

DESCRIPTION

DEPOSITION APPARATUS, METHOD OF MEASURING THICKNESS OF
ORGANIC DEPOSITED LAYER, AND THICKENSS SENSOR FOR
ORGANIC DEPOSITED LAYER

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Technical Field

[0001] The present invention relates to a deposition
apparatus including a thickness sensor, a method of
measuring a thickness of an organic deposited layer,
10 and a thickness sensor for an organic deposited layer.

Background Art

[0002] In a deposition apparatus such as a vacuum
deposition apparatus in the related art, a quartz
crystal microbalance (QCM) technology is used to
15 measure a thickness of a layer deposited on a substrate
and a deposition rate. The technology utilizes a
phenomenon that a resonant frequency of a crystal
quartz oscillator arranged within a chamber decreases

as a mass increases by deposition of a vapor deposition substance. It is therefore possible to measure the thickness and the deposition rate by measuring a change in a resonant frequency of the crystal quartz oscillator.

[0003] In recent years, in the art of manufacturing an electroluminescence (EL) device, a vacuum deposition method is widely used for depositing an organic layer. For example, in an organic EL display, a highly precise thickness control is necessary because a variability in a thickness of an organic deposited layer across pixels greatly affects an image quality.

[0004] On the other hand, in the thickness sensor of this type, as a deposition amount increases, the resonant frequency of the crystal quartz oscillator gradually decreases. Once it reaches a predetermined frequency, a change in the frequency is too great to measure stably the thickness. Accordingly, if the

resonant frequency decreases beyond a predetermined value, the crystal quartz oscillator is replaced as it regards that it comes to the end of the life. For ease of the replacement, Patent Document 1 describes a

5 sensor head that holds a plurality of crystal quartz plates having a resonant frequency of 5 MHz and can switch individually the crystal quartz plates.

[0005] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-139505

10 Disclosure of the Invention

Problem to be solved by the Invention

[0006] However, in the crystal quartz oscillator, resonant characteristics are significantly degraded by the deposition of the organic layer as compared with a

15 metal layer or a metal compound layer. Undesirably, a deposition rate and a thickness of the organic deposited layer are not able to be stably controlled.

In addition, a life of the oscillator is short, and the

oscillator needs to be replaced frequently.

[0007] In view of the circumstances as described

above, it is an object of the present invention to

provide a deposition apparatus that can control a

5 deposition rate of an organic layer and measure a

thickness of the organic layer with high precision, a

method of measuring a thickness of an organic deposited

layer, and a thickness sensor for an organic deposited

layer.

10 Means for solving the Problem

[0008] A deposition apparatus according to an

embodiment of the present invention includes a vacuum

chamber, an organic material source, a substrate

holder, a thickness sensor, and a measurement unit.

15 The organic material source is arranged inside of

the vacuum chamber and is configured to be capable of

discharging organic material particles.

The substrate holder is arranged facing to the

organic material source and is configured to be capable of holding a substrate.

The thickness sensor is arranged inside of the vacuum chamber and includes a crystal quartz oscillator having a fundamental frequency of 4 MHz or less.

The measurement unit measures a thickness of an organic layer deposited on the substrate over the substrate holder based on a change in a resonant frequency of the crystal quartz oscillator.

[0009] In the deposition apparatus, the organic material particles discharged from the organic material source deposit on a surface of the substrate on the substrate holder and on a surface of the crystal quartz oscillator of the thickness sensor. The resonant frequency of the crystal quartz oscillator decreases as a deposition amount of the organic material particles increases. The measurement unit measures the thickness of the organic layer deposited on the substrate based

on the change in the resonant frequency of the crystal quartz oscillator.

[0010] Here, in the deposition apparatus, the crystal quartz oscillator of the thickness sensor has a fundamental frequency of 4 MHz or less. As compared with the crystal quartz oscillator having a fundamental frequency of 5 MHz or more, increases of the equivalent resistance and the half value frequency width by deposition of the organic layer are lowered, and stable resonant vibration is ensured for a long term. It is therefore possible to measure the thickness and the deposition rate of the organic layer with high precision.

[0011] The crystal quartz oscillator is typically an AT cut crystal quartz oscillator or an SC cut crystal quartz oscillator.

[0012] The measurement circuit may include an oscillation circuit, a reference signal generation

circuit, a mixer circuit, a counter, and a controller.

