PATTERN FORMING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2015-179289; filed on September 11, 2015; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a pattern forming method.

BACKGROUND

Recently, a lithography technology which uses a self-organizing (hereinafter, also referred to as directed self-assembly (DSA)) material is developed. The DSA material can be used for forming dot patterns, hole patterns, pillar patterns, line patterns, or the like which have various sizes, by adjusting the amount of molecules. In order to form the patterns, a guide for controlling a position at which a polymer phase formed by DSA is generated is required. The guide includes a physical guide (grapho-epitaxy) which can form a microphase separation pattern in a concave portion of a roughness structure, and a chemical guide (chemical-epitaxy) which controls a position at which a microphase separation pattern is formed, based on a difference between the surface energy of a base material.

For example, a resist film is formed on a workpiece film by using optical lithography, and a hole pattern which is a physical guide is formed in the resist film. Then, a block copolymer is applied and heated so as to be buried in the hole pattern. By doing so, the block copolymer is phase-separated. A hole pattern which is obtained by shrinking the hole pattern formed by the optical lithography is obtained by selectively removing a part of the phase-separated polymer.

In the hole shrinking process, a hole diameter is determined by the amount of molecules of a block copolymer. Hence, in order to form multiple patterns in which hole diameters are different from each other, different materials of the block copolymer are required for each pattern. In this case, a lithography process is required for each material of block copolymer, and thus, the number of processes and costs increase.

An example of related art includes JP-A-2014-22550.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view illustrating a pattern forming method according to a first embodiment.

FIGS. 2A and 2B are sectional views illustrating the pattern forming method in addition to FIG. 1.

FIGS. 3A and 3B are planar views illustrating the pattern forming method in addition to FIG. 1.

FIGS. 4A and 4B are sectional views illustrating the pattern forming method in addition to FIGS. 2A to 3B.

FIGS. 5A and 5B are sectional views illustrating the pattern forming method in addition to FIGS. 4A and 4B.

FIGS. 6A and 6B are planar views illustrating the pattern forming method in addition to FIGS. 4A and 4B.

FIGS. 7A and 7B are sectional views illustrating the pattern forming method in addition to FIGS. 5A to 6B.

FIGS. 8A and 8B are sectional views illustrating the pattern forming method in addition to FIGS. 7A and 7B.

FIGS. 9A and 9B are planar views illustrating modification examples of a third hole pattern in a second region.

FIG. 10 is a sectional view illustrating a pattern forming method according to a second embodiment.

FIG. 11 is a planar view illustrating the pattern forming method according to the second embodiment.

FIG. 12 is a sectional view illustrating the pattern forming method in addition to FIGS. 10 and 11.

FIG. 13 is a sectional view illustrating the pattern forming method in addition to FIG. 12.

FIG. 14 is a planar view illustrating the pattern forming method in addition to FIG. 12.

FIG. 15 is a sectional view illustrating the pattern forming method in addition to FIGS. 13 and 14.

FIGS. 16A and 16B are planar views illustrating modification examples of a first space pattern.

FIGS. 17A and 17B are planar views illustrating other modification examples of the first space pattern.

DETAILED DESCRIPTION

[0006]Embodiments are to provide a pattern forming method which can easily form multiple patterns having hole diameters different from each other.

[0007] According to one embodiment, a pattern forming method includes forming a mask member that includes a first pattern with a first opening width in which a self-organizing material is phase-separated in a first region on a workpiece film, a second pattern with a second opening width greater than the first opening width, and a third pattern with a width smaller than the first opening width in a second region on the workpiece film. Subsequently, the self-organizing material is supplied onto the mask member. Subsequently, the self-organizing material in the first and second patterns is phase-separated into a first polymer portion and a second polymer portion, without phase-separation of the self-organizing material in the third pattern. A hole pattern is formed by removing the second polymer portion while leaving the first polymer portion. The workpiece film is processed by using the mask member and the first polymer portion as a mask.

[0009]Hereinafter, embodiments will be described with reference to the drawings. The invention is not limited to the embodiments.

First Embodiment

[0010]FIG. 1 to FIG. 8B are sectional views or planar views illustrating a pattern forming method according to a first embodiment. FIG. 1, FIG. 2A, FIG. 2B, FIG. 4A to FIG. 5B, and FIG. 7A to FIG. 8B are sectional views. FIG. 3A, FIG. 3B, FIG. 6A, and FIG. 6B are planar views. Meanwhile, FIG. 2A is a sectional view taken along line IIA-IIA of FIG. 3A, and FIG. 2B is a sectional view taken along line IIB-IIB of FIG. 3B. FIG. 5A is a sectional view taken along line VA-VA of FIG. 6A, and FIG. 5B is a sectional view taken along line VB-VB of FIG. 6B.

[0011]Firstly, as illustrated in FIG. 1, a hard mask 102 is formed on a material film 101, and an anti-reflective film 103 is formed on the hard mask 102. The material film 101 is, for example, an oxide film with a thickness of 300 nm which is provided over a semiconductor substrate. The hard mask 102 is, for example, a carbon film with a thickness of 100 nm which is formed by using a chemical vapor deposition (CVD) method or coating. In addition, the anti-reflective film 103 is, for example, an oxide film with a thickness of 15 nm which is formed by using the CVD method or coating.

[0012]Secondly, as illustrated in FIGS. 2A and 2B, and FIGS. 3A and 3B, the anti-reflective film 103 is spin-coated with a resist film 104 with a thickness of 120 nm, and is exposed and developed by an ArF immersion excimer laser with the amount of exposure of 20 mJ/cm2, and thereby hole patterns 105a, 105b, and 105c are formed in a resist film 104 as a mask member. The first hole pattern (first pattern) 105a is formed in a first region R1 on an upper surface of the anti-reflective film 103 as a workpiece film. The second hole pattern (second pattern) 105b and the third hole pattern (third pattern) 105c are formed in a second region R2 on an upper surface of the anti-reflective film 103. The first region R1 and the second region R2 are located at the upper surface of the anti-reflective film 103 as a workpiece film and are different from each other. The first region R1 and the second region R2 may be adjacent to each other or may be separated from each other. In addition, the first region R1 and the second region R2 may have the same area or may have different areas from each other.

[0013]Meanwhile, the hard mask 102 and the anti-reflective film 103 are formed by using the resist film 104 and polymer layers (107a and 107b of FIGS. 7A and 7B) which are formed on the anti-reflective film 103, as masks, in post processes. Hence, here, the resist film 104 and the polymer layers will be referred to as mask members, and the hard mask 102 and the anti-reflective film 103 will be referred to as films to be processed.

[0014]A layout shape (planar shape) of the hole patterns 105a to 105c may be any one of an approximately circular shape, an approximately oval shape, an approximately rectangular shape, and a groove. However, as illustrated in FIG. 3A and 3B, a diameter (first opening width) F1 of the first hole pattern 105a is smaller than a diameter (second opening width) F2 of the second hole pattern 105b, and is greater than a diameter (third opening width) F3 of the third hole pattern 105c. The diameter (first opening width) F1 of the first hole pattern 105a is, for example, approximately 70 nm. The diameter (second opening width) F2 of the second hole pattern 105b is greater than the first opening width F1 and the third opening width F3 and is, for example, approximately 100 nm. The diameter (third opening width) F3 of the third hole pattern 105c is smaller than the first opening width F1 and the second opening width F2 and is, for example, approximately 45 nm. The diameters of the hole patterns 105a to 105c will be described below in detail.

[0015]The resist film 104 having the hole patterns 105a to 105c functions as a physical guide layer when microphase separation of a block copolymer which is formed in a post process occurs. Microphase separation patterns which are formed in the hole patterns 105a and 105b become a source of a pattern which is transferred to the material film 101. Meanwhile, the third hole pattern 105c is a dummy pattern which is formed for adjusting a coverage ratio (or opening ratio) of the resist film 104. A ratio (Sb/Sa) of an area (disposition area) Sb which is covered with the resist film 104 in the region to an area Sa of a certain region on an upper surface of the anti-reflective film 103is referred to as the coverage ratio. Meanwhile, a ratio (Sc/Sa) of an area Sc of the hole patterns 105a to 105c which are formed in the region to the area Sa of a certain region on the upper surface of the anti-reflective film 103 is referred to as the opening ratio. Meanwhile, Sb is an area which is covered with the resist film 104 in the upper surface of the anti-reflective film 103, and Sc is an area portion in which the resist film 104 is removed in the upper surface of the anti-reflective film 103. Hence, the sum of Sb/Sa and Sc/Sa becomes approximately 1.

[0016]For example, as illustrated in FIG. 3A, the first hole pattern 105a is formed in the first region R1. The third hole pattern 105c which is as a dummy pattern is not formed in the first region R1. Meanwhile, as illustrated in FIG. 3B, the third hole pattern 105c is formed together with the second hole pattern 105b in the second region R2. By forming the third hole pattern 105c which is a dummy pattern in the second region R2, the coverage ratio of the resist film 104 in the second region R2 is reliably less than the coverage ratio of the resist film 104 in the first region R1. In contrast to this, the opening ratios of the hole patterns 105b and 105c in the second region R2 are greater than the opening ratio of the first hole pattern 105a in the first region R1. As a result, as will be described below, a thickness of a block copolymer 106 in the second region R2 may be smaller than that of the first region R1. The first region R1 is not particularly limited, but, for example, is a memory cell region which needs to be processed in a fine hole pattern. The second region R2 is not particularly limited, but, for example, is a peripheral circuit region which can be processed in a relatively large hole pattern.

[0017]Subsequently, as illustrated in FIGS. 4A and 4B, the resist film 104 is coated with the block copolymer 106. The block copolymer 106 which is a self-organizing material includes a block copolymer (PS-b-PMMA) of polystyrene (PS) and polymethyl methacrylate (PMMA). For example, a ratio of a number average molecular amount (Mn) between a PS block and a PMMA block of PS-b-PMMA is approximately 24000 to approximately 4700. The resist film 104 is spin-coated by the number of rotation of 2000 rpm with a propylene glycol monomethyl ether acetate (PGMEA) solution which contains PS-b-PMMA at a concentration of approximately 1.0 wt%. As a result, the block copolymer 106 is supplied to the inside of the hole patterns 105a to 105c.

[0018]As described above, a coverage ratio of the resist film 104 in the second region R2 is less than the coverage ratio of the resist film 104 in the first region R1. For this reason, when the resist film 104 is spin-coated with the PS-b-PMMA solution, a thickness T2 of the block copolymer 106 staying in the second hole pattern 105b is smaller than a thickness T1 of the block copolymer 106 staying in the first hole pattern 105a, as illustrated in FIGS. 4A and 4B. This is because the diameter F2 of the second hole pattern 105b is greater than diameter F1 of the first hole pattern 105a, and the opening ratio of the hole patterns 105b and 105c in the second region R2 are greater than the opening ratio of the hole pattern 105a in the first region R1. That is, when the resist film 104 is spin-coated with the block copolymer 106, the block copolymer 106 easily flows out from the second hole pattern 105b with a relatively large opening width, but hardly flow out from the first hole pattern 105a with a relatively small opening width, thereby easily saying. In addition, the block copolymer 106 hardly flows out from the third hole pattern 105c with a smaller opening width than that of the first hole pattern 105a by capillary force. Furthermore, the less the coverage ratio of the resist film 104 is, the greater the opening ratio of the hole pattern is, and the block copolymer 106 stays over a wider range. Hence, if the resist film 104 is spin-coated with the block copolymer 106, the thickness of the block copolymer 106 is smaller in the second region R2 having both the second and third hole patterns 105b and 105c (with large opening ratio), and is relatively great in the first region R1 only having the first hole pattern 105a (with small opening ratio). As a result, as illustrated in FIGS. 4A and 4B, if both the opening widths F1 to F3 of the hole patterns 105a to 105c and the coverage ratios (opening ratios) of the resist film 104 are taken into account, the thickness of the block copolymer 106 is relatively small in the second hole pattern 105b, and relatively great in the first hole pattern 105a. That is, if the thickness of the block copolymer 106 in the first hole pattern 105a is referred to as T1 and the thickness of the block copolymer 106 in the second hole pattern 105b is referred to as T2, T2 < T1 is satisfied. In addition, the third hole pattern 105c is filled with the block copolymer 106, and the thickness of the block copolymer 106 is significantly great. That is, if the thickness of the block copolymer 106 in the third hole pattern 105c is referred to as T3, T2 < T1 £ T3 is satisfied. In this way, in the present embodiment, the thickness of the block copolymer 106 is controlled by using the opening widths F1 to F3 of the hole patterns 105a to 105c and the coverage ratios (opening ratios) of the resist film 104.

[0019]Subsequently, as illustrated in FIGS. 5A and 5B, the material film 101 or the like is heated for 90 seconds at approximately 110°C on a hot plate, and furthermore, heated for three minutes at approximately 220°C at a nitrogen atmosphere. By doing so, microphase separation of the block copolymer 106 occurs, and self-organizing phases 109a and 109b, which include first polymer portions 107a and 107b including first polymer block chains, and second polymer portions 108a and 108b including second polymer block chains, are formed. For example, the first polymer portions 107a and 107b which include PS with hydrophobicity are respectively formed (segregated) on side wall portions of the first and second hole patterns 105a and 105b. The second polymer portions 108a and 108b which include PMMA with hydrophilicity are respectively formed (segregated) in a central portion of the first and second hole patterns 105a and 105b. By doing so, the second polymer portions 108a and 108b are formed in a vertical cylinder shape (pillar shape). The diameter of the second polymer portion 108a is, for example, approximately 25 nm, and the diameter of the second polymer portion 108b is, for example, approximately 30 nm. At this time, microphase separation of the block copolymer 106 which is filled in the third hole pattern 105c as a dummy pattern does not occur.

[0020]Hereinafter, the opening widths F1 to F3 of the first to third hole patterns 105a to 105c will be described. As described above, if the diameter (first opening width) of the first hole pattern 105a is referred to as F1, the diameter (second opening width) of the second hole pattern 105b is referred to as F2, and the diameter (third opening width) of the third hole pattern 105c is referred to as F3, a relationship of F1 > F2 > F3 is established. Furthermore, the first and second opening widths F1 and F2 are greater than or equal to a phase separation period of the block copolymer 106, such that microphase separation of the block copolymer 106 occurs in the first and second hole patterns 105a and 105b. That is, the first and second opening widths F1 and F2 have widths in which phase separation of the block copolymer 106 can occur. In addition, the third opening width F3 is smaller than the phase separation period of the block copolymer 106, such that microphase separation of the block copolymer 106 does not occur in the third hole pattern 105c. That is, the third opening width F3 has a width in which phase separation of the block copolymer 106 cannot occur.

[0021]For example, if the above-described PS-b-PMMA is used as a material of the block copolymer 106, a phase separation period L0 of the block copolymer 106 is approximately 50 nm. The phase separation period L0 is repetitive intervals (pitch) of multiple polymers in a state that is not pulled, when phase separation of the block copolymer 106 occurs. For example, if the diameter of the first hole pattern 105a is equal to the phase separation period L0, the phase separation of the block copolymer 106 occurs in a state that is not pulled in the first hole pattern 105a. Hence, in this case, the diameter (diameter of a cylinder shape in a cross section in a direction parallel with a surface of a workpiece film) of all of the second polymer portion 108a of a cylinder shape and the first polymer portion 107a provided in the periphery of the second polymer portion becomes the phase separation period L0.

[0022]As illustrated in FIGS. 6A and 6B, by setting the first and second opening widths F1 and F2 to be greater than or equal to the phase separation period L0 of the block copolymer 106, phase separation of the block copolymer 106 in the first and second hole patterns 105a and 105b can be made into the first polymer portions 107a and 107b and the second polymer portions 108a and 108b. Meanwhile, as described below, if an opening width of a hole pattern is greater than the phase separation period L0, a block copolymer whose phase separation is made is pulled in a certain degree by the hole pattern, and is greater than the phase separation period L0. Meanwhile, as illustrated in FIG. 6B, by setting the third opening width F3 to be smaller than the phase separation period L0 of the block copolymer 106, the phase separation of the block copolymer 106 in the third hole pattern 105c is not made. For example, as described above, if the phase separation period L0 is set to approximately 50 nm, the first opening width F1 is set to 70 nm, the second opening width F2 is set to 100 nm, and the third opening width F3 is set to 45 nm. By doing so, it is possible to make a selective phase separation of the block copolymer 106 in the first and second hole patterns 105a and 105b, without phase separation of the block copolymer 106 in the third hole pattern 105c.

[0023]Furthermore, in order to prevent random phase separation of the block copolymer 106 from being made in the second hole pattern 105b, it is preferable that the second opening width F2 is less than or equal to a period which is double the phase separation period L0 of the block copolymer 106. The above-described relationship can be represented by Expression 1.

[0024]

2 ´ L0 ³ F2 > F1 ³ L0 > F3 (Expression 1)

Next, the first polymer portions 107a and 107b remain and the second polymer portions 108a and 108b are selectively removed by using an oxygen reactive ion etching (RIE) method. By doing so, shrunk hole patterns 110a and 110b are formed, as illustrated in FIGS. 7A and 7B. The shrunk hole patterns 110a and 110b respectively correspond to the hole patterns 105a and 105b which shrink. The second opening width F2 of the second hole pattern 105b is greater than the phase separation period L0, and is greater than the first opening width F1 of the first hole pattern 105a. Hence, each molecule in the polymer portion 107b which is buried in the second hole pattern 105b is pulled toward a side wall of the second hole pattern 105b, and thus, according to this, the shrunk hole pattern 110b becomes larger by a predetermined size than the shrunk hole pattern 110a. For example, the diameter of the shrunk hole pattern 110a is approximately 25 nm, and the diameter of the shrunk hole pattern 110b is approximately 30 nm.

[0025]Meanwhile, since phase separation of the block copolymer 106 in the third hole pattern 105c is not made, the block copolymer is rarely etched by the oxygen RIE method. Hence, the third hole pattern 105c remains to be filled with the block copolymer 106, and a hole pattern which is formed by shrinking the third hole pattern 105c is not formed in the third hole pattern 105c.

[0026]Subsequently, as illustrated in FIGS. 8A and 8B, the anti-reflective film 103 and the hard mask 102 are processed by using a RIE method which uses fluorine gas, using the remaining first polymer portions 107a and 107b, the block copolymer 106, and the resist film 104 as a mask. At this time, the shrunk hole patterns 110a and 110b are transferred to the anti-reflective film 103 and the hard mask 102.

[0027]As described with reference to FIGS. 4A and 4B, the thickness of the block copolymer 106 in the second hole pattern 105b is smaller than that of the block copolymer 106 in the first hole pattern 105a, and thus, the thickness of the first polymer portion 107b in the second hole pattern 105b is also smaller than that of the first polymer portion 107a in the first hole pattern 105a. Hence, the first polymer portion 107b is shaved and becomes smaller, when the anti-reflective film 103 and the hard mask 102 are processed.

[0028]Furthermore, in reality, an upper surface of the block copolymer 106 has a meniscus shape by interaction with the side wall of the resist film 104, in the first and second hole patterns 105a and 105b, as illustrated in FIGS. 4A and 4B. According to this, an upper surface of the first polymer portion 107b also has a meniscus shape, and thus, the periphery of the central portion of the second hole pattern 105b is relatively thin, and a portion far away from the central portion is thick. Hence, the first polymer portion 107b is gradually shaved from the periphery of the central portion of the second hole pattern 105b toward the side wall of the second hole pattern 105b by the anti-reflective film 103 and the hard mask 102 which are etched. According to this, while the anti-reflective film 103 and the hard mask 102 are etched, the opening width of the shrunk hole pattern 110b becomes greater, and then becomes similar to the second opening width F2 of the second hole pattern 105b. As a result, the shrunk hole pattern 110b is greatly expanded when the anti-reflective film 103 and the hard mask 102 are processed, as illustrated in FIG. 7B and FIG. 8B. For example, the diameter of the shrunk hole pattern 110b, which is transferred to the anti-reflective film 103 and the hard mask 102, is approximately 60 nm.

[0029]In this way, the first polymer portion 107b includes a relatively large shrunk hole pattern 110b which is formed by pulling force from the hole patterns 105b as a physical guide layer, the thickness of the first polymer portion 107b is relatively small, and a surface of the first polymer portion has a meniscus shape. As a result, the diameter of the shrunk hole pattern 110b which is transferred to the anti-reflective film 103 and the hard mask 102 becomes sufficiently greater than that of the hole pattern 110a. Meanwhile, the first polymer portion 107b is shaved, and thereby the diameter of the shrunk hole pattern 110b may be approximately equal to the second opening width F2.

[0030]In addition, the surface of the first polymer portion 107b has an approximately concentric smooth meniscus shape along the shape of the second hole pattern 105b, and thus, a good hole pattern of critical dimension uniformity (CDU) can be transferred to the anti-reflective film 103 and the hard mask 102 in accordance with the shape of the second hole pattern 105b. As a result, it is possible to prevent the diameter of the shrunk hole pattern 110b from varying.

[0031]Meanwhile, the thickness of the block copolymer 106 in the first hole pattern 105a is greater than that of the block copolymer 106 in the second hole pattern 105b, and thus the thickness of the first polymer portion 107a in the first hole pattern 105a is also greater sufficiently than that of the first polymer portion 107b in the second hole pattern 105b. Hence, even if the first polymer portion 107a is shaved in a predetermined degree when the anti-reflective film 103 and the hard mask 102 are processed, the opening width of the hole pattern 110a does not change as the shrunk hole pattern 110b. Hence, as illustrated in FIG. 7A and FIG. 8A, the hole pattern 110a is rarely widened when the anti-reflective film 103 and the hard mask 102 are processed, and is transferred to the anti-reflective film 103 and the hard mask 102 nearly as it is. Hence, the diameter of the hole pattern 110a is maintained to be, for example, approximately 25 nm.

[0032]Since the third hole pattern 105c is maintained to be filled with the block copolymer 106, the third hole pattern 105c is not transferred to the anti-reflective film 103 and the hard mask 102.

[0033]Thereafter, the material film 101 is further processed by using the RIE method, using the processed hard mask 102 as a mask. By doing so, the pattern of the hard mask 102 is transferred to the material film 101. The hole pattern which is transferred to the material film 101 is used as, for example, a contact hole or the like.

[0034]As described above, according to the present embodiment, the third hole pattern 105c as a dummy pattern is provided in the second region R2, and thus the coverage ratio of the resist film 104 in the second region R2 is less than that of the resist film 104 in the first region R1. Furthermore, the second opening width F2 of the second hole pattern 105b is greater than the opening width F1 of the first hole pattern 105a. As a result, when the resist film 104 is spin-coated with the solution of the block copolymer 106, the thickness T2 of the block copolymer 106 in the second hole pattern 105b becomes smaller than the thickness T1 of the block copolymer 106 in the first hole pattern 105a. According to this, the first polymer portion 107a which is used as a mask when the anti-reflective film 103 and the hard mask 102 are processed is also thinner in the second hole pattern 105b than in the first hole pattern 105a. As a result, in a processing process of the anti-reflective film 103 and the hard mask 102, the diameter of the hole pattern 110a in the first hole pattern 105a is maintained nearly as it is, and the diameter of the shrunk hole pattern 110b in the second hole pattern 105b can be selectively expanded. As a result, it is possible to simultaneously transfer both the hole pattern 110a with a small opening width and the shrunk hole pattern 110b with a large opening width to the anti-reflective film 103 and the hard mask 102 as a workpiece film. That is, according to the present embodiment, it is possible to easily transfer multiple hole patterns with opening widths different from each other to a workpiece film.

[0035]In addition, the opening widths F1 and F2 of the first and second hole patterns 105a and 105b are greater than or equal to the phase separation period L0 of the block copolymer 106, and the third opening width F3 of the third hole pattern 105c is smaller than the phase separation period L0 of the block copolymer 106. By doing so, the block copolymer 106 which is filled in the third hole pattern 105c as a dummy pattern stays as it is without phase separation, and the selective phase separation of the block copolymer 106 which is provided in the first and second hole patterns 105a and 105b is made. Hence, the third hole pattern 105c as a dummy pattern is not transferred to the anti-reflective film 103 and the hard mask 102, and it is possible to selectively transfer the hole patterns 110a and 110b in the first and second hole patterns 105a and 105b to the anti-reflective film 103 and the hard mask 102.

[0036]In the above-described embodiment, there are two types of the opening widths of the hole patterns (105a, 105b) which are transferred, but there may be three types or more of opening widths of hole patterns which are transferred. In this case, in a third region (not illustrated) on the anti-reflective film 103, the opening widths of the hole patterns, the number of dummy patterns, or the like may change, and the thickness of the first polymer portion 107a may be adjusted.

[0037]In addition, if the first to third hole patterns 105a to 105c are a substantially oval shape, a substantially rectangular shape, or a groove shape, the first to third opening widths F1 to F3 may be a minimum diameter (minimum guide width) of an opening width. Here, the hole pattern 105c of a groove shape indicates a line pattern. For example, FIGS. 9A and 9B are planar views illustrating modification examples of the third hole pattern (dummy pattern) 105c in the second region R2. In FIG. 9A, the third hole pattern 105c is a substantially rectangular shape or a groove shape. In FIG. 9B, the third hole pattern 105c is a substantially oval shape. The third hole pattern 105c is a substantially oval shape. In this way, even though the third hole pattern 105c is a substantially oval shape, a substantially rectangular shape, or a groove shape, if the minimum guide width F3 of the opening width is smaller than the phase separation period L0 of the block copolymer 106, the phase separation of the block copolymer 106 in the third hole pattern 105c can be prevented from being made. In addition, even though the second hole pattern 105b is a substantially oval shape, a substantially rectangular shape, or a groove shape, if the minimum guide width F2 of the opening width is greater than or equal to the phase separation period L0 of the block copolymer 106, the phase separation of the block copolymer 106 in the second hole pattern 105b can be made. While not illustrated, also in the first hole pattern 105a, if the minimum guide width F1 of the opening width is greater than or equal to the phase separation period L0 of the block copolymer 106, the phase separation of the block copolymer 106 in the first hole pattern 105a can be made.

Second Embodiment

[0038]FIG. 10 to FIG. 15 are sectional views or planar views illustrating a pattern forming method according to a second embodiment. FIG. 11 and FIG. 14 are planar views of the second region R2. FIG. 10 is a sectional view taken along line X-X of FIG. 11, and FIG. 13 is a sectional view taken along line XIII-XIII of FIG. 14. Meanwhile, sectional views and planar views of the first region R1 are the same as those illustrated in FIG. 3A, FIG. 4A, FIG. 5A, FIG. 6A, FIG. 7A, and FIG. 8A, and thus, description thereof will be omitted.

[0039]Firstly, after the processes described with reference to FIG. 1 are performed, the resist film 104 is formed on the anti-reflective film 103 to be patterned. By doing so, a structure illustrated in FIG. 10 and FIG. 11 is obtained.

[0040]In the second embodiment, the resist film 104 as a mask member includes a first space pattern 205b and a second space pattern 205c, in the second region R2, as illustrated in FIG. 11. The first and second space patterns 205b and 205c are surrounded by multiple the pillar patterns 215 which are formed of the resist film 104, and are space patterns in which the resist film 104 is not provided. The multiple pillar patterns 215 adjacent to each other are disposed so as to be separated by an interval Dp. The first space pattern 205b is a region which is surrounded by, for example, six pillar patterns 215, and is formed as a space pattern by omitting the pillar pattern 215 in a central portion thereof. The second space pattern 205c is a region which is surrounded by, for example, three pillar patterns 215. The space width of the first space pattern 205b is set to F2, and the space width of the second space pattern 205c is set to F3.

[0041]Hereinafter, the space widths F2 and F3 will be described. The space width F2 of the first space pattern 205b is greater than or equal to the phase separation period L0 of the block copolymer 106 and smaller than or equal to a period which is double the phase separation period L0. The space width F3 of the second space pattern 205c is smaller than the phase separation period L0 of the block copolymer 106. Furthermore, the space width F2 of the first space pattern 205b is greater than the first opening width F1 of the first hole pattern 105a. That is, the first opening width F1, and the space widths F2 and F3 satisfy the above-described Expression 1. As a result, the block copolymers 106 in the first hole pattern 105a and the first space pattern 205b can be phase-separated into the first polymer portions 107a and 107b, and the second polymer portions 108a and 108b. Meanwhile, the block copolymer 106 in the second space pattern 205c is not phase-separated. That is, the second space pattern 205c functions as a dummy pattern.

[0042]For example, if PS-b-PMMA is used as a material of the block copolymer 106, the phase separation period L0 becomes approximately 50 nm. In this case, the first opening width F1 is set to approximately 70 nm, the first space width F2 is set to approximately 100 nm, and the second space width F3 is set to approximately 45 nm. By doing so, the block copolymer 106 in the second space pattern 205c is not phase-separated, and the block copolymer 106 in the first hole pattern 105a and the first space pattern 205b can be selectively phase-separated.

[0043]In order to prevent the block copolymer 106 from being randomly phase-separated in the first space pattern 205b, it is preferable that the first space width F2 is smaller than or equal to a period which is double the phase separation period L0 of the block copolymer 106. As described above, also in the second embodiment, it is preferable that the first opening width F1, and the space widths F2 and F3 satisfy Expression 1.

[0044]In addition, in the second region R2, the resist film 104 remains in the pillar patterns 215, but the resist film 104 is removed from the space patterns 205b and 205c other than the pillar patterns 215. By doing so, the coverage ratio of the resist film 104 in the second region R2 is less than the coverage ratio of the resist film 104 in the first region R1. Furthermore, the space width F2 of the first space pattern 205b is greater than the first opening width F1 of the first hole pattern 105a. As a result, when the resist film 104 is spin-coated with the solution of the block copolymer 106, the thickness T2 of the block copolymer 106 in the first space pattern 205b is smaller than the thickness T1 (refer to FIG. 4A) of the block copolymer 106 in the first hole pattern 105a. In addition, since the space width F3 of the second space pattern 205c is smaller than the first opening width F1 the space width F2, the thickness T3 of the block copolymer 106 in the second space pattern 205c is formed to be greater than the thicknesses T1 and T2. Meanwhile, in the second embodiment, the space patterns 205b and 205c are not completely separated by the resist film 104, and there is a link portion P (FIG. 11) between the space patterns 205b and 205c, in which the resist film 104 is not provided. The block copolymer 106 can move between the space patterns 205b and 205c through the link portion P. Hence, the block copolymer 106 is moved (adsorbed) from the first space pattern 205b to the second space pattern 205c by a difference between capillary forces according to a difference between areas of the space patterns 205b and 205c. Hence, the thickness T3 of the block copolymer 106 in the second space pattern 205c is greater than the thicknesses T1 and T2.

[0045]In this way, in the second embodiment, the thickness of the block copolymer 106 is controlled by using the opening width F1 of the first hole pattern 105a, the space widths F2 and F3 of the first and second space patterns 205b and 205c, and the coverage ratio (opening width) of the resist film 104. Meanwhile, in reality, the upper surface of the block copolymer 106 has a meniscus shape, as illustrated in FIG. 4A and FIG. 12.

[0046]Subsequently, as described with reference to FIGS. 5A and 5B, the material film 101 or the like is heated on a hot plate. As described above, the first opening width F1, and the space widths F2 and F3 satisfy the above-described Expression 1. As a result, microphase separation of the block copolymer 106 in the first space pattern 205b is made, and the self-organizing phase 109b which includes the first polymer portion 107b and the second polymer portion 108b is formed, as illustrated in FIG. 13 and FIG. 14. The block copolymer 106 is phase-separated in the first hole pattern 105a in the first region R1, as illustrated in FIG. 5A and FIG. 6A. Meanwhile, microphase separation of the block copolymer 106 in the second space pattern 205c as a dummy pattern is not made.

[0047]Subsequently, as described with reference to FIGS. 7A and 7B, the second polymer portions 108a and 108b are selectively removed by using the oxygen RIE method, in a state in which the first polymer portions 107a and 107b remain. Furthermore, as described with reference to FIGS. 8A and 8B, the anti-reflective film 103 and the hard mask 102 are processed by using the RIE method which uses fluorine gas, using the remaining first polymer portions 107a and 107b and the resist film 104 as a mask. By doing so, a structure illustrated in FIG. 15 is obtained.

[0048]Here, since the thickness T2 of the block copolymer 106 in the first space pattern 205b is smaller than the thickness T1 of the block copolymer 106 in the first hole pattern 105a, and thus the thickness of the first polymer portion 107b in the first space pattern 205b is also smaller than the thickness of the first polymer portion 107a in the first hole pattern 105a. Hence, the first polymer portion 107b is shaved and becomes smaller, when the anti-reflective film 103 and the hard mask 102 are processed. The first polymer portion 107b has a meniscus shape, and thus, the periphery of the central portion of the first space pattern 205b is relatively thin, and a portion far away from the central portion is thick. Hence, the first polymer portion 107b is gradually shaved from the periphery of the central portion of the first space pattern 205b toward the side wall of the first space pattern 205b by the anti-reflective film 103 and the hard mask 102 which are processed. According to this, while the anti-reflective film 103 and the hard mask 102 are processed, the opening width of the shrunk hole pattern 110b becomes greater. As a result, the shrunk hole pattern 110b is greatly expanded when the anti-reflective film 103 and the hard mask 102 are processed, as illustrated in FIG. 15.

[0049]In addition, the surface of the first polymer portion 107b has a smooth meniscus shape along the shape of the first space pattern 205b, and thus, a good hole pattern of CDU can be transferred to the anti-reflective film 103 and the hard mask 102 in accordance with the shape of the first space pattern 205b. That is, it is possible to prevent the diameter of the shrunk hole pattern 110b from varying.

[0050]Meanwhile, as described with reference to FIG. 7A and FIG. 8A, the hole pattern 110a in the first hole pattern 105a is rarely widened when the anti-reflective film 103 and the hard mask 102 are processed, and is transferred to the anti-reflective film 103 and the hard mask 102 nearly as it is.

[0051]In addition, since the second space pattern 205c is maintained to be filled with the block copolymer 106, the third hole pattern 105c is not transferred to the anti-reflective film 103 and the hard mask 102.

[0052]Thereafter, the material film 101 is further processed by using the RIE method, using the processed hard mask 102 as a mask. By doing so, the pattern of the hard mask 102 is transferred to the material film 101.

[0053]As described above, in the second embodiment, the pillar patterns 215 function as a physical guide layer, the block copolymer 106 is not phase-separated in the second space pattern 205c, and is selectively phase-separated in the first space pattern 205b. By doing so, even if the space patterns 205b and 205c which are surrounded by the pillar patterns 215 are used, a hole pattern with a small opening width and a hole pattern with a great opening width can be simultaneously transferred to a workpiece film. Furthermore, in the second embodiment, it is also possible to obtain effects different from the effects of the first embodiment.

[0054]Meanwhile, in the second embodiment, the planar shape (layout shape) of the pillar pattern 215 is a substantially circular shape, but may be a substantially oval shape or a substantially rectangular shape. In addition, the number of the pillar patterns 215 which surround the space patterns 205b and 205c is not particularly limited.

[0055]For example, FIGS. 16A and 16B are planar views illustrating modification examples of the first space pattern 205b. As illustrated in FIG. 16A, the first space pattern 205b may be a cross-shaped region which is surrounded by four pillar patterns 215. In this case, as illustrated in FIG. 16B, the block copolymer 106 can be phase-separated in the central portion of the first space pattern 205b. Meanwhile, the second space pattern 205c is a narrow region between the pillar patterns 215 adjacent to each other.

[0056]Furthermore, the multiple pillar patterns 215 of a planar shape may be combined. For example, FIGS. 17A and 17B are planar views illustrating other modification examples of the first space pattern 205b. As illustrated in FIG. 17a, the first space pattern 205b may be a region which is surrounded by a pillar pattern 215a of a substantially circular shape and a pillar pattern 215b of a substantially rectangular shape. In this case, as illustrated in FIG. 17B, the block copolymer 106 can be phase-separated so as to be symmetrical with the center between the pillar patterns 215a and the center between the pillar patterns 215b, in a wide region which is positioned between the pillar patterns 215a and between the pillar patterns 215b. In this way, the first and second space patterns 205b and 205c can be formed in various shapes in accordance with the shapes and combinations of the pillar patterns 215.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

WHAT IS CLAIMED IS:

1. A pattern forming method comprising:

forming a mask member that includes a first pattern with a first opening width in which a self-organizing material is phase-separated in a first region on a workpiece film, a second pattern with a second opening width greater than the first opening width, and a third pattern with a width smaller than the first opening width in a second region on the workpiece film;

supplying the self-organizing material onto the mask material;

phase-separating the self-organizing material in the first and second patterns into a first polymer portion and a second polymer portion, without phase-separation of the self-organizing material in the third pattern;

forming a hole pattern by removing the second polymer portion while leaving the first polymer portion; and

processing the workpiece film by using the mask member and the first polymer portion as a mask.

2. The method according to Claim 1, wherein, when the self-organizing material is supplied onto the mask member, a thickness of the self-organizing material in the second pattern is smaller than a thickness of the self-organizing material in the first pattern.

3. The method according to Claim 1 or 2, wherein the second opening width is less than or equal to a period which is double a phase separation period of the self-organizing material.

4. The method according to any one of Claims 1 to 3, wherein a ratio of an area in which the mask member is disposed in the second region to an area of the second region and is less than a ratio of an area in which the mask member is disposed in the first region to an area of the first region.

5. A pattern forming method comprising:

forming a mask member that includes a hole pattern with a first opening width in a first region on a workpiece film, and a first space pattern and a second space pattern which are surrounded by a plurality of pillar patterns in a second region on the workpiece film;

supplying a self-organizing material onto the mask member;

phase-separating the self-organizing material in the hole pattern and the first space pattern into a first polymer portion and a second polymer portion;

forming a hole pattern by removing the second polymer portion while leaving the first polymer portion; and

processing the workpiece film by using the mask member and the first polymer portion as a mask,

wherein an opening width of the hole pattern and a space width of the first space pattern are greater than or equal to a phase separation period of the self-organizing material, and a space width of the second space pattern is smaller than the phase separation period of the self-organizing material, and

wherein the space width of the first space pattern is greater than the opening width of the hole pattern.

6. A pattern forming method comprising:

forming a mask member that includes a first hole pattern with a first opening width in a first region on a workpiece film, a second hole pattern with a second opening width, and a third hole pattern with a third opening width in a second region on the workpiece film;

supplying a self-organizing material onto the mask member;

phase-separating the self-organizing material in the first and second hole patterns into a first polymer portion and a second polymer portion;

forming a hole pattern by removing the second polymer portion while leaving the first polymer portion; and

processing the workpiece film by using the mask member and the first polymer portion as a mask,

wherein the first and second opening widths are greater than or equal to a phase separation period of the self-organizing material, and the third opening width is smaller than the phase separation period of the self-organizing material, and

wherein the second opening width is greater than the first opening width.

ABSTRACT

According to one embodiment, a pattern forming method includes forming a mask member that includes a first pattern with a first opening width in which a self-organizing material is phase-separated in a first region on a workpiece film, a second pattern with a second opening width greater than the first opening width, and a third pattern with a width smaller than the first opening width in a second region on the workpiece film. Subsequently, the self-organizing material is supplied onto the mask member. Subsequently, the self-organizing material in the first and second patterns is phase-separated into a first polymer portion and a second polymer portion, without phase-separation of the self-organizing material in the third pattern. A hole pattern is formed by removing the second polymer portion while leaving the first polymer portion. The workpiece film is processed by using the mask member and the first polymer portion as a mask.