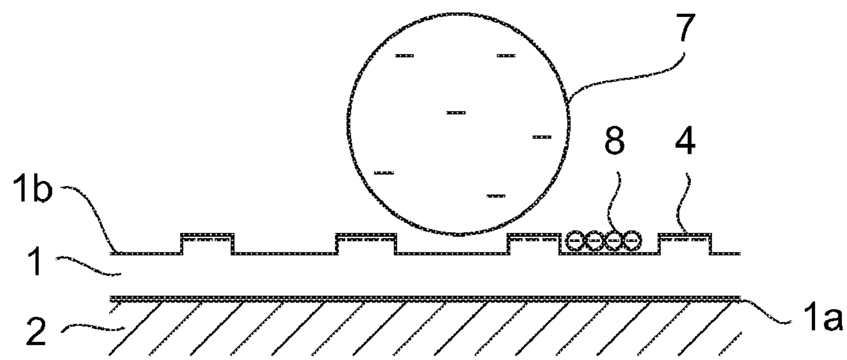


Fig. 3B

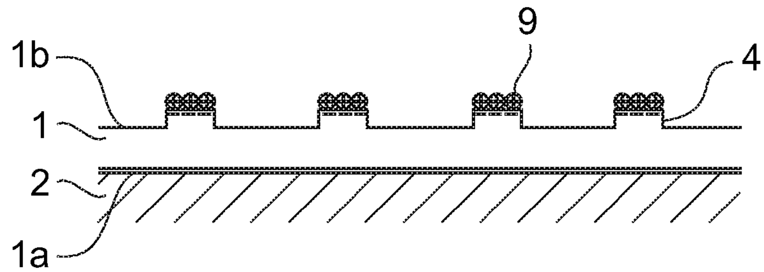


Fig. 4A

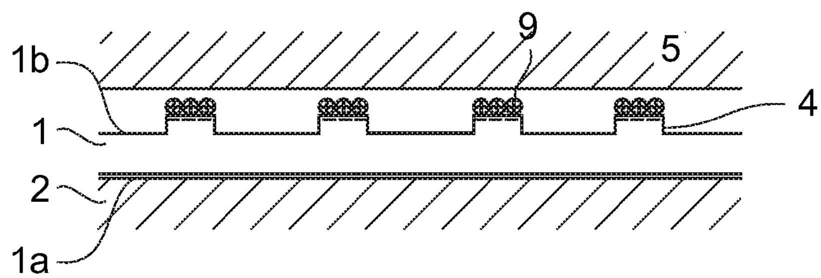


Fig. 4B

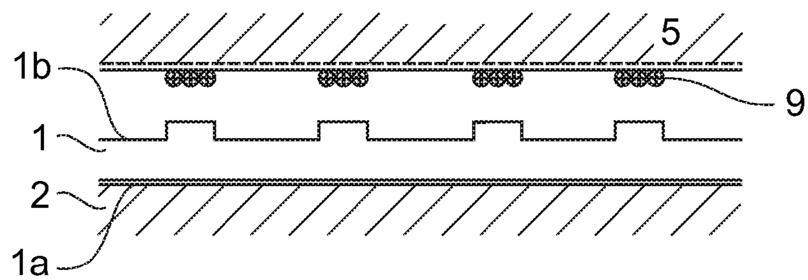


Fig. 4C

Fig. 5A

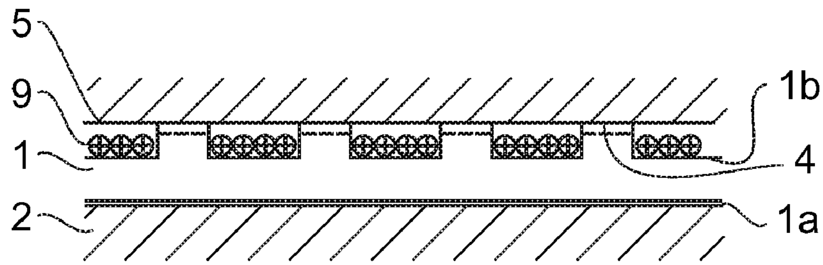


Fig. 5B

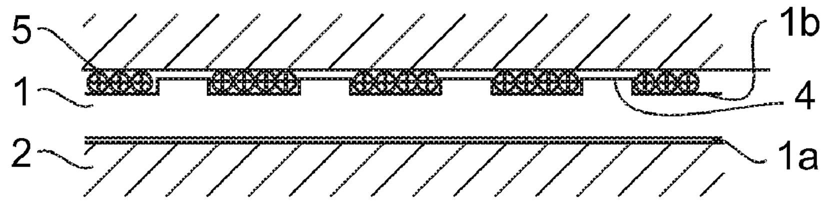
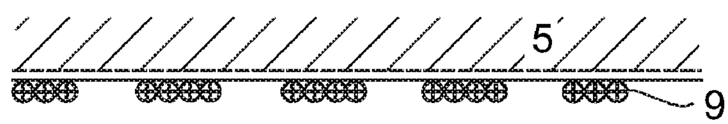


Fig. 5C



DEVICE AND METHOD FOR PATTERNING A SURFACE OF A POLYMER LAYER

FIELD OF THE INVENTION

[0001] The present invention relates to a device and a method for patterning a surface of a polymer layer. In particular, the present invention relates to a device and a method for forming topographic features and, more specifically, protrusions, on a surface of a polymer layer.

BACKGROUND OF THE INVENTION

[0002] A probe-type data storage device based on the atomic force microscope (AFM) is disclosed in "The millipede—more than 1,000 tips for future AFM data storage" by P. Vettiger et al., IBM Journal Research Development, Vol. 44, No. 3, March 2000. The storage device has a read and write function based on a mechanical x-, y-scanning of a storage medium with an array of probes each having a tip. The probes operate in parallel with each probe scanning, during operation, an associated field of the storage medium. The storage medium comprises a polymethylmethacrylate (PMMA) layer. The tips, which each have a diameter of between 5 nm to 40 nm, are moved across the surface of the polymer layer in a contact mode. The contact mode is achieved by applying forces to the probes so that the tips of the probes can touch the surface of the polymer layer. For this purpose, the probes comprise cantilevers, which carry the tips on their end sections. Bits are represented by indentation marks, each encoding a logical "1", or non-indentation marks, each encoding a logical "0", in the polymer layer. The cantilevers respond to these topographic changes while they are moved across the surface of the polymer layer during operation of the device in read/write mode.