The oscillation circuit oscillates the crystal quartz oscillator. The reference signal generation circuit oscillates a signal of a reference frequency.

5 The mixer circuit mixes a signal outputted from the oscillation circuit with the signal of the reference frequency. The counter measures a frequency of a signal of a low frequency component from the signal generated at the mixer circuit. The controller
10 calculates an oscillating frequency of the oscillation circuit based on a difference between the frequency measured by the counter and the reference frequency.

In this manner, the high frequency resolution can be kept, even if the crystal quartz oscillator having
15 the relatively low oscillating frequency of 4 MHz or less is used.

[0013] A method of measuring a thickness of an organic deposited layer according to an embodiment of

the present invention includes depositing organic material particles discharged from an organic material source on a substrate.

5 The organic material particles are deposited on a crystal quartz oscillator that oscillates at a resonant frequency of 4 MHz or less.

A thickness of the organic material particles deposited on the substrate is measured based on a change in the resonant frequency of the crystal quartz oscillator.

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It is therefore possible to measure the thickness and the deposition rate of the organic layer with high precision.

[0014] A thickness sensor for an organic deposited layer according to an embodiment of the present invention includes a crystal quartz oscillator having a fundamental frequency of 4 MHz or less.

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It is therefore possible to measure the thickness

and the deposition rate of the organic layer with high precision.

Effects of the Invention

[0015] As described above, according to the present
5 invention, the deposition rate of the organic layer can be controlled and the thickness of the organic deposited layer can be measured with high precision.

Brief Description of Drawings

[0016]
10 [Fig. 1] A schematic cross-sectional diagram showing a deposition apparatus according to an embodiment of the present invention.

[Fig. 2] A schematic cross-sectional diagram showing a thickness sensor of the deposition apparatus.

15 [Fig. 3] A front diagram showing a crystal quartz oscillator of the thickness sensor.

[Fig. 4] A rear diagram showing a crystal quartz oscillator of the thickness sensor.

[Fig. 5] An experimental result showing each equivalent resistance of a plurality of crystal quartz oscillators having different fundamental frequencies.

[Fig. 6] An experimental result showing each half value
5 frequency width of a plurality of crystal quartz oscillators having different fundamental frequencies.

[Fig. 7] An experimental result showing a deposition rate of an organic layer (Alq3(tris(8-quinolinato)aluminum)) measured by using a crystal
10 quartz oscillator having a fundamental frequency of 5 MHz.

[Fig. 8] An experimental result showing a deposition rate of an organic layer (Alq3(tris(8-quinolinato)aluminum)) measured by using a crystal
15 quartz oscillator having a fundamental frequency of 4 MHz.

[Fig. 9] An experimental result showing temperature characteristics of a plurality of crystal quartz

oscillators having different fundamental frequencies.

[Fig. 10] An experimental result showing thermal shock characteristics of a plurality of crystal quartz

oscillators having different fundamental frequencies.

5 [Fig. 11] A block diagram showing a configuration of a measurement unit of the deposition apparatus.

[Fig. 12] An experimental result showing a deposition rate by sequentially changing 12 crystal quartz oscillators per 5 minutes.

10 [Fig. 13] A plot of a variability of average rates of 12 crystal quartz oscillators.

[Fig. 14] A diagram showing by comparing a variability in measurement rates by sequentially changing 12 crystal quartz oscillators (sample 1) having a

15 fundamental frequency of 5 MHz and surface roughness (Ra) of 0.27 μm with a variability in measurement rates by sequentially changing 12 crystal quartz oscillators (sample 2) having surface roughness (Ra) of 0.02 μm .

[Fig. 15] A diagram showing by a variability in measurement rates by sequentially changing 12 crystal quartz oscillators (sample 3) having a fundamental frequency of 4 MHz and surface roughness (Ra) of 0.02 μm .

Best Modes for Carrying Out the Invention

[0017] Hereinafter, embodiments according to the present invention will be described with reference to the drawings.

10 [0018] [Deposition Apparatus]

Fig. 1 is a schematic cross-sectional diagram showing a deposition apparatus according to an embodiment of the present invention. The deposition apparatus according to this embodiment is configured as a vacuum deposition apparatus for depositing an organic layer.

[0019] A deposition apparatus 10 according to this embodiment includes a vacuum chamber 11, an organic

material source 12 arranged inside of the vacuum chamber 11, a substrate holder 13 facing to the organic material source 12, and a thickness sensor 14 arranged inside of the vacuum chamber 11.

