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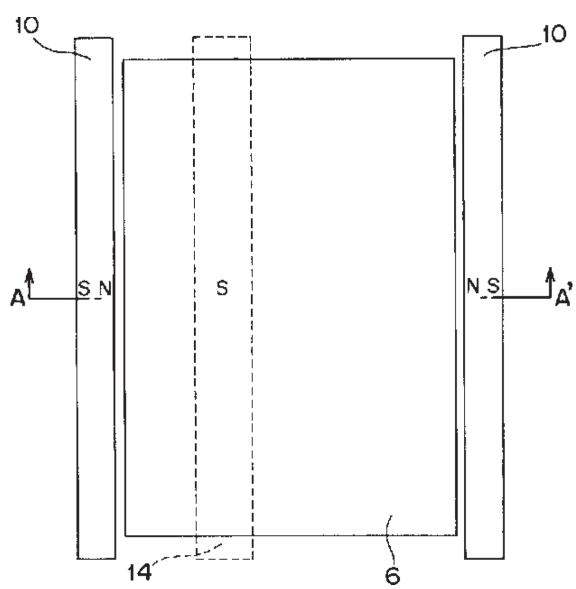
(54) **[Title of the Invention] Device and Method for Sputtering**

(57) **[Abstract]**

**PROBLEM TO BE SOLVED.** To provide a sputtering device and method for holding a target, capable of making the progression of erosion on a target occur in an approximately uniform manner.

**SOLUTION.** A magnet 10 is placed along one edge of a target 6, and a facing magnet 10 sandwiching the target 6 is set to have the same polarity. Also, the progression of erosion on the target 6 becomes approximately uniform by configuring a magnet 14 placed on the rear side surface of the target 6 to face the rear side surface of the target 6 with a polarity different from the polarity of the facing magnets 10 that are sandwiching the target 6, and also such that the magnet 14 is able to move, back and forth, in an orthogonal direction 91 to the one edge of the target.



## CLAIMS

**[Claim 1]** A sputtering device for sputtering using a rectangular target 6, characterized by rod-shaped first magnets 10 being placed along each of a pair of edges of the target 6, as well as by a rod-shaped second magnet 14 being placed so as to be movable on the rear side surface of the target.

**[Claim 2]** The sputtering device of claim 1, the polarity of the first magnets 10 being arranged such that like poles are facing, and the second magnet 14 being set with a pole facing the rear surface of the target that differs from the magnetic pole with which the first magnets face one another.

**[Claim 3]** The sputtering device of claim 1 or claim 2, the second magnet 14 being set on the rear side surface of the target so as to move back and forth in a range corresponding to between the first magnets 10.

**[Claim 4]** The sputtering device of any of claims 1-3, the second magnet 14 being configured from a plurality of rod-shaped magnets.

**[Claim 5]** A sputtering device that performs sputtering using a round target 46, characterized by a third magnet 15 being placed facing an edge of the target and a fourth magnet 16 being placed on the rear side surface of the target so as to be able to move in an approximately circular pattern.

**[Claim 6]** The sputtering device of claim 5, the polarity of the third magnet 15 being set such that like poles face the center of the target, and the fourth magnet 16 being set to face the rear side surface of the target with a pole that differs from the pole with which the third magnets face the center of the target.

**[Claim 7]** The sputtering device of claim 5 or claim 6, the fourth magnet 16 being a plurality of magnets.

**[Claim 8]** The sputtering device of any of claims 5-7, the fourth magnet 16 being configured to move in a spiraling pattern.

**[Claim 9]** A sputtering device for sputtering using a round target 46, characterized by a plurality of electromagnets 17, 57 being placed facing an edge of the target and by being configured such that the magnetic polarity of the electromagnets temporally changes.

**[Claim 10]** The sputtering device of claim 9, the electromagnet being configured such that poles facing the inside of the target can be independently controlled.

**[Claim 11]** The sputtering device of claim 9 or claim 10, the number of electromagnets being an even number of four or greater.