[0003] Indentation marks are formed on the polymer layer by thermomechanical recording. This is achieved by heating the tip of a respective probe operated in contact mode with respect to the polymer layer. Heating of the tip is achieved via a heater dedicated to the writing/formation of the indentation marks. The polymer layer softens locally where it is contacted by the heated tip. The result is an indentation mark, for example, having a nanoscale diameter comparable to the diameter of the tip that is used in its formation, being produced on the layer. Reading of the indentation mark is also accomplished by a thermomechanical concept and may be done using the same probe as that used for writing the indentation mark. Due to the mechanical stress that is used for writing indentation marks in the polymer layer, tip and/or media wear may be typically expected to occur.

[0004] In another previously-proposed probe-type data storage device as described in Ultramicroscopy, 42-44 (1992) 262, data is encoded on an insulator such as Nitride-Silicon Dioxide-Silicon by charge injection, that is, bits are represented by localized trapped charges on the insulator surface. Thus, each trapped charge denotes a logical "1" and the absence thereof denotes a logical "0". Data is retrieved by detecting the electrical stray field associated to each of the localized trapped charges, which field gives rise to a measurable but relatively small interaction force that is on the order of, for example, 1 nN. Other issues that may need to be considered in the detection of the localized trapped charges are: (1) the aforementioned electrical stray field is long range by nature and so may result in the "smearing out" of a bit location; (2) a localized trapped charge is typically screened by polar contaminants, for example, water molecules, thereby reducing the magnitude of an associated electrical stray field by an order of magnitude within a short time, typically within 24 hours, of charge injection, and (3) the magnitude of the aforementioned interaction force may limit data rates on the order of kHz rather than MHz.