5 [0020] The vacuum chamber 11 is connected to a vacuum exhaust system 15, and may be exhausted and be kept internally at a predetermined reduced pressure atmosphere.

10 [0021] The organic material source 12 may discharge organic material particles. In this embodiment, the organic material source 12 configures an evaporation source for heating and evaporating the organic material and discharging the organic material particles. The type of the evaporation source is not especially

15 limited. A variety of types such as a resistance heating type, an induction heating type and an electron beam heating type is applicable.

 [0022] The substrate holder 13 is configured to be

capable of holding a substrate W such as a semiconductor wafer and a glass substrate toward the organic material source 12.

[0023] The thickness sensor 14 in which a crystal quartz oscillator having a predetermined fundamental frequency (eigen frequency) is built configures a sensor head for measuring a thickness and a deposition rate of an organic layer deposited on the substrate W. The thickness sensor 14 is arranged inside of the vacuum chamber 11 facing to the organic material source 12. The thickness sensor 14 is typically arranged near the substrate holder 13.

[0024] An output from the thickness sensor 14 is supplied to a measurement unit 17. The measurement unit 17 measures the thickness and the deposition rate based on a change in a resonant frequency of the crystal quartz oscillator, and also controls the organic material source 12 such that the deposition

rate reaches a predetermined value. For a relationship between the frequency change and a mass load by QCM adsorption, the Sauerbrey formula represented by the following numerical formula (1) is used.

5 [0025] [Numerical Formula 1]

$$\Delta F_s = \frac{2Nf_0^2}{(\rho_Q \cdot \mu_Q)^{1/2}} \frac{\Delta m}{A} \dots (1)$$

[0026]

In the numerical formula (1), ΔF_s represents a frequency change amount, Δm represents a mass change amount, f_0 represents a fundamental frequency, ρ_Q

10 represents a density of crystal quartz, μ_Q represents a shear stress of crystal quartz, A represents an electrode area, and N represents a constant, respectively.

[0027] The deposition apparatus 10 further includes

15 a shutter 16. The shutter 16 is disposed between the organic material source 12 and the substrate holder 13, and can open or close an incident path of the organic

material particles from the organic material source 12
to the substrate holder 13 and the thickness sensor 14.

[0028] Opening and closing of the shutter 16 is

controlled by a control unit (not shown). Typically,

5 the shutter 16 is closed until a discharge of the

organic material particles is stabilized in the organic

material source 12 after the vapor deposition is

started. When the discharge of the organic material

particles is stabilized, the shutter 16 is open. In

10 this manner, the organic material particles from the

organic material source 12 reach the substrate W on the

substrate holder 13, and a deposition process of the

substrate W is started. At the same time, the organic

material particles from the organic material source 12

15 reach the thickness sensor 14, and the thickness and

the deposition rate of the organic layer deposited on

the substrate W are monitored.

[0029] [Thickness Sensor]

Next, the thickness sensor 14 will be described in detail.

[0030] Fig. 2 is a schematic cross-sectional diagram of the thickness sensor 14. As shown in Fig. 2, the thickness sensor 14 includes an oscillator 20, and a case 140 that oscillatably houses the oscillator 20. The oscillator 20 is housed in the case 140 such that a surface 21 of the oscillator 20 faces to the organic material source 12.

[0031] Fig. 3 and Fig. 4 are a front diagram and a rear diagram of the crystal quartz oscillator 20, respectively.

[0032] The oscillator 20 is configured of disk-shaped piezoelectric crystal. In this embodiment, an

AT cut crystal quartz oscillator (cut angle θ of $35^{\circ} 15' \pm 20'$) having relatively good temperature characteristics is used. Besides this, as the oscillator 20, an SC cut crystal quartz oscillator (cut

angle θ of $33^{\circ} 30' \pm 11'$, ϕ of $20^{\circ} 25' \pm 6'$) having temperature characteristics better than the AT cut oscillator may be used.

[0033] On the surface 21 and a rear surface 22 of the oscillator 20, electrode films 31, 32 each having a predetermined shape are formed. The electrode films 31, 32 are formed in different shapes each other as shown by hatching in Fig. 3 and Fig. 4. However, the shapes of the electrode films 31, 32 are not limited to the example shown. The electrode films 31, 32 are formed in metal films of gold, silver, or the like.

