

NANOIMPRINTING MOULD DEVICE

Technical Field

The present disclosure relates to nanoimprinting machines for use in, for example, roll-to-roll and roll-to-plate nanoimprinting among other nanoimprinting techniques. The present
5 disclosure more particularly relates to nanoimprinting moulds, mould devices, and rolls used in roll-to-roll and roll-to-plate nanoimprinting.

Background

Nanoimprinting, or nanoimprint lithography, is a method of fabricating nanometer to micrometer scaled patterns in a substrate.

10 In some nanoimprinting techniques, a mould is brought into contact with a substrate to form a pattern in the substrate by mechanical deformation. Alternatively, fluid material (e.g. resin) can flow into patterned features on the mould and is set in a form negative to that of the mould pattern. In some cases there are additional curing and/or etching steps performed to transfer the pattern from one, easily moulded layer of material (e.g. a top layer of the
15 substrate, or a patterned resin layer (freestanding or attached to a substrate) to an underlying substrate layer.

To mass-produce nanometre scale patterns, roll-to-roll and roll-to-plate nanoimprinting is commonly used. In these processes a mould is formed or positioned on a roll and the roll is rotated against a moving substrate to progressively form the pattern in the substrate.

20 The mould contains a negative pattern that is filled by material during nanoimprinting, to form the positive pattern in the substrate material. Developing moulds for roll-to-roll and roll-to-plate nanoimprinting is expensive due to the difficulty in forming negative patterns on a curved surface of the nanoimprinting roll. The technologies for doing so are not as advanced

as those available for flat sheet mould fabrication. Moreover, imprint drums, or nanoimprinting roll bodies, typically have a large radius to minimize pattern feature distortion. The roll bodies are therefore expensive, heavy and difficult to handle when interchanging or replacing moulds.

- 5 Removable nanoimprinting moulds have been proposed, whereby metal bars are riveted or screwed to the nanoimprinting mould, and the bars are detachably attached to the nanoimprinting roll. To avoid the metal bars imprinting on the substrate, they are attached to the roll body at positions recessed inwardly of the circumference of the roll body (e.g. insets or recesses). Also, to ensure the pattern is accurately imprinted, the moulds are tensioned to
10 pull flat against the circumference of a body of the nanoimprinting roll.

Methods employing removable nanoimprinting moulds create stress concentrations in the mould, at the locations of the rivets or screws, which damage or distort the moulds particularly during tensioning. Moreover, in order to pass inwardly from the circumference of the roll body, the mould must bend around a radius that is less than that of the circumference
15 of the roll body. As a result, moulds are often bent past their plastic radius – the radius above which the mould will return to a flat condition once removed from the roll body, and below which plastic deformation of the mould begins to occur.

Summary

According to a first aspect, the present disclosure provides a nanoimprinting mould device
20 comprising:

a nanoimprinting mould for forming a pattern in a substrate; and
a connector adhered to a surface of the nanoimprinting mould and comprising engagement means for engaging a nanoimprinting shell or roll thereby to secure the mould to the shell or

roll, the shell or roll being rotatable, in use, to bring the mould against the substrate to form the pattern in the substrate.

According to a second aspect, the present disclosure provides a nanoimprinting roll assembly comprising:

- 5 a nanoimprinting roll; and
- at least one nanoimprinting mould device of the first aspect, the at least one nanoimprinting mould being secured to the nanoimprinting roll.

According to a third aspect, the present disclosure provides a nanoimprinting roll assembly comprising:

- 10 a nanoimprinting shell fittable over a nanoimprinting roll and rotatable with rotation of the nanoimprinting roll; and
- at least one nanoimprinting mould device of the first aspect, the at least one nanoimprinting mould being secured to the nanoimprinting shell.

According to a fourth aspect, the present disclosure provides a nanoimprinting machine

- 15 comprising:
 - a nanoimprinting roll assembly according to the third; and
 - a motor for rotating the nanoimprinting roll assembly.

According to a fifth aspect, the present disclosure provides a method of forming a nanoimprinting device, the method comprising:

- 20 providing a nanoimprinting mould and a connector;
- applying adhesive to a surface of the mould and/or the connector; and
- bringing the mould and connector together so that the adhesive forms a bond between the mould and connector.