[0005] In yet another previously-proposed probe-type data storage device, bits are stored as oriented domains in ferroelectric media analogous to magnetic recording. Detection of an electric dipole orientation associated to a domain may be performed by measuring the strength of a corresponding electrical stray field. However, the issues listed under (1) to (3) above may also need to be considered in the present case. Alternatively, detection of the electric dipole orientation may be done by measuring the piezo-electric response, which induces minute, well-localized modulations of the surface topography on the order of a fraction of a nanometer, which requires sensitive lock-in schemes for their detection. In this case, it could be that signal degradation may be avoided by the electromechanical transduction. However, by virtue of being on the order of 0.1 nm, the topographic features may be comparable to or less than the roughness of the surface on which they are present. Furthermore, the detection of such sub-nanometre dimensioned features using known detectors may typically be done with a limited data rate in the kHz range.

[0006] It is known to pattern a surface of a polymer layer by imprinting, as used in lithography, and embossing, which is known in relation to probe-storage applications.

[0007] In these cases, an indenter body is typically impressed onto the surface of the polymer layer and a mechanical pressure is applied to the indenter body, thereby to imprint/replicate the features of the indenter body in the surface of the polymer layer. Additional energy in the form of heat, for example, may be used in combination with the applied mechanical pressure.

[0008] With the above-described techniques, features of the indenter body are imprinted into the surface of the polymer layer, i.e. they extend in a sub-surface direction. It is a challenge to produce asperities such as, for example, protrusions, on the surface of a polymer layer using these techniques.

[0009] Accordingly, it is desirable to provide a device and a method for forming protrusions on a surface of a polymer layer.

SUMMARY OF THE INVENTION

[0010] According to an embodiment of a first aspect of the present invention, there is provided a device for forming topographic features on a surface of a polymer layer comprising:

a polymer layer; a substrate comprising a conductor, a first surface of the polymer layer being provided on the substrate; and at least one electrode which, when the device is in use, interacts with a second surface of the polymer layer, wherein, when in use, the device is operable to apply a first electrical potential to the at least one electrode relative to the substrate, thereby to cause a protrusion to be formed on the second surface of the polymer layer.

[0011] A device embodying the present invention comprises a polymer layer, a first surface of which is provided on a substrate comprising a conductor and a second surface of which is provided so as to interact with at least one electrode. By applying an electrical potential, a first electrical potential, to the at least one electrode relative to the substrate, charge is injected onto the second surface of the polymer layer. The charge injected into the second surface of the polymer material remains localized thereon by virtue of the polymer material being non-conducting. Where the charge is injected on the second surface of the polymer layer, the polymer material swells and a protrusion is formed. Deformation of the topographic landscape of the second surface of the polymer layer by the formation of a protrusion thereon is in contrast to previously-proposed techniques where (and as described above), the topographic features that are formed extend in a sub-surface direction/are depressions in the surface of the polymer layer.

[0012] Preferably, the at least one electrode interacts with the second surface of the polymer layer by being in contact therewith. In this case, once the at least one electrode is brought into contact with the second surface of the polymer layer, it is preferably scanned relative thereto and/or a loading force is applied to the at least one electrode.

[0013] In an embodiment of the present invention where a protrusion is formed on the second surface of the polymer layer by establishing contact between the second surface of the polymer layer and the at least one electrode, the magnitude of the first electrical potential applied to the at least one electrode is relatively lower than if the second surface of the polymer layer and the at least one electrode were separated. Formation of the protrusion on the second surface of the polymer layer may be assisted by a scanning motion of the at least one electrode and/or a vertical impact motion of the at least one electrode in response to a loading force being applied thereto. By way of example, the loading force applied to the at least one electrode may be a pre-defined value and such that a pressure in a range of 1 MPa to 100 MPa results between the at least one electrode and the second surface of the polymer layer.

[0014] Alternatively, the at least one electrode may interact with the second surface of the polymer layer by being in out of contact, i.e. with there being a separation between the at least one electrode and the second surface of the polymer layer. In this case, the distance between the at least one electrode and the second surface of the polymer layer is preferably at least 1 nm.

[0015] In this alternative case, neither the second surface of the polymer layer nor the at least one electrode are subjected to wear.

[0016] Preferably, the device is operable to apply a second electrical potential to the at least one electrode, which interacts with the second surface of the polymer layer in the region where the protrusion has been formed, the second electrical potential having an opposite polarity to the first electrical potential. By the selection of an appropriate polarity and magnitude for the second electrical potential, a protrusion formed on the second surface of the polymer layer may be enhanced, reduced or the second surface of the polymer layer may even be returned to an uncharged, neutral state. Furthermore, such reversible operation allows modification of the topographic landscape of the second surface of the polymer layer to be done sequentially.