[0034] The oscillator 20 oscillates in a thickness slip vibration mode by applying a high frequency voltage to the electrode films 31, 32. In this embodiment, as the oscillator 20, a crystal quartz oscillator having a fundamental frequency (eigen frequency) of 4 MHz is used. As described later, a long-term stable oscillation operation is possible,

thereby measuring the thickness and the deposition rate with high precision.

[0035] The fundamental frequency of the oscillator

20 is not limited to 4 MHz. The crystal quartz

5 oscillator having the fundamental frequency of any

frequencies not more than 4 MHz (for example, 3.25 MHz,

2.5 MHz, etc.) is applicable.

[0036] Here, vibration characteristics of the

crystal quartz oscillator can be evaluated by

10 equivalent resistance and a Q value. That is to say,

the smaller the equivalent resistance is, the more the

oscillator vibrates. The higher the Q value is, the

more stable resonant vibration is.

[0037] The present inventors prepare samples of the

15 AT cut crystal quartz oscillators having fundamental

frequencies of 3.25 MHz, 4 MHz, 5 MHz and 6 MHz. For

each sample, an organic layer (Alq3(tris(8-

quinolinato)aluminum) having a thickness of 60 μm on

one surface, the equivalent resistance (R_1) and the Q value were measured. For the measurement, a network analyzer was used. Fig. 5 and Fig. 6 show the results.

[0038] Fig. 5 and Fig. 6 each shows the equivalent resistance (R_1) and the half value frequency width (FW) of each oscillator sample. Here, the half value frequency width (FW) refers to a frequency full width (Δf) at the point where is 3 dB (decibel) lower than a peak value in an amplitude peak frequency (f_0), and the Q value is represented by $f_0/\Delta f$.

[0039] As shown in Fig. 5 and Fig. 6, as the fundamental frequency of the oscillator increases, both of the equivalent resistance (R_1) and the half value frequency width (FW) increase. For example, when the fundamental frequency is 5 MHz, the equivalent resistance (R_1) and the half value frequency width (FW) are about 3.5 k Ω and about 4 kHz. When the fundamental frequency is 4 MHz, the equivalent resistance (R_1) and

the half value frequency width (FW) are about 2 k Ω and 800 Hz. The more the equivalent resistance (R1) increases, the less the oscillator oscillates. The more the half value frequency width (FW) increases, the lower the Q value of the oscillator is. It can be therefore said that the organic layer is advantageously formed if the equivalent resistance (R1) and the half value frequency width (FW) are as low as possible.

[0040] In this embodiment, as the oscillator 20, the crystal quartz oscillator having the fundamental frequency of 4 MHz or less is used. As compared with the crystal quartz oscillator having the fundamental frequency of 5 MHz or more, both of the equivalent resistance (R1) and the half value frequency width (FW) are low, and stable resonant vibration can be therefore achieved.

[0041] For example, Fig. 7 is an experimental result showing the deposition rate of the organic layer

(Alq3(tris(8-quinolinato)aluminum)) measured by using the crystal quartz oscillator having the fundamental frequency of 5 MHz. As shown in Fig. 7, it reveals that the rate starts to change greatly after about 100 minutes in the crystal quartz oscillator.

[0042] In contrast, Fig. 8 is an experimental result showing a deposition rate of the above-described organic layer measured by using a crystal quartz oscillator having a fundamental frequency of 4 MHz. As shown in Fig. 8, the rate little changes, and a resonant status can be maintained stably for a long period of time.

[0043] Thus, the difference between rate stabilities caused by the difference in the fundamental frequencies of the crystal quartz oscillator is strongly correlated with the magnitudes of the above-described equivalent resistance (R1) and the half value frequency width (FW). In particular, a remarkable difference in the rate

stability is recognized when the fundamental frequency is 5 MHz or 4 MHz.

[0044] As described above, by setting the fundamental frequency of the crystal quartz oscillator to 4 MHz or less, a life of the oscillator as the thickness sensor can be prolonged, and the thickness and the deposition rate of the organic layer can be stably measured, as compared with the crystal quartz oscillator having the fundamental frequency of 5 MHz or more. This allow the thickness and the deposition rate of the organic layer to be controlled with high precision in a manufacturing process of the organic EL display, for example.