**[Claim 12]** The sputtering device of any of claims 9-11, the coil of the electromagnet being in the atmosphere side of a vacuum chamber.

**[Claim 13]** A sputtering method for sputtering using a rectangular target 6 in a state in which, in addition to rod-shaped first magnets 10 being placed along each of a pair of edges of a target 6, a rod-shaped second magnet 14 is placed so as to be movable on the rear side surface of the target,

characterized by sputtering being performed while the second magnet is made to move on the rear side surface of the target, the direction of the magnetic flux being temporally changed, and the plasma density on the surface of the target being made temporally approximately balanced.

**[Claim 14]** The sputtering method of claim 13, the polarity of the first magnets being arranged such that like poles are facing, and the second magnet 14 being set with a pole facing the rear surface of the target that differs from the magnetic pole with which the first magnets are facing one another.

**[Claim 15]** The sputtering method of claim 13 or claim 14, the second magnet 14 being on the rear side surface of a target and configured to move in a spiraling pattern in a range corresponding to between the first magnets 10.

**[Claim 16]** A sputtering method for sputtering in a state in which, in addition to a third magnet 15 being placed facing an edge of the target, a fourth magnet 16 is placed so as to be movable on the rear side surface of the target, characterized by sputtering being performed while the fourth magnet moves in an approximately circular pattern on the rear side surface of the target, temporally changing the direction of magnetic flux and making plasma density on the target surface temporally balanced.

**[Claim 17]** The sputtering method of claim 16. the polarity of the third magnets 15 being set such that like poles face the center of the target and the fourth magnet 16 being set with a pole facing the rear surface of the target that differs from the pole with which the third magnets face the center of the target.

**[Claim 18]** The sputtering method of claim 16 or claim 17, the fourth magnet 16 being configured so as to move in a spiraling pattern.

**[Claim 19]** A sputtering method for sputtering with a round target 46 in a state in which a plurality of electromagnets 17, 57 are placed facing an edge of the target, characterized by the magnetic polarity of the electromagnets being temporally changed, the direction of magnetic flux being changed, and the direction 93 from which electrons inside the plasma receive force being changed, and the plasma density on the target surface being made approximately uniform when averaged over time.

**[Claim 20]** The sputtering method of claim 19, the direction of magnetic flux being changed by temporally changing the magnetic polarity of the electromagnet, and plasma density on the target surface temporally made approximately uniform when averaged over time, by rotating 360 degrees the direction 93 from which electrons in the plasma receive force.

## DETAILED DESCRIPTION OF THE INVENTION

**[0001]**

**TECHNICAL FIELD TO WHICH THE INVENTION BELONGS.** The present invention pertains to a magnetron sputtering device and method, one technology for forming thin film.

**[0002]**

**CONVENTIONAL TECHNOLOGY.** A sputtering method is a method for producing thin film by generating plasma and causing the positive ions of the plasma to collide with a target mounted on a negative electrode called a cathode. Particles sputtered by the collision adhere to the substrate and form a thin film. This sputtering method is widely used in film creation processes because it is relatively simple to control the composition and to operate the device. However, conventional sputtering methods have the drawback of being slow to generate film in comparison to vacuum deposition methods. Magnetron sputtering methods, which use a permanent magnet or electromagnet in a magnetic circuit to form a magnetic field near a target, were designed for this reason. These methods improve the speed of thin film formation and make it possible to use sputtering methods in mass production processes, manufacturing semiconductor and electronic components and the like.

**[0003]** Because magnetron sputtering methods have problems with inconsistencies in film thickness and quality due to localized erosion on the target, devices were invented to form an even magnetic field orthogonal to an electric field. **Fig. 20** shows the configuration of a conventional sputtering device. In **Fig. 20**, 1 indicates a chamber, 2 is a vacuum exhaust port of the chamber 1 for exhausting with a vacuum pump, 3 is a pipe for introducing gas into the chamber 1, and 4 is a gas flow control device mounted on the gas introduction pipe 3. The number 5 indicates discharge gas introduced into the chamber 1 from the gas introduction pipe 3. The number 6 indicates a target, 7 is a sputtering electrode, 8 is a discharge power supply, 9 is a magnet holder, 10 is a magnet, and 11 is a substrate holder. The number 12 indicates a substrate upon which a thin film is formed.