[0017] Preferably, the device is operable to apply heat, irradiation or a combination thereof to the polymer layer. Protrusions formed on the second surface of the polymer layer may be globally removed by applying a suitable form of energy such as, for example, the application of heat, irradiating with ultra-violet radiation and/or charged particles, or a combination thereof. In this way, the second surface of the polymer layer may be returned to a state where new protrusions may subsequently be written thereon in a simple and time-efficient manner. In this case, it is preferable that the polymer layer is heated to a temperature of between 100° C. to 200° C. Since the decay rate of the injected charge typically increases by one order of magnitude per 20° C. change in temperature, charge could be neutralized in a timescale of seconds by heating the polymer layer to temperatures between 100° C. to 200° C. in an embodiment of the present invention.

[0018] Preferably, the polymer layer comprises polystyrene-r-benzocyclobutene 30% random copolymer, PS-30%-BCB.

[0019] In an embodiment of the present invention, the polymer layer comprises a cross-linkable and non-conducting polymer such as, for example, polystyrene-r-benzocyclobutene 30% random copolymer, PS-30%-BCB. By virtue of these properties being exhibited by the polymer layer, a protrusion formed on the second surface of the polymer layer remains localized thereon without substantially losing form for a period of time spanning days for storage of the polymer layer at room temperature.

[0020] Preferably, the at least one electrode has a substantially extended configuration.

[0021] In this case, contact between the at least one electrode and the second surface of the polymer layer may be established selectively and in a manner reminiscent of imprint lithography.

[0022] Preferably, the at least one electrode interacts with the second surface of the polymer layer via a surface having a patterned structure.

[0023] In this case, the surface having a patterned structure may be the surface of the at least one electrode by way of which interaction is established with the second surface of the polymer layer, the patterned structure being in accordance with how topographic patterning of the second surface of the polymer layer is desired. It could also be that the surface having a patterned structure is, for example, a mask.

[0024] A corresponding method aspect of the invention is provided, and thus in an embodiment of a second aspect of the present invention, there is provided a method for forming topographic features on a surface of a polymer layer, a first surface of the polymer layer being provided on a substrate comprising a conductor, the method comprising the steps of: interacting at least one electrode with a second surface of the polymer layer; and

applying a first electrical potential to the at least one electrode relative to the substrate, thereby to cause a protrusion to be formed on the second surface of the polymer layer.

[0025] In an embodiment of a third aspect of the present invention, there is provided a polymer layer, a surface of which is patterned with topographic features using a device embodying the first aspect of the present invention or a method embodying the second aspect of the present invention.

[0026] Any of the device features may be applied to the method aspect of the invention and vice versa. Features of one aspect may be applied to any other aspect. Any disclosed embodiment may be combined with one or several of the other embodiments shown and/or described. This is also possible for one or more features of the embodiments.

DESCRIPTION OF THE DRAWINGS

[0027] Reference will now be made, by way of example, to the accompanying drawings, in which:

[0028] FIGS. **1***a* and **1***b* schematically illustrate the principle of an embodiment of the present invention;

[0029] FIG. **2** shows a reversible adhesion application in which an embodiment of the present invention may be used;

[0030] FIGS. **3***a* and **3***b* schematically illustrate the application of an embodiment of the present invention for the size selective separation of certain species of particles;

[0031] FIGS. **4***a* to **4***c* schematically illustrate the application of an embodiment of the present invention for a method of transferring ink in printing; and

[0032] FIGS. **5***a* to **5***c* schematically illustrate the application of an embodiment of the present invention for another method of transferring of ink in printing.

DETAILED DESCRIPTION OF THE INVENTION

[0033] FIGS. **1***a* and **1***b* schematically illustrate the principle of an embodiment of the present invention.

[0034] A first surface **1***a* of a polymer layer **1** is provided on a substrate **2**. It may be provided directly on the substrate **2** or on a spacer layer which may, for example, be silicon oxide. The polymer layer **1** comprises polystyrene-r-benzocyclobutene 30% random copolymer, PS-30%-BCB. The present invention is, however, not limited to PS-30%-BCB and any other polymer that is non-conducting and, optionally, cross-linkable may be used. The substrate **2** comprises silicon with an n-type doping concentration of, for example, 10^{16} cm^{-3}. The substrate **2** is, of course, not limited to the use of silicon and any other material having an appropriate electrical conductance may be used.