[0045] In particular, in the deposition of the organic layer, the equivalent resistance and the half value frequency width are significantly greater than those in the deposition of the inorganic layer. As one example, the equivalent resistance (R_1) is 1.2 k Ω , and

the half value frequency width is 500 Hz when a metal aluminum layer having a thickness of 60 μm is deposited on the crystal quartz oscillator having the fundamental frequency of 5 MHz. This also reveals that the low

5 fundamental frequency of the crystal quartz oscillator is preferable in order to ensure the stable resonant vibration when the organic layer is deposited.

[0046] Here, if the organic layer is considered not as a rigid layer such as the metal layer, but as a

10 viscoelastic layer, the half value frequency width (FW) can be represented by the following numerical formula (2).

[0047] [Numerical Formula 2]

$$\Delta F_w = -\frac{F_0}{\pi Z_q} \left(\frac{G'' \omega^3 \rho_f^2 h_f^3}{3|G|^2} \right) \dots (2)$$

[0048]

15 In the numerical formula (2), ΔF_w represents a half value of a half value frequency width (FW), G represents a complex elastic modulus (MPa) of the

organic layer, G'' represents a loss elastic modulus (MPa) of the organic layer, ω represents an angular frequency, h_f represents a thickness (nm) of the organic layer deposited, ρ_f represents a density (g/cm^3) of the organic layer deposited, F_0 represents the fundamental frequency (Hz), and Z_q represents shear mode acoustic impedance ($\text{gm}/\text{sec}/\text{cm}^2$) of crystal quartz, respectively.

[0049] From the numerical formula (2), it is found

that the half value frequency width (FW) is proportional to about the fourth power of the frequency ($F_0 \times \omega^3$). On the other hand, the equivalent resistance (R_1) is proportional to about the square of the frequency from $FW = R_1/2\pi L$ or $F = 4\pi/\sqrt{LC}$. The results well match with the results in Fig. 5 and Fig. 6.

[0050] Furthermore, it also reveals that decreasing the fundamental frequency of the crystal quartz

oscillator is effective not only for the stable resonant frequency but also for the improvement of the temperature characteristics and the thermal shock characteristics.

5 [0051] Fig. 9 shows temperature characteristics of each oscillator described above where an organic layer (Alq3(tris(8-quinolinato)aluminum) having a thickness of 60 μm is deposited on one surface. Here, the temperature characteristics means temperature
10 dependence characteristics of the oscillating frequency of the crystal quartz oscillator.

 [0052] On the other hand, Fig. 10 shows the thermal shock characteristics of each above-described oscillator where the organic layer having the above-
15 described thickness is deposited or not deposited. Here, the thermal shock characteristics means frequency characteristics when the crystal quartz oscillator is momentarily subjected to radiated heat like when the

shutter 16 (Fig. 1) is open, for example.

[0053] As shown in Fig. 9 and Fig. 10, the frequency

change of the crystal quartz oscillator having the

fundamental frequency of 4 MHz or less is very small to

5 the temperature change and the thermal shock as

compared with the crystal quartz oscillator having the

fundamental frequency of 5 MHz or more. According to

this embodiment, it is possible to stably measure the

thickness and to stably control the deposition rate

10 without affecting by a temperature change in a chamber

or by the radiated heat accompanied by opening and

closing the shutter. In addition, as it does not need

a complex temperature compensation operation based on

the temperature characteristics of the oscillator and a

15 control that stops the operation until the frequency of

the crystal quartz oscillator is stabilized upon the

opening of the shutter, the measurement unit 17 can be

controlled simply.

[0054] [Measurement Unit]

Next, the measurement unit 17 will be described.

[0055] Fig. 11 is a block diagram showing a

configuration of the measurement unit 17. The

5 measurement unit 17 includes an oscillation circuit 41,
a measurement circuit 42, and a controller 43.

[0056] The oscillation circuit 41 oscillates the

oscillator 20 (crystal quartz oscillator) of the

thickness sensor 14. The measurement circuit 42 is for

10 measuring the resonant frequency of the oscillator 20

outputted from the oscillation circuit 41. The

controller 43 calculates the resonant frequency of the

oscillator 20 from the output of the measurement

circuit 42, and calculates the deposition rate of the

15 organic material particles on the substrate W and the

thickness of the organic layer deposited on the

substrate W. The controller 43 further controls the

organic material source 12 so that the deposition rate

has the predetermined value.