According to a sixth aspect, the present disclosure provides a jig for forming a nanoimprinting mould device, the jig comprising:

a support surface for supporting one of a nanoimprinting mould and a connector during formation of the nanoimprinting mould device;

5 alignment features to facilitate proper alignment of components such that the nanoimprinting mould device formed using the jig fits to a nanoimprinting roller drum;

one or more press members in use to apply a pressure to the nanoimprinting mould and connector during adhesion of the nanoimprinting mould to the connector; and

10 one or more pressure for adjusting the pressure applied by the one or more press members

The mould may be attached to the roll drum by fasteners. The fasteners may be screws or bolts the rotation of which selectively increase or decreases tension in the nanoimprinting mould.

As used herein, the terms “adhere”, “adhesion” and similar are intended to include within
15 their scope the connection of a nanoimprinting mould to a connector using means other than those requiring penetrations to be formed in the mould, for example, bolting or riveting the mould to the connector. Forms of connection within the scope of the term “adhere” include, but are not limited to, friction-fitting, adhesive connection, magnetic attraction and vacuum suction.

20 Similarly, the term “continuous” when used in the context of a surface refers to the body, which comprises the surface, having no full thickness penetrations.

As used herein, the terms “plastic bending radius” or “plastic radius” refer to the radius above which a mould will return to a flat condition once removed from the roll body, and below which plastic deformation of the mould begins to occur. In other words, if a bending force is

applied to a mould to bend it to a radius less than its plastic radius, when that force is removed the mould will have been plastically deformed, distorting the negative pattern on the mould. Conversely, if a bending force is applied to a mould to bend it to a radius greater than its plastic radius, when that force is removed the mould will return to its original shape.

- 5 As used herein and unless context dictates otherwise, the term “between” should be construed to be exclusive. For example, a mould positioned “between” curved sections of engagement members of a nanoimprinting roll body does not extend into or over those curved sections.

Brief Description of the Drawings

FIG. 1 is an image of a nanoimprinting, or nanoimprint lithography machine incorporating a
10 nanoimprinting roll in accordance with present teachings;

FIG. 2 shows an exploded, front perspective view of a nanoimprinting roll assembly including a nanoimprinting mould device in accordance with present teachings;

FIG. 3 shows an alternative, front perspective view of the roll depicted in FIG. 2;

FIG. 4 shows a nanoimprinting mould device in accordance with present teachings;

15 FIG. 5 shows a jig for forming the nanoimprinting mould device of FIG. 4; and

FIG. 6 shows an alternative embodiment of a mould and connector of a nanoimprinting device in accordance with present teachings.

Detailed Description

FIG. 1 shows a nanoimprinting machine 10. The nanoimprinting machine 10 is used to
20 control the application of a mould to a substrate to imprint a pattern in the substrate.

The nanoimprinting machine 10 includes a nanoimprinting roll 12 and a motor (not shown) for rotating the nanoimprinting roll 12. The roll 12 includes a nanoimprinting mould device (see FIG. 4) on which a negative pattern is formed. As the motor rotates the roll 12 the mould rolls over the substrate. In so doing, the negative pattern imprints a positive pattern (i.e. the opposite of the negative) onto the substrate or results in deposition of a patterned resin layer on the substrate.

The nanoimprinting machine 10 is therefore particularly suited for use in roll-to-roll and roll-to-plate nanoimprinting processes.

FIG. 2 shows an exploded view of a nanoimprinting roll assembly 20. The nanoimprinting roll assembly 20 includes a nanoimprinting skin, or shell 22, and a nanoimprinting mould device 24 secured to the shell 22. For the avoidance of doubt, the embodiments described herein, with reference to the figures, show a nanoimprinting mould device 24 attached to a nanoimprinting shell or skin 22 that is fittable to a nanoimprinting roll 12 the rotates in order to rotate the shell or skin 22 and thereby rotate the mould 24. From the present disclosure it will be understood that the teachings herein can be similarly applied to embodiments in which a nanoimprinting mould device 24 is attached directly to a nanoimprinting roll. In such cases, the roll would be understood to comprise the cooperating engagement means and other components otherwise provided on the shell or skin 22 of the illustrated embodiments.

When in use, the nanoimprinting roll assembly 20 is installed on a nanoimprinting machine (see FIG. 1) and is rotatable by a motor in that machine. During rotation, a substrate (not shown) is brought into contact with a nanoimprinting mould device 24 and the mould device 24 imprints a pattern in the substrate.

With reference to FIG. 4, the mould device 24 includes a nanoimprinting mould 26, presently embodied by a sheet 26, and a connector, presently in the form of a pair of extensions 28. The connector reversibly attaches the mould device 24 to the shell 22.

The sheet 26 is used for forming the pattern in the substrate. The sheet 26 includes a
5 patterned surface 30, and an opposing rear surface 32. The patterned surface 30 includes the negative of the pattern desired to be imprinted onto the substrate. As the patterned surface 30 is pressed against the substrate, the substrate fills the recesses and voids in the patterned surface 30, thereby creating the desired pattern (i.e. the positive pattern) in the substrate.

The sheet 26 is substantially planar and rectangular. It is formed from Nickel (Ni) although
10 other metals, polymers and other materials may be used. In the present illustrative embodiment, Nickel is used due to its ability to receive and maintain nanometre scale patterns. The sheet 26 is less than 200 microns thick, and will usually be around 150 microns thick, although other thicknesses may be used as needed, depending on the stiffness of the material. The sheet 26 is sufficiently flexible to elastically bend around the radius of the shell
15 22 to bring the connector into contact with engagement means 62 on the shell 22. The sheet 26 of the present embodiment has a length, between ends 42, of 270 mm and a width of 200 mm although other lengths (e.g. 280mm or less) and widths may be used as desired.

The connector comprises extensions 28 and engagement means, presently embodied by engagement members 34, 36, for engaging the shell 22 to secure the sheet 26 to the shell 22.

20 Once the sheet 26 is located on the shell 22, the connector can also be used to apply tension to the sheet 26 so that it conforms very closely to the circumferential surface 44 of the shell 22 (see FIG. 2). In the illustrated embodiment, the sheet 26 comes into conformal contact with the circumferential surface 44, but does not contact the corresponding engagements

means 62 of the shell 22. In other words, the sheet 26 is positioned between the corresponding engagement means 62.

The extensions 28 are adhered to a surface, namely rear surface 32, of the sheet 26. In particular, the extensions 28 are adhered to a strip 38 of surface 32. The strip 38 is defined by
5 the region between broken line 40 and the respective end 42 of the sheet 26.

Adhesion may be achieved using any appropriate method, such as cold welding or using liquid or solid (e.g. pressure or temperature sensitive) adhesives. In the embodiment shown in FIG. 4, adhesion is achieved by depositing an adhesive along one or both of the strip 38 and region of the respective extension 28 that comes into contact with the strip 38. The adhesive
10 is deposited so that it forms a substantially uniform film over the strip 38 or corresponding region of the extension 28 (i.e. the region that will be in contact with the strip 38 when formed into a mould device 24). It will be appreciated that the adhesive may alternatively be deposited at irregular intervals or using any suitable deposition method.

The region of the surface 32, namely strip 38, over which the extensions 28 adhere to the
15 surface 32 is continuous. In other words, there are no penetrations through the sheet 26. The adhesion therefore forms a connection between the connector and mould, or sheet 26, on only one side of the mould, or sheet 26. In use, there is no part of the connector that projects outwardly of the sheet 26, away from the circumferential surface 42 of the shell 22 (see FIG. 2).

20 The connector must be sufficiently thin that it can fit between the sheet 26 and circumferential surface 44 of the shell 22 without deforming or bending the sheet 26 when the sheet 26 is tensioned onto the circumferential surface 44. To achieve this, while maintaining low or no ductility so as not to inhibit tensioning of the mould device 24, the extensions 28 may be thin and flexible stainless steel spring forms. Alternatively, the shell 22

may include a recess (not shown) with same or similar depth as the thickness of the extensions 28 and in which the extensions 28 will be received when the mould device 24 is in position on the shell 22. These measures ensure the pattern, when imprinted on the substrate, is not distorted.

- 5 As discussed below, it is desirable that the connector is thin so that it can be readily bent.

In addition, the connector may comprise a unitary, integrally formed or non-integrally formed, body extending the full length of the mould 26. Similarly, the connector may form more than two bodies, if needed, to properly secure the mould 26 to the shell 22.

- The two extensions 28 extend from respectively opposite ends 42 of the mould 26. The
- 10 engagement means comprises engagement members 34, 36 formed on respective extensions 28 so that, in use, the mould device 24 can engage the shell 22. The extensions 28 enable a variety of sheet sizes to be used with a single size of shell 22. While maintaining the same length L between opposite ends of opposite extensions 28, different sized sheets 26 may be used. For larger sheets 26 the strip 38 will be broader, and for smaller sheets the strip 38 will
- 15 be narrower. Alternatively, the length of the extensions 28 may be adjusted to maintain the same strip width 38 and the same distance L for various sizes of sheet 26. The extensions 28 may also include indicia to ensure the sheet 26 is positioned on the extensions 28 at a consistent distance from both reinforcement bars 50, 52. The extensions 28 may also include
- 20 jig holes 60 that align with holes in a jig (see FIG. 5) to enable the extensions 28 to be fastened to the jig during formation of the mould device 24.

The extensions 28 and/or the engagement members 34, 36 may similarly extend across the full depth D (see FIG. 2) of the shell 22. However, results will generally be similar provided the extensions 28 extend at least the full width of the mould 26. If the extensions 28 do not extend the full width of the mould 26 then, as tension is applied between the engagement

members 34, 36, the tension in the sheet 26 will be non-uniform. This can result in stress concentrations developing in the sheet 26 and, consequently, distortion of the pattern imprinted onto the substrate. Thus, the present mould device 24 can accommodate any size of sheet 26 up to a maximum length L (which corresponds to the length between recesses 62 around the circumference of the shell 22) and maximum width equal to the depth D of the shell 22.

The extensions 28 include a number of apertures 46 received, in use, hooked around a like number of lugs 48 of the shell 22. These apertures 46 ensure the mould device 24 is properly aligned with the shell 22 when in position. The apertures 46 have the same length as the lugs 48, with respect to the depth D of the shell 22. However, the apertures 46 are slightly longer than the lugs 48 so that they can accommodate some movement about the lugs 48 during tensioning of the sheet 26. One of more of the lugs 48 may include a groove into which an edge of the respective aperture 46 is received to more securely hold the edge of the aperture 46, and thereby hold the sheet 26, in position on the lug 48.

Formed on the outermost end of each extension 28 is an engagement member 34, 36. The engagement members 34, 36 affix the mould device 24 on the shell 22. The engagement members 34, 36 each comprise a reinforcement bar. One engagement member 36 is in the form of a first reinforcement bar 50 (the first reinforcement bar has a rectangular cross-section) and the other engagement member 34 is in the form of a second reinforcement bar 52 (the second reinforcement bar has a triangular cross-section). The reinforcement bars 50, 52 are anchored to the shell 22, in use, to mechanically connect the mould device 24 to the shell 22.

The reinforcement bars 50, 52 are made from stainless steel welded to respective stainless extensions 28. To make welding easy, the extensions 28 may similarly be fabricated from

stainless steel. Other attachment methods may be used and, similarly, materials other than stainless steel may be used. Also, other shapes of the reinforcement bars may be used, as appropriate, to cooperate with different configurations of the shell 22.

5 The reinforcement bars 50, 52 are secured to the shell 22 using bolts or screws that may, in use, form part of the engagement means of the mould device 24. To accommodate the bolts or screws, the reinforcement bars 50, 52 both include a series of fastener holes 54, 56, 58.

The holes 54, 56, 58 may be regularly spaced. The holes 54, 56, 58 may alternatively be spaced at irregular intervals.

10 With further reference to FIGs. 2 and 3, nanoimprinting shell 22 supports the nanoimprinting mould device 24 during use. The shell 22 is substantially cylindrical. When the nanoimprinting mould device 24 is in position on the shell 22, the sheet 26 lies against the circumferential surface 44 of the shell 22.

The patterned surface 30 of the sheet 26 faces outwardly of the shell 22 and is brought into contact with the substrate with rotation of the shell 22.

15 The shell 22 includes a number of cooperating engagement means, presently embodied by pairs of opposing triangular recesses 62. The reinforcement bars 50, 52 are received in recesses 62 of the shell 22 and are secured to the shell 22.

Each recess 62 includes a series of holes 64, 66 that align with holes 54, 56, 58 so that fasteners can be inserted through the reinforcement bars 50, 52 and into the holes 64, 66 to
20 secure the reinforcement bars 50, 52, and thereby the mould device 24, to the shell 22. Each triangular recess 62 has two opposing sidewalls, with holes 64 being formed in one sidewall and holes 66 being formed in the other, opposing, sidewall.

With reference to FIG. 4, the fastener holes 54, 58 penetrate through the rectangular and triangular reinforcement bars 50, 52 respectively, substantially perpendicularly to the plane of the sheet 26. In contrast, fastener holes 56 penetrate through the triangular reinforcement bar 52 parallel to the plane of the sheet 26. Moreover, the fastener holes 56 extend away from the ends 42 of the sheet.

When installing the mould device 24 onto the shell 22, the rectangular reinforcement bar 50 is first attached to the shell 22. To do so, the rectangular reinforcement bar 50 is inserted into a recess 62. Fasteners are then inserted through holes 54 and into holes 64. The fasteners are then tightened to secure the rectangular reinforcement bar on the shell 22.

The triangular reinforcement bar 52 is then attached to the shell 22. To do so, the triangular reinforcement bar 52 is inserted into a recess 62. Fasteners are then inserted through holes 58 and into holes 68. Following this, before fully tightening the screws in 58, fasteners are inserted through holes 56 and into holes 66 that extend away from the end 42 of the sheet 26. As the fasteners in holes 56 are tightened, they pull the reinforcement bar 52 in a direction away from the end 42 of the sheet 26, thereby applying tension to the sheet 26. This tension brings the sheet 26 against, and into close fitting conformity with, the circumferential surface 44 of the shell 22. This ensures that no, or little, distortion of the imprinted pattern occurs due to the sheet 26 buckling or bowing outwardly of the shell 22.

Once the triangular reinforcement bar 52 is tightened onto the shell 22, screws in holes 58 are tightened to hold the mould firmly in place. Thus at least one of the engagement members 34, 36 of the connector, and presently engagement member 34 which incorporates triangular reinforcement bar 52, is adjustable to apply tension to the mould 26 when in engagement with the shell 22. However, it may be desirable in some instance that both engagement members 34, 36 are capable of adjustment to apply tension to the sheet 26.

Once the mould device 24 is secured to the roll drum, the reinforcement bars 50, 52 are covered by covers, such as curvature restoration cover 67 (see FIG. 2), to restore the smooth, round external surface of the shell 22.

To remove the mould device 24 from the shell 22, the reverse process is applied. Since the sheet 26 does not bend into the inset regions, or recesses 62, during attachment to the shell 22 there is no permanent deformation of the sheet 26 once removed from the shell 22. Similarly, since the extensions 28 are highly flexible, they do not experience permanent deformation after being removed from the inset regions, or recesses 62. The mould device 24 therefore returns to a flat condition after removal from the shell 22, and can easily be stored. This allows flat plate nanoimprint pattern formation methods to be used in the fabrication of sheets 26 for the mould device 24. In addition, since an operator need only lift a mould device 24 comprising a sheet 26 and potentially very light connector (e.g. extensions 28 and engagement means 34, 36) it is easy to attach and remove mould devices 24 from shells 22. Moreover, since the present connector attaches to the sheet 26 without penetrations, the sheet 26 is not damaged by formation of those penetrations nor by stress concentrations created during tensioning about (i.e. against or in the vicinity of) fasteners received through the penetrations.

While the above steps are applicable to fitting nanoimprinting mould device 24 to shell 22, the method as applied to nanoimprinting devices of the present teachings more generally, will involve engaging one of the engagement members of the connector with the shell. The nanoimprinting mould is brought into contact with the circumferential surface of the shell along the entire length of the nanoimprinting mould. The other engagement member of the connector can then be engaged with the shell, and whichever (or both) of the engagement members enables tension to be applied to the mould is then adjusted (e.g. by screw

tightening) to apply that tension. Nanoimprinting mould devices in accordance with present teachings are therefore easy to mount, remove and replace on nanoimprinting shells.

To accommodate different sizes of sheet 26, the connector projects from the ends 42 of the sheet 26. With reference to FIG. 4, the connector, or rather the extensions 28, project from the ends 42 of the mould or sheet 26 so as to extend at least part way around the circumference of the shell 22. In other words, by extending from the ends 42 of the sheet 26, the engagement members 34, 36 can engage the shell 22 at positions of the shell, presently the triangular recesses 62 that are spaced from the respectively opposite ends 42 of the sheet 26. The sheet 26 is therefore distanced from the positions at which the mould device 24 is secured to the shell 22.

So that the reinforcement bars 50, 52 do not project outwardly from the circumference of the shell 22 further than the sheet 26, the reinforcement bars pass around curved sections 68 of the cooperating engagement members, or recesses 62 (see FIG. 3). The curved sections 68 pass from being substantially coplanar with the circumference of the shell 22 to being substantially coplanar with a sidewall of the recess 62. The radius of curvature of the curved sections 68 will often be smaller than the plastic radius of the mould or sheet 26.

In addition to enabling a variety of sheet sizes to be accommodated on a single shell 22, the extensions 28 also avoid damage to expensive moulds or sheets 26 as a result of those moulds or sheets 26 being bent around a radius less than their plastic radius. In use, the extensions 28 extend from the mould or sheet 26 around the respective curved sections 68 – in other words, the sheet 26 does not bend around the curved sections 68 and is instead positioned exclusively between the curved sections 68.

To facilitate bending, the extensions 28 are formed from a flexible material, or are formed from a sufficiently thin sheet of material (e.g. stainless steel) that it readily bends. Though

they desirably bend, the extensions 28 should in most cases have little or no ductility. This ensures adequate tension can be applied to the sheet 26. Using highly flexible extensions 28 enables a small radius of curvature to be used for curved sections 68. This provides for a reduction in the area taken up by cooperating engagement means (i.e. recesses 62), a
5 corresponding increase in the distance between cooperating engagement means around the circumference of the shell 22 of a particular diameter and thus an increase in the maximum length of sheet 26 that can be used with that shell 22.

While sections 68 are curved, they may alternatively have a bevelled or tapered edge, or any other appropriate shape to facilitate attachment of the reinforcement bars 50, 52 to the shell
10 22.

In the present embodiment, the nanoimprinting shell 22 includes three cooperating engagement members, presently embodied by pairs of oppositely facing substantially triangular recesses 62 as mentioned above, and is therefore capable of supporting more than one (presently three) nanoimprinting mould devices 24 at any one time.

15 Where the nanoimprinting shell 22 supports two or more nanoimprinting mould devices 24, each mould device 24 may provide the same negative pattern for imprinting onto a substrate. Alternatively, each mould device 24 may provide a different negative pattern for imprinting onto a substrate. Moreover, particularly for very complex patterns, each nanoimprinting mould device 24 may provide a negative of only part of the pattern, with the other
20 nanoimprinting mould device(s) providing the negative of the remainder of the pattern. In this case, all nanoimprinting mould devices 24 may sequentially imprint onto the same substrate.

To form the nanoimprinting mould device 24 a jig may be used, such as jig 70 as shown in FIG. 5. Some of the features described with reference to FIG. 5 have names similar to those described above and it will be understood that the description provided above in relation to

the similarly named features will also be applicable to the features described below. The jig 70 facilitates alignment of the mould with the connector and can enable pressure application to ensure sufficient bond strength during adhesion of the mould to the connector. The pressure application also ensures the adhesive layer is thin, uniform across the region of

5 adhesion between the mould and connector, and flat. The jig 70 includes a support surface 72, a pair of press members 74 and pressure adjustment members (refer to numerals 76 and 77).

Support surfaces will support one of a nanoimprinting mould and a connector during formation of the nanoimprinting mould device. The present support surface 72 is configured to support the connector, or rather extensions 73. The jig 70 also includes alignment features

10 (e.g. side guides 78 and locating pins 80 located on the support surface 72 that fit through holes 86 and 84 located on extensions 73 and the epoxy application stencil 82 respectively) to facilitate proper alignment of components and epoxy application such that the nanoimprinting mould device formed using the jig fits precisely to a nanoimprinting roller drum. The side guides 78 ensure that sides of a mould are properly aligned with the extensions 73 when the
15 mould is positioned in the jig 70.

When attaching the extensions 73 to the supporting surface 72 preformed holes 86 in the extensions 73 are aligned with locating pins 80 on the support surface 72.

A stencil 82 is brought down over each extension 73, the stencil 82 exposing only the region of the extension 73 upon which glue (e.g. epoxy resin) is to be deposited. The stencil 82
20 includes holes 84 that align with holes 86 to ensure proper and consistent positioning of the stencil. Once the glue is applied to the extensions 73, the stencil 82 is removed. The stencil 82 may be selected to correspond with the width of the sheet 26 to be affixed to the extensions 73 and is used to ensure glue application of consistent uniform thickness and

amount in the correct location. Uniform glue thickness reduces the likelihood of distortion of the mould and ensures that it lies flat against the roller drum upon attachment thereto.

The mould 88 is brought down onto the extensions 73 to cover the regions on which glue has been deposited. The position of the mould 88 is guided by alignment pins (not shown) on the jig 70. When the mould 88 is in position, press members 74 are brought down over pins 77 of the pressure adjustment members. Knobs 76 are subsequently screwed onto the tops of pins 77 and are tightened to force the press members 74 against the mould 88. The press members 74 thereby apply a uniform pressure to the nanoimprinting mould 88 and connector, or extensions 73, during adhesion of the former to the latter.

- 10 The amount of pressure applied by the press members 74 is adjusted by the pressure adjustment members (refer to numerals 76, 77) in a known manner.

In a most basic method, nanoimprinting mould devices can be formed (e.g. using the jig 70) by:

- providing a nanoimprinting mould and a connector. The mould will often be a sheet material, but may have another form suitable for a particular application. The connector may comprise a pair of extensions. The connector may alternatively have some other form.
- applying adhesive to a surface of the mould and/or the connector. In most cases, it is envisaged that adhesive will be applied to only one of the mould and connector.
- 20 - bringing the mould and connector together so that the adhesive forms a bond between the mould and connector.

In some cases a better adhesive bond will be formed by applying pressure to the mould and connector during curing (i.e. during formation of the bond).

In a further embodiment, the nanoimprinting mould device may not employ an adhesive, but may instead create adhesion between the mould and connector by friction-fit. Also, the friction-fit may be used in addition to an adhesive. A connection between a mould 90 and connector 92 that can provide a friction-fit is shown in FIG. 6. The connector 92 comprises a slot 94 for receiving the mould 90. The slot 94 is narrower than a thickness of the mould 90 so that the connector 92 is adhered to the mould 90 at least partially by friction between the slot 94 and mould 90. Alternatively, or in addition to creating friction, opposed sides 96, 98 of the slot 94 may be adhered to respectively opposite ones of the patterned surface 100 and opposing rear surface 102 of the mould 90 using an adhesive. The adhesive may be deposited on the connector 92 or mould 90 as desired.

For illustrative purposes, an extension 104 and triangular reinforcement bar 106 have also been shown.

In yet a further embodiment, the connector may be adhered to the mould by magnetic attraction. The connector and mould may each comprise a magnetic material at least in the vicinity of the region of adhesion (e.g. strip 38 of FIG. 4), such that the connector magnetically adheres to the mould. Alternatively, the connector may comprise a magnetic element (e.g. one or more strips on each extension) for adhering to a mould comprising a magnetic material at least in the vicinity of the region of adhesion. Conversely, the mould may comprise a magnetic element (e.g. one or more strips towards each end 42) for adhering to a connector comprising a magnetic material at least in the vicinity of the region of adhesion. As a further alternative, both the mould and connector may each comprise a magnetic element, the magnetic elements attracting each other to adhere the connector to the mould.

As will now be appreciated, there are many variations for attaching the mould and connector using adhesion methods – in other words, methods that do not result in the need for penetrations to be formed in the mould that would otherwise enable the mould to be secured to connectors using fasteners. Such penetrations can damage the negative pattern formed on the mould and can result in stress concentrations around the fasteners.

Claims

1. A nanoimprinting mould device comprising:

a nanoimprinting mould for forming a pattern in a substrate; and

a connector adhered to a surface of the nanoimprinting mould and comprising

5 engagement means for engaging a nanoimprinting shell or roll thereby to secure the mould to the shell or roll, the shell or roll being rotatable, in use, to bring the mould against the substrate to form the pattern in the substrate.

2. The nanoimprinting mould device of claim 1, wherein the connector is adhered to the

10 mould by an adhesive.

3. The nanoimprinting mould device of claim 1, wherein the connector is adhered to the

mould by welding.

15 4. The nanoimprinting mould device of any preceding claim, wherein a region of the

surface over which the connector adheres to the surface is continuous.

5. The nanoimprinting mould device of any preceding claim, wherein the mould

comprises a patterned surface facing, in use, outwardly of the shell or roll and an opposing

20 rear surface facing, in use, towards the shell or roll, the connector being adhered to the opposing rear surface.

6. The nanoimprinting mould device of claim 5, wherein the connector adheres to the

nanoimprinting mould by magnetic attraction.

25 7. The nanoimprinting mould device of claim 5, wherein the connector comprises a slot

for receiving the mould and:

opposed sides of the slot are adhered to respectively opposite ones of the patterned surface and opposing rear surface; and/or

the slot is narrower than a thickness of the mould so that the connector is adhered to the mould at least partially by friction between the slot and mould.

5 8. The nanoimprinting mould device of any preceding claim, wherein the connector projects from an end of the mould so as to extend, in use, at least part way around a circumference of the shell or roll.

10 9. The nanoimprinting mould device of claim 8, wherein the connector comprises two extensions extending from respectively opposite ends of the mould.

10. The nanoimprinting mould device of claim 9, wherein the engagement means comprises an engagement member formed on each extension.

15 11. The nanoimprinting mould device of claim 9, wherein the engagement members engage the shell or roll at positions of the shell or roll that are spaced from the respectively opposite ends of the mould.

20 12. The nanoimprinting mould device of claim 11, wherein engagement members engage corresponding engagement members of the shell or roll, each corresponding engagement member comprising a curved section, and wherein the extensions extend from the mould around the respective curved sections.

25 13. The nanoimprinting mould device of claim 12, wherein the curved sections have a radius that is less than the plastic radius of the mould, and the mould is positioned between the curved sections.

14. The nanoimprinting mould device of any one of claims 9 to 13, wherein at least one of the engagement members of the connector, when in engagement with the shell or roll, is adjustable to apply a selected amount of tension to the mould.

5 15. The nanoimprinting mould device of claim 14, where one engagement member of the connector comprises a first reinforcement bar and the other engagement member of the connector comprises a second reinforcement bar, one or more fastener holes and, in use, one or more fasteners project through the fastener holes to secure the mould to the shell or roll.

10 16. The nanoimprinting mould device of claim 15, wherein the second reinforcement bar comprises two sets of fastener holes, the holes in one set extending in a substantially perpendicular direction to the holes in the other set.

15 17. The nanoimprinting mould device of claim 16, wherein fasteners extending through the holes in one of the sets of holes are used to apply tension to the mould, in use, and fasteners extending through the other set of holes are used to anchor the triangular reinforcement bar in position after tension has been applied.

20 18. The nanoimprinting mould device of any one of claims 15 to 17, wherein the first reinforcement bar is rectangular.

19. The nanoimprinting mould device of any one of claims 15 to 18, wherein the second reinforcement bar is triangular.

25 20. The nanoimprinting mould device of any preceding claim, wherein the engagement means reversibly secure the mould to the shell or roll.

21. A nanoimprinting roll assembly comprising:

a nanoimprinting roll; and

at least one nanoimprinting mould device of any one of claims 1 to 20, the at least one
5 nanoimprinting mould being secured to the nanoimprinting roll.

22. A nanoimprinting roll assembly comprising:

a nanoimprinting shell fittable over a nanoimprinting roll and rotatable with rotation
of the nanoimprinting roll; and

10 at least one nanoimprinting mould device of any one of claims 1 to 20, the at least one
nanoimprinting mould being secured to the nanoimprinting shell.

23. A nanoimprinting machine comprising:

a nanoimprinting roll assembly according to claim 21 or 22; and

15 a motor for rotating the nanoimprinting roll assembly.

24. A method of forming a nanoimprinting device, the method comprising:

providing a nanoimprinting mould and a connector;

applying adhesive to a surface of the mould and/or the connector; and

20 bringing the mould and connector together so that the adhesive forms a bond between
the mould and connector.

25. A method according to claim 24, wherein the step of bringing the mould and

connector together comprises applying pressure to the mould and connector, at or near the

25 adhesive, so as to strengthen the bond as it is formed.

26. A method of fitting a nanoimprinting mould device according to any one of claims 14 to 20, to a nanoimprinting shell or roll, the method comprising:

engaging one of the engagement members of the connector with the shell or roll;

bringing the nanoimprinting mould into contact with a circumferential surface of the

5 shell or roll along the entire length of the nanoimprinting mould;

engaging the other engagement member of the connector with the shell or roll; and

adjusting the one of the engagement members to apply tension to the nanoimprinting mould.

10 27. A jig for forming a nanoimprinting mould device, the jig comprising:

a support surface for supporting one of a nanoimprinting mould and a connector during formation of the nanoimprinting mould device;

alignment features to facilitate proper alignment of components such that the nanoimprinting mould device formed using the jig fits to a nanoimprinting roller drum;

15 one or more press members in use to apply a pressure to the nanoimprinting mould and connector during adhesion of the nanoimprinting mould to the connector; and

one or more pressure for adjusting the pressure applied by the one or more press members.

20 28. The jig of claim 27, wherein the support surface is configured to support a connector, during formation of the nanoimprinting mould device, comprising two extensions in positions to extend from ends of the mould during formation of the mould device.