[0035] A second surface **1***b* of the polymer layer **1** is provided so as to interact with at least one electrode **3** either by being in contact with or in close proximity thereto, i.e. with there being a separation between the second surface **1***b* of the polymer layer **1** and the at least one electrode **3**. By applying an electrical potential, a first electrical potential P**1**, to the at least one electrode **3** relative to the substrate **2** via an electrical switch S**1**, charge is injected onto the second surface **1***b* of the polymer layer **1**. By virtue of the polymer layer **1** comprising a material that is non-conducting, the charge injected in the second surface **1***b* of the polymer layer **1** remains localized on the surface thereof. As can be seen from FIG. **1***b*, where the charge is injected on the second surface **1***b* of the polymer layer **1**, the polymer material swells and a protrusion **4** is formed.

[0036] In an embodiment of the present invention, electro-mechanical transduction, that is, the transduction of an electrical signal, which is the electrical potential applied to the at least one electrode **3**, to cause the injection of charge onto the second surface **1***b* of the polymer layer **1** and thereby a charge-induced swelling/protrusion to be formed on the second surface **1***b* of the polymer layer **1**, is used to topographically pattern the surface of a polymer layer **1**. Deformation of the topographic landscape of the second surface **1***b* of the polymer layer **1** by the formation of a protrusion **4** thereon is in contrast to previously-proposed techniques where (and as described above), the topographic features that are formed extend in a sub-surface direction/are depressions in the surface of the polymer layer.

[0037] Experimental results pertaining to an embodiment of the present invention have shown that when the polymer layer **1** comprises, in particular, PS-30%-BCB, not only does the charge injected on the second surface **1***b* accumulate at the surface thereof but also that this charge is retained without substantial dissipation for a period of time spanning days for the storage of the polymer layer **1** at room temperature.

[0038] The polarity of the charge injected onto the second surface **1***b* of the polymer layer **1**, by the application of the first electrical potential P**1** to the at least one electrode **3** when it interacts with the second surface **1***b* of the polymer layer **1**, can be reversed. This is preferably done by arranging the at least one electrode **3** so that it interacts with the region on the second surface **1***b* where charge has been injected, i.e. where a protrusion **4** has been formed, and applying a second electrical potential P**2** that is of opposite polarity to the first electrical potential P**1** to the at least one electrode **3**. In this case, the at least one electrode **3** may, for example, be rescanned on the charged area on the second surface **1***b* of the polymer layer **1**. By the selection of an appropriate polarity and magnitude for the second electrical potential P**2**, a protrusion **4** formed on the second surface **1***b* of the polymer layer **1** may be enhanced, reduced or the second surface **1***b* may even be returned to an uncharged, neutral state. Furthermore, such reversible operation allows charge injection and, therefore, modification of the topographic landscape of the second surface **1***b* of the polymer layer **1** to be done sequentially.

[0039] As discussed previously, the at least one electrode **3** interacts with the second surface **1***b* of the polymer layer **1** either by being in contact therewith, hereinafter referred to as the contact-mode of operation or by being in close proximity thereto, for example, being separated by at least 1 nm, hereinafter being referred to as the non-contact mode of operation.

[0040] In the case of operation in the non-contact mode, the at least one electrode **3** and the second surface **1***b* of the polymer layer **1** are respectively subjected to less wear than if they were maintained in contact.

[0041] For operation in the contact-mode, the amount of charge that may be injected on the second surface **1***b* of the polymer layer **1** is on the order of ϵ_0 multiplied by the first electrical potential P**1** applied to the at least one electrode **3** divided by the depth by which the charge carriers can penetrate into the polymer layer **1**, or the penetration depth, where ϵ_0=8.84×10^−12CV^−1 m^1 and the penetration depth is on the order of 1 nm. Hence, charge densities on the order of 0.1 electron/nm^2 may be achieved with a first electrical potential P**1** of <10V being applied to the at least one electrode **3**. This is particularly advantageous when compared to the injection of charge by field emission as done when operation is conducted in the non-contact mode where, in order to achieve the above-mentioned charge densities, the magnitude of the first electrical potential P**1** applied to the at least one electrode **3** would be have to be on the order of 100V. This also has the associated effect that the injected charge would penetrate deeper into the second surface **1***b* of the polymer layer **1** than would be the case for operation in the contact-mode.