[0057] The measurement circuit 42 includes a mixer circuit 51, a low pass filter 52, a low frequency counter 53, a high frequency counter 54, and a
5 reference signal generation circuit 55. The signal outputted from the oscillation circuit 41 is inputted into the high frequency counter 54, and a roughly estimated value of the oscillating frequency of the oscillation circuit 41 is firstly measured.

10 [0058] The roughly estimated value of the oscillating frequency of the oscillation circuit 41 measured by the high frequency counter 54 is outputted to the controller 43. The controller 43 oscillates the reference signal generation circuit 55 at the reference
15 frequency closer to the frequency of the roughly estimated value measured. The signal of the frequency oscillated at the reference frequency and the signal outputted from the oscillation circuit 41 are inputted

to the mixer circuit 51.

[0059] The mixer circuit 51 mixes two types of signals inputted, and outputs them to the low frequency circuit 53 via the low pass filter 52. Here, if the
5 signal inputted from the oscillation circuit 41 denotes $\cos((\omega + \alpha)t)$ and the signal inputted from the reference signal generation circuit denotes $\cos(\omega t)$, an alternating current signal represented by a numerical formula, $\cos(\omega t) \cdot \cos((\omega + \alpha)t)$ is generated within the
10 mixer circuit 51. In the numerical formula, $\cos(\omega t)$ is multiplied by $\cos((\omega + \alpha)t)$. The alternative current signal represented by the formula equals to a sum of the signal of a high frequency component represented by $\cos((2\omega + \alpha)t)$ and a signal of a low frequency
15 component represented by $\cos(\alpha t)$.

[0060] The signal generated at the mixer circuit 51 is inputted to the low pass filter 52, the signal $\cos((2\omega + \alpha)t)$ of the high frequency component is

removed, and only the signal $\cos(\alpha t)$ of the low frequency component is inputted to the low frequency counter 53. In other words, to the low frequency counter 53, an absolute value $|\alpha|$ of the signal of the low frequency component that is a frequency difference between the signal $\cos((\omega + \alpha)t)$ of the oscillation circuit 41 and the signal $\cos(\omega t)$ of the reference signal generation circuit 55 is inputted.

[0061] The low frequency counter 53 measures the

frequency of the signal of the low frequency component, and outputs the measurement value to the controller 43.

The controller 43 calculates a frequency of a signal outputted by the oscillation circuit 41 from the frequency measured at the low frequency counter 53 and

a frequency of an output signal from the reference signal generation circuit 55. Specifically, if the frequency of the output signal from the reference signal generation circuit 55 is smaller than the

frequency of the output signal by the oscillation
circuit 41, the frequency of the signal of the low
frequency component is added to the output signal by
the oscillation circuit 41. In vice versa, it is
5 subtracted.

[0062] For example, if the measurement value of the
oscillating frequency of the oscillation circuit 41 by
the high frequency counter 54 exceeds 4 MHz, and the
reference signal generation circuit 55 is oscillated at
10 the frequency of 4 MHz, the oscillating frequency of
the reference signal generation circuit 55 is lower
than an actual oscillating frequency of the oscillation
circuit 41. Accordingly, in order to determine an
actual oscillating frequency of the oscillation circuit
15 41, the frequency $|\alpha|$ of the signal of the low
frequency component determined by the low frequency
counter 53 may be added to a setting frequency 4 MHz of
the reference signal generation circuit 55. If the

frequency $|\alpha|$ of the low frequency component is 10 kHz,
an accurate oscillating frequency of the oscillation
circuit 41 will be 4.01 MHz.

[0063] A resolution power of the low frequency
5 counter 53 has an upper limit. However, the resolution
power may be allocated to measure the difference
frequency $|\alpha|$. As compared with the measurement of the
oscillating frequency of the oscillation circuit 41
within the same resolution power, the frequency can be
10 accurately measured.

[0064] The oscillating frequency of the reference
signal generation circuit 55 is controlled by the
controller 43, and can be set so that the difference
frequency $|\alpha|$ is smaller than the predetermined value.
15 Thus, the resolution power of the low frequency counter
53 can be effectively utilized. The value of the
frequency determined is stored in the controller 43.