**[0004]** The operations of a sputtering device configured as above are explained below. First, a vacuum pump is used to exhaust the inside of the chamber 1 from the vacuum exhaust port to a level of $10^{-7}$ Torr. Next, discharge gas 5 is introduced into the chamber 1 through the gas introduction pipe 3 connected to one end of the chamber 1, maintaining pressure inside the chamber 1 at $10^{-2}$ — $10^{-3}$ Torr. A negative voltage or high frequency voltage is applied to the target 6 attached to the sputtering electrode 7 from a DC or high-frequency power supply for sputtering 8, and the electric field from the power supply 8 and the magnetic field from the magnet 10 housed in the magnet holder 9 work to generate plasma from discharge close to the front surface of the target 6. The phenomenon of sputtering occurs, and with the sputter particles released from the target 6 a thin film is formed on a substrate 12 placed in a substrate holder 11. However, with a sputtering device when a target 6 is a ferromagnetic material a large portion of magnetic flux generated from a magnet 10 passes through the inside of the target 6, and very little magnetic flux contributes to plasma formation. This causes a problematic decrease in the speed of film creation. Thus, as disclosed in Japanese Unexamined Patent Publication No. Sho 61 (1985)-124567, an effort has been made to avoid slowing the speed of film creation in ferromagnetic material by placing a magnet on the rear surface of a target in addition to a magnet placed on the front surface of the target. **Fig. 21** shows a sputtering electrode configuration wherein magnets 10, 13 are placed on the front and back sides of a target 16. With this configuration magnetic flux generated from the magnet 13 placed on the rear surface of the target 6 fills the inside of the ferromagnetic target 6 and magnetic flux generated by the magnet 10 placed on the front surface of the target is prevented from passing through the inside of the target 6. As a result, a decrease in the speed of film creation on the ferromagnetic target 6 is prevented.

**[0005]**

**PROBLEM THE INVENTION PURPORTS TO SOLVE**. However, although it was possible to improve the rate of film generation on targets of ferromagnetic material, because the magnetic flux faced the same direction across the entire surface of the target, electrons in the plasma received force in the same direction across the entire surface of the target. The density of electrons in the plasma therefore became non-uniform in the target surface, and as a result erosion on the target progressed rapidly in the direction in which electrons received force and slowly in the opposite direction. As a result, problems developed with non-uniform progression of erosion. This not only caused extremely inefficient use of target material but made it impossible to ensure evenness in the thickness of thin film created on the surface of a substrate. The present invention aims to solve these problems and to provide a sputtering device and method which make it possible to cause erosion of the target to progress in an approximately uniform manner, regardless of magnetic material.

**[0006]**

**MEANS OF SOLVING THE PROBLEM.** In order to attain the above objective, the present invention is configured as follows. According to a sputtering device of Embodiment 1 of the present invention, a sputtering device for performing sputtering using a rectangular target is configured such that in addition to rod-shaped first magnets placed along each of a pair of edges of the target, a rod-shaped second magnet is placed so as to be movable on the rear side surface of the target. According to Embodiment 3, it is possible to configure Embodiment 1 or 2 such that the second magnet is on the rear surface side of the target and moves back and forth in a range corresponding to between the first magnets. According to Embodiment 4 of the present invention, it is possible to configure any of Embodiments 1-3 such that the second magnet is a plurality of rod-shaped magnets.

**[0007]** According to a sputtering device of Embodiment 5 of the present invention a sputtering device for sputtering using a circular target is configured such that, in addition to third magnets being placed facing edges of the target, a fourth magnet is placed on the rear side surface of the target so as to be able to move in an approximately circular pattern. According to Embodiment 6 of the present invention, it is possible to configure Embodiment 5 such that the polarity of the third magnet is arranged with like poles facing the center of the target and the fourth magnet is set with a pole facing the rear surface of the target that differs from the pole with which the third magnet faces the center of the target. According to Embodiment 7 of the present invention, it is possible to configure the fourth magnet in Embodiment 5 or 6 as a plurality of magnets. According to Embodiment 8 of the present invention, it is possible to configure any of Embodiments 5-7 such that the fourth magnet moves in a spiraling pattern.

**[0008]** According to a sputtering device of Embodiment 9 of the present invention a sputtering device for sputtering a circular target is configured with a plurality of electromagnets placed facing edges of the target such that the magnetic poles of the electromagnets temporally change. According to Embodiment 10 of the present invention it is possible to configure Embodiment 9 such that poles of the electromagnets facing the inside of the target can each be controlled independently. According to Embodiment 11 it is possible to configure Embodiment 9 or 10 such that the number of electromagnets is an even number of 4 of more. According to Embodiment 12 it is possible to configure any of Embodiments 9-11 such that the coil of the electromagnet is in the atmosphere side of a vacuum chamber.

**[0009]** According to a sputtering method of Embodiment 13 of the present invention, with a sputtering method for sputtering using a rectangular target in a state in which rod-shaped first magnets are placed along each of a pair of edges of the target, and in addition a rod-shaped second magnet is placed so as to be able to move on the rear side surface of the target, sputtering is done while the second magnet is moved over the rear side surface of the target, temporally changing the direction of magnetic flux and temporally making the plasma density on the target surface approximately balanced. According to Embodiment 14 of the present invention it is possible to configure Embodiment 13 by arranging the polarity of the first magnets with like poles facing and setting the second magnets with a pole facing the rear surface of the target that differs from the magnetic pole with which the first magnets face one another. According to Embodiment 15 of the present invention, it is possible to configure Embodiment 13 or 14 such that the second magnet moves back and forth on the rear side surface of a target in a range corresponding to between the first magnets.

**[0010]** According to a sputtering method of Embodiment 16 of the present invention a sputtering method for sputtering using a round target in a state in which a third magnet is placed facing an edge of the target and a fourth magnet is also placed so as to be movable on the rear side surface of the target is configured such that sputtering is done while the fourth magnet moves in an approximately circular pattern on the rear side surface of the target, temporally changing the direction of magnetic flux and temporally making plasma density on the target surface approximately balanced. According to Embodiment 17 of the present invention it is possible to also configure Embodiment 16 such that the polarity of the third magnets is arranged with like poles facing the center of the target and setting the fourth magnet with a pole facing the rear surface of the target that differs from the pole with which the third magnets face the center of the target. According to Embodiment 18 of the present invention it is possible to configure Embodiment 16 or 17 such that the fourth magnet moves in a spiraling pattern.

**[0011]** According to a sputtering method of Embodiment 19 of the present invention a sputtering method for sputtering a round target in a state in which a plurality of electromagnets are placed facing the edge of a target is configured so as to temporally change the magnetic pole of the electromagnets, change the direction of magnetic flux, change the direction from which electrons in plasma receive force, and to temporally make the plasma density on a target surface approximately uniform. According to Embodiment 20 of the present invention, it is possible, by temporally changing the magnetic pole of electromagnets, to configure Embodiment 19 so as to change the direction of magnetic flux, to rotate the direction from which electrons in the plasma receive force 360 degrees, and to make plasma density on a target surface, averaged over time, approximately uniform.

**[0012]**

**WORKING EXAMPLES OF THE INVENTION.**

Embodiments of the present invention are explained below with reference to **Fig. 1-19**.

**Embodiment 1. Fig. 1** shows the configuration of a sputtering device for implementing a sputtering method of Embodiment 1 of the present invention. In **Fig. 1** the number 1 indicates a vacuum chamber, 2 is a vacuum exhaust port provided to the chamber 1 and opening to a vacuum pump, 3 is a gas introduction pipe provided to the chamber 1, and 4 is a gas flow control device mounted on the gas introduction pipe 3. The number 5 indicates discharge gas, usually argon gas, introduced into the chamber 1 from the gas introduction pipe 3. The number 6 indicates a rectangular target placed inside a chamber 1; 7 is a supporting electrode for supporting the target 6, mounted on the chamber 1 by means of an insulating body 80; 8 is a DC or high frequency discharge source for discharge that applies to negative voltage or high frequency voltage in the sputtering electrode; 9 is a pair of magnet holders placed inside the chamber 1 along a pair of edges that run in the longitudinal direction of the target 6; and 10 is a pair of rod-shaped magnets placed along a pair of edges of the target 6 and supported by a pair of magnet holders. The number 11 is a substrate holder placed inside the chamber 1 in a position facing the target 6. The number 12 indicates a substrate upon which a thin film is formed, supported by a substrate holder 11. The number 14 indicates rod-shaped magnets placed inside a sputtering electrode 7 as well as on the rear side surface of a target and also along the longitudinal direction of the target 6, and this magnet 14 is provided with a movement mechanism that moves on the rear side surface of the target 6 in a direction orthogonal to the longitudinal direction of the target 6.

**[0013] Fig. 2** shows a plane figure of part of the sputtering electrode inside the sputtering device shown in **Fig 1**. In addition, **Fig. 3** shows an A—A' cross-section of **Fig. 2**. Each magnet 10 is placed on the outer side of a rectangular target 6 along each edge in the longitudinal direction as shown in **Fig. 2**, facing and sandwiching the target 6, the polarity of a pair of magnets 10 arranged to be the same. In **Fig. 2**, N poles in a pair of magnets 10 are configured to face one another. Also, a magnet 14 placed on the rear side surface of a target 6 is arranged to face the rear surface of the target with a polarity that is the reverse of the polarity with which the magnets 10 are facing and sandwiching the target. In **Fig. 2**, because magnets 10 are facing N poles, the S pole of a magnet 14 on the rear side surface of a target is configured to face the rear surface of the target. A magnet 14 on the rear side surface of a target is configured so as to be able to move, back and forth, in an orthogonal direction to the longitudinal direction of the target 6, i.e., direction 91, with time moving as shown in **Fig. 4** from (A) through (B) to (C), and then from (C) through (B) to (A). In short, in a range corresponding to the space between a pair of magnets 10 on the rear side surface of a target 6, the magnet 14 gradually distances from the vicinity of a magnet 10 on one side and approaches a magnet 10 on the other side. Then, when positioned in the vicinity of the magnet 10 on the other side, the magnet 14 conversely gradually distances from the vicinity of the magnet 10 on that side and approaches the magnet 10 on the first side. The magnet 14 is then positioned in the vicinity of the magnet 10 on the first side. During this time it is desirable that the magnet 14 moves with uniform velocity in order to temporally make the plasma density approximately balanced.

**[0014]** By means of the above configuration the strength and direction of the magnetic field are changed on all points on the target 6. By way of example, **Fig. 5** uses solid and dotted lines to show temporal change in magnetic flux density in the A-A' direction at a distance of 2mm from the front surface of the target when the moving speed of magnets 14 placed on the rear side surface of the target is set to 50mm/s, for a position at the center of the target 6 and a position 50mm away from the center of the target 6 on line A-A' in **Fig. 2**, respectively. The left-facing movement of the magnet 14 in **Fig. 3** is shown as positive. As can be seen in **Fig. 5**, the strength and direction of the magnetic field are temporally changed on all points on the target 6.

**[0015]** In **Fig. 2,** when magnetic flux faces to the right, electrons in the plasma receive force facing toward the bottom of **Fig. 2**. Also, when magnetic flux faces to the left, electrons in the plasma receive force facing toward the top of **Fig. 2**. Thus, by temporally changing the direction of magnetic flux it becomes possible to increase the plasma density confining the plasma on the target surface, increasing the rate of erosion and the rate of generating film on the substrate. Furthermore, plasma density on the target surface is temporally balanced, and as shown in **Fig.**

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