[0042] When operation is conducted in the contact-mode, the injection of charge onto the second surface **1***b* of the polymer layer **1** may be assisted by a scanning motion of the at least one electrode **3** and/or a vertical impact motion of the at least one electrode **3** in response to a loading force being applied thereto. By way of example, the loading force applied to the at least one electrode **3** may be a pre-defined value and such that a pressure in a range of 1 MPa to 100 MPa results between the at least one electrode **3** and the second surface **1***b* of the polymer layer **1**. By virtue of the at least one electrode **3** to which the first electrical potential P**1** is applied being rubbed relative to the second surface **1***b* of the polymer layer **1**, charge is injected on the surface thereof by a triboelectric effect.

[0043] The charge injected onto the second surface **1***b* of the polymer layer **1**, and therefore the topographic features/protrusions **4** created thereon, may be globally removed by applying a suitable form of energy such as, for example, the application of heat, irradiating with ultra-violet radiation and/or charged particles, or a combination thereof. Since the decay rate of the injected charge typically increases by one order of magnitude per 20° C. change in temperature, charge could be neutralized in a timescale of seconds by heating the polymer layer **1** to temperatures between 100° C. to 200° C.

[0044] As can be seen from FIGS. **1***a* and **1***b*, the at least one electrode **3** may have a substantially extended configuration so that contact with the second surface **1***b* of the polymer layer **1** may be established selectively and in a manner reminiscent of imprint lithography.

[0045] The at least one electrode **3** may be provided so as to interact with the second surface **1***b* of the polymer layer **1** via a surface having a patterned structure. The surface having a patterned structure may be the surface of the at least one electrode **3** by way of which interaction is established with the second surface **1***b* of the polymer layer **1**, the patterned structure being in accordance with how topographic patterning of the second surface **1***b* of the polymer layer **1** is desired. It could also be that the surface having a patterned structure is, for example, a mask.

[0046] A polymer layer **1** whose surface is patterned in accordance with an embodiment of the present invention may be exploited in a number of diverse applications of nanotechnology such as lithography, bio-engineering, life-sciences, etc., as will be described herebelow.

Reversible Adhesion

[0047] It is known that the adhesion of two surfaces may be mediated by interlocking asperities respectively thereon. Reference is made to FIG. **2**, which shows a reversible adhesion application in which an embodiment of the present invention may be used. A second surface **1***b* of a polymer layer **1** is structured according to an embodiment of the present invention and as hereinbefore described with reference to FIG. **1** such that a plurality of protrusions **4** are created thereon. In the example shown in FIG. **2**, the protrusions **4** have an associated negative charge.

[0048] The second surface **1***b* is brought into contact with a cover surface **5**. The protrusions **4** of the second surface **1***b* interlock with corresponding asperities **6** on the cover surface **5**. Adhesion between the second surface **1***b* and the cover surface **5** is further assisted by the image-polarization interaction induced at the cover surface **5** by the charge associated to the protrusions **4** on the second surface **1***b* of the polymer layer **1**. As can be seen from FIG. **2**, since the protrusions **4** have an associated negative charge, a positive charge is induced in the asperities of the cover surface **5** that correspond to the protrusions **4**. In this way, the second surface **1***b* of the polymer layer **1** and the cover surface **5** may be held together. The bond between them may be released by supplying energy, for example, heat, to the system thereby neutralizing the charge on the second surface **1***b* of the polymer layer **1**, which subsequently reverts to its initial non-functionalized state and separates from the cover surface **5**.

Size Selective Adhesion

[0049] It is desirable to be able to separate certain species of particles on the basis of their size and, in particular, on the nanometer scale. Reference is made to FIG. **3**, which shows how an embodiment of the present invention may be applied for the size selective separation of certain species of particles. In the example shown in FIG. **3**, the particles to be separated are like-charged.

[0050] A second surface **1***b* of a polymer layer **1** is structured according to an embodiment of the present invention and as hereinbefore described with reference to FIG. **1** such that a plurality of protrusions **4** are created thereon. In the example shown in FIG. **3**, the protrusions **4** have an associated negative charge. The protrusions **4** are created with a predetermined separation, which is smaller than a diameter of a negatively-charged particle **7** that is desired to be screened from another negatively-charged particle **8**.

[0051] As can be seen from FIG. **3***a*, since the protrusions **4** on the second surface **1***b* of the polymer layer **1** have an associated negative charge, the particles **8** having a diameter smaller than/corresponding to the separation between adjacent protrusions **4** will adsorb to the second surface **1***b* between adjacent protrusions **4**. Where the negatively-charged particles **8** adsorb to the second surface **1***b* of the polymer layer **1**, a positive charge is induced so that the particles **8** adhere thereon by electrostatic attraction. By contrast and as can be seen from FIG. **3***b*, the larger particles **7** are unable to adhere to the second surface **1***b* of the polymer layer **1** by virtue of having a larger diameter than the separation between adjacent protrusions **4** and also by being repelled by the negative charge associated to the protrusions **4**.

Ink Transfer in Printing

[0052] An embodiment of the present invention may also find application for the transfer of ink in printing as will be described with reference to FIGS. **4***a* to **4***c*. Only by way of example, the application of the present invention in this domain is described with respect to ink molecules **9** having an associated positive charge. Similarly, the method would also work for molecules with higher order charge distributions such as a dipole, quadrupole, etc. Also, the method would work for uncharged molecules by virtue of the image charge effect which effectively provides dipolar electrostatic interaction.

[0053] Referring to FIG. **4***a*, the ink molecules **9** are adsorbed onto the protrusions **4** created on the second surface **1***b* of a polymer layer **1**, which is patterned in accordance with an embodiment of the present invention. In the present example, the protrusions **4** have an associated negative charge.

[0054] As can be seen from FIG. **4***b*, the second surface **1***b* of the polymer layer **1** modified by the adsorption of the ink molecules **9** thereon is brought into contact with a cover surface **5**.

[0055] Referring to FIG. **4***c*, by energizing the polymer layer **1**, for example, by heating, it is returned to a non-functionalised state so that adhesion to the ink molecules **9** is removed. In this way, transfer of the ink molecules **9** onto the cover surface **5** is done, such transfer being further assisted by the image-polarisation interaction induced at the cover surface **5** due to the charge associated to the ink molecules **9**.

[0056] Since adhesion and/or transfer of the ink molecules **9** onto a desired surface may be controlled on the nanometer scale using a combination of topography and charge, an edge bleaching effect that is very often encountered in conventional printing schemes may be avoided.

[0057] A further application of an embodiment of the present invention for the transfer of ink in printing will be described with reference to FIGS. **5***a* to **5***c*.

[0058] Referring to FIG. **5***a*, the second surface **1***b* of a polymer layer **1** is patterned in accordance with an embodiment of the present invention. Particularly, a height of the protrusions **4** is chosen to be larger than a diameter of the ink molecules **9** that are to be transferred onto a cover surface **5**. In this way, the ink molecules **9** are protected from being scraped away when the cover surface **5** is aligned with the second surface **1***b* of the polymer layer **1**.

[0059] Furthermore, the protrusions **4** are formed at a predetermined separation. In the example shown in FIG. **5***a*, the predetermined separation between adjacent protrusions **4** is chosen to be fixed and so that at least four ink molecules **9** are adsorbed in a trough between adjacent protrusions **4**. Of course, the separation between a pair of adjacent protrusions **4** is not restricted thereto and may also be chosen to be different from that of another pair of adjacent protrusions **4**. In this way, the predetermined separation between adjacent pairs of protrusions **4** provides a pattern for the adsorption of the ink molecules **9**. The protrusions **4** also serve to prevent leakage of the ink molecules **9** at the boundaries.

[0060] Referring to FIG. **5***b*, by providing energy, for example, heat, to the polymer layer **1**, the surface charge on the polymer layer **1** is removed, causing the protrusions **4** to level out. Due to the levelling, the ink molecules **9** eventually come into contact with the cover surface **5**, which then takes them up by adhesion. The adhesion may be enhanced by charge-polarisation in the cover surface **5**, which may occur in response to the charge associated to the ink molecules **9**. Such adhesion may be further assisted by pre-charging the cover surface **5** before it is aligned with the second surface **1***b* of the polymer layer **1**. The adhesion may also be enhanced by using a suitable material for cover surface **5**, which provides higher adhesion, a favorable interfacial energy, to the ink particles **9** than the second surface **1***b*.

[0061] With reference being made to FIG. **5***b*, the configuration shown therein may be used for transporting and/or storing the ink molecules **9** in a specific pattern. Of course, this configuration is not limited to ink molecules **9** and other molecules, for example, proteins may also be stored and/or transported in this way. This may, for example, be useful for bio-assay applications in which proteins need to be protected against the environment during transfer of samples, such as, between assay preparation by a medical doctor or patient and subsequent analysis in a remote laboratory.

[0062] The present invention has been described above purely by way of example and modifications of detail can be made within the scope of the invention.

[0063] Each feature disclosed in the description and (where appropriate) the claims and drawings may be provided independently or in any appropriate combination.

1. A device for forming topographic features on a surface of a polymer layer comprising:

a polymer layer;

a substrate comprising a conductor, a first surface of the polymer layer being provided on the substrate; and

at least one electrode which, when the device is in use, interacts with a second surface of the polymer layer,

wherein, when in use, the device is operable to apply a first electrical potential to the at least one electrode relative to the substrate, thereby to cause a protrusion to be formed on the second surface of the polymer layer.

2. A device as claimed in claim **1** wherein the at least one electrode interacts with the second surface of the polymer layer by being in contact therewith.

3. (canceled)

4. A device as claimed in claim **1** wherein the at least one electrode interacts with the second surface of the polymer layer by being out of contact.

5. A device as claimed in claim **4** wherein the distance between the at least one electrode and the second surface of the polymer layer is at least 1 nm.

6. A device as claimed in claim **1** wherein the device is operable to apply a second electrical potential to the at least one electrode, which interacts with the second surface of the polymer layer in the region where the protrusion has been formed, the second electrical potential having an opposite polarity to the first electrical potential.

7. A device as claimed claim **1** wherein the device is operable to apply heat, irradiation or a combination thereof to the polymer layer.

8. A device as claimed in claim **7** wherein the polymer layer is heated to a temperature of between 100° C. to 200° C.

9. A device as claimed in claim **1** wherein the polymer layer comprises polystyrene-r-benzocyclobutene 30% random copolymer, PS-30%-BCB.

10. A device as claimed in claim **1** wherein the at least one electrode has a substantially extended configuration.

11. A device as claimed in claim **1** wherein the at least one electrode interacts with the second surface of the polymer layer via a surface having a patterned structure.

12. A method for forming topographic features on a surface of a polymer layer, a first surface of the polymer layer being provided on a substrate comprising a conductor, the method comprising the steps of:

interacting at least one electrode with a second surface of the polymer layer; and

applying a first electrical potential to the at least one electrode relative to the substrate, thereby to cause a protrusion to be formed on the second surface of the polymer layer.

13. A method as claimed in claim **12** wherein the at least one electrode interacts with the second surface of the polymer layer by being in contact therewith.

14. A method as claimed in claim **13** further comprising at least one of the step of scanning the at least one electrode relative to the second surface of the polymer layer and the step of applying a loading force to the at least one electrode once the at least one electrode is brought into contact with the second surface of the polymer layer.

15. A method as claimed in claim **12** wherein the at least one electrode interacts with the second surface of the polymer layer by being out of contact.

16. A method as claimed in claim **15** wherein the distance between the at least one electrode and the second surface of the polymer layer is at least 1 nm.

17. A method as claimed in claim **12** further comprising the step of applying a second electrical potential to the at least one electrode, which interacts with the second surface of the polymer layer in the region where the protrusion has been formed, the second electrical potential having an opposite polarity to the first electrical potential.

18. A method as claimed in claim **12** further comprising the step of applying heat, irradiation or a combination thereof to the polymer layer.

19. A method as claimed in claim **18** wherein method further comprises heating the polymer layer to a temperature of between 100° C. to 200° C.

20. (canceled)

21. A method as claimed in claim **12** wherein the at least one electrode has a substantially extended configuration.

22. A method as claimed in claim **12** wherein the at least one electrode interacts with the second surface of the polymer layer via a surface having a patterned structure.

23. (canceled)

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