[0065] As described above, according to this

embodiment, the measurement unit 17 having the above-described configuration is used, thereby keeping the high frequency resolution even if the crystal quartz oscillator having the relatively low oscillating

5 frequency of 4 MHz or less is used. It is thus possible to ensure a thickness measurement accuracy similar to that or more of the crystal quartz oscillator having the fundamental frequency of 5 MHz or more.

10 [0066] [Surface Roughness of Crystal Quartz Oscillator]

As described above, in the thickness sensor utilizing the QCM technology, the oscillating frequency of the crystal quartz oscillator gradually decreases accompanied by an increase in a deposition amount.

15 Once the frequency reaches the predetermined value, the frequency change becomes too great not to measure stably the thickness. Accordingly, if the resonant frequency decreases to the predetermined value or lower,

the crystal quartz oscillator is replaced as it regards
that it comes to the end of the life. For ease of the
replacement, a sensor head that holds a plurality of
crystal quartz oscillators and can switch individually
5 the respective crystal quartz oscillators is typically
used.

[0067] For the thickness sensor used for vapor
deposition of a metal layer or an oxide layer, a
crystal quartz oscillator having a deposition surface
10 is polished with particles of about #1000 (having
surface roughness (Ra) of about 0.27 μm) is used. This
is for ease of workability and for not peeling easily
when the metal layer or the oxide layer is deposited
thick on the deposition surface.

15 [0068] However, if the crystal quartz oscillator is
used for the thickness sensor of the organic layer, the
measurement value of the deposition rate may be changed
greatly. For example, Fig. 12 shows an experimental

result of the deposition rate by sequentially changing
12 crystal quartz oscillators per 5 minutes using 12
sensor heads. A vertical axis represents the
measurement rate [angstrom/s], and a horizontal axis
5 represents a time [minutes]. Fig. 13 is a plot of a
variability of average rates of the crystal quartz
oscillators. A vertical axis represents the
variability [%] of the average rates of the crystal
quartz oscillators immediately before switching, and a
10 horizontal axis represents the numbers of the crystal
quartz oscillators.

[0069] For the measurement of the deposition rate,
the measurement unit 17 described referring to Fig. 11
was used. As the crystal quartz oscillator (oscillator
15 20), a crystal quartz oscillator having a fundamental
frequency of 5 MHz was used.

[0070] As shown in Fig. 12, the measurement rate is
changed about ± 5 to 10% before and after switching the

crystal quartz oscillators. As shown in Fig. 13, the variability of the rate of each crystal quartz oscillator is not uniform, and it is difficult to measure stably the deposition rate.

5 [0071] The present inventors have focused that the above-described phenomenon is based on a fact that a quality of the organic layer deposited on the deposition surface of the crystal quartz oscillator is attributable to roughness of electrodes on a crystal quartz plate. The smaller the surface roughness of the deposition surface is, the more the organic layer uniformly deposits on the crystal quartz plate. In this way, it can decrease the variability in the measurement rate. By the present inventors, the deposition surface of the crystal quartz oscillator is smoothed to be a mirror surface, thereby inhibiting the variability in the measurement rate before and after switching the crystal quartz oscillators.

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[0072] Fig. 14 shows a comparison between a
variability in measurement rates by sequentially
changing 12 crystal quartz oscillators (hereinafter
referred to as sample 1) having a fundamental frequency
5 of 5 MHz and surface roughness (Ra) of 0.27 μm with a
variability in measurement rates by sequentially
changing 12 crystal quartz oscillators (herein referred
to as sample 2) having surface roughness (Ra) of 0.02
 μm .

10 [0073] As the electrode films 31, 32 (see Figs. 3,
4), a gold thin film having a thickness of 0.25 μm was
formed respectively on each surface of the samples 1, 2.
The surface roughness (Ra) of the electrode films 31,
32 was equivalent to the surface roughness (Ra) of the
15 crystal quartz oscillator.

[0074] As shown in Fig. 14, the sample 2 has the
variability in the measurement rate smaller than the
sample 1. It is therefore possible to measure the

deposition rate stably with high precision in the sample 2.

[0075] The lower the fundamental frequency of the crystal quartz oscillator is, the smaller the variability in the measurement rate is. Fig. 15 shows a comparison between a variability in measurement rates by sequentially changing 12 crystal quartz oscillators (hereinafter referred to as sample 3) having a fundamental frequency of 4 MHz and surface roughness (Ra) of 0.02 μm with that in the sample 2.

[0076] As described above, the nearer the deposition surface of the crystal quartz oscillator is and the lower the fundamental frequency of the crystal quartz oscillator is, the smaller the variability in the measurement rate can be. Thus, it is possible to measure the deposition rate stably with high precision.

[0077] The surface roughness (Ra) of the deposition surface of the crystal quartz oscillator is, for

example, 0.2 μm or less, preferably 0.1 μm or less.

Thus, it is possible to measure the deposition rate of the organic layer with high precision. If the

deposition surface of the crystal quartz oscillator is

5 a mirror surface (for example, 0.1 μm or less), the

fundamental frequency may be 5 MHz or less, more

preferably, 4 MHz or less, as described above.

[0078] While the embodiments of the present

technology have been described, it should be

10 appreciated that the present technology is not limited

to the above-described embodiments, and a variety of

modifications may be made without departing from the

scope of the present technology.

[0079] For example, in the above-described

15 embodiments, $\text{Alq}_3(\text{tris}(8\text{-quinolinato})\text{aluminum})$ is

illustrated as the organic layer. The organic layer is

not limited thereto. The present invention is

applicable to deposition of other organic layer such as

a synthesized resin layer.

[0080] In addition, in the above-described
embodiments, the vacuum deposition apparatus is
illustrated as the deposition apparatus, which is not
5 limited thereto. The present invention is applicable
to other deposition apparatus such as a sputtering
apparatus. In the case of the sputtering apparatus,
the organic material source is configured of a sputter
cathode including a target composed of an organic
10 material.

Description of Symbols

[0081]

- 10 deposition apparatus
- 11 vacuum chamber
- 15 12 organic material source
- 13 substrate holder
- 14 thickness sensor
- 16 shutter

	17	measurement unit
	20	oscillator
	41	oscillation circuit
	42	measurement circuit
5	43	controller
	W	substrate

Claims

[1] A deposition apparatus, comprising:

a vacuum chamber;

an organic material source arranged inside of the

5 vacuum chamber, the organic material source being

configured to be capable of discharging organic

material particles;

a substrate holder arranged facing to the organic

material source, the substrate holder being configured

10 to be capable of holding a substrate;

a thickness sensor arranged inside of the vacuum

chamber and including a crystal quartz oscillator

having a fundamental frequency of 4 MHz or less; and

a measurement unit that measures a thickness of an

15 organic layer deposited on the substrate over the

substrate holder based on a change in a resonant

frequency of the crystal quartz oscillator.

[2] The deposition apparatus according to claim 1,

wherein

the crystal quartz oscillator is an AT cut crystal quartz oscillator or an SC cut crystal quartz oscillator.

5 [3] The deposition apparatus according to claim 1 or 2, wherein

the measurement circuit includes

an oscillation circuit that oscillates the crystal quartz oscillator,

10 a reference signal generation circuit that oscillates a signal of a reference frequency,

a mixer circuit that mixes a signal outputted from the oscillation circuit with the signal of the reference frequency,

15 a counter that measures a frequency of a signal of a low frequency component from the signal generated at the mixer circuit, and

a controller that calculates an oscillating

frequency of the oscillation circuit based on a difference between the frequency measured by the counter and the reference frequency.

[4] The deposition apparatus according to any one of
5 claims 1 to 3, further comprising:

a shutter that can block discharging of the organic material particles from the organic material source to the substrate holder and the crystal quartz oscillator.

10 [5] The deposition apparatus according to any one of claims 1 to 4, wherein

the crystal quartz oscillator has a deposition surface on which the organic layer is deposited, the deposition surface having surface roughness (Ra) of 0.1
15 μm or less.

[6] A method of measuring a thickness of an organic deposited layer, comprising:

depositing organic material particles discharged

from an organic material source on a substrate;

depositing the organic material particles on a
crystal quartz oscillator that oscillates at a resonant
frequency of 4 MHz or less; and

5 measuring a thickness of the organic material
particles deposited on the substrate based on a change
in the resonant frequency of the crystal quartz
oscillator.

[7] A thickness sensor for an organic deposited layer
10 mounted to an organic deposition apparatus, comprising:

a crystal quartz oscillator having a fundamental
frequency of 4 MHz or less.

[8] The thickness sensor for an organic deposited
layer according to claim 7, wherein

15 the crystal quartz oscillator has a deposition
surface on which the organic layer is deposited, the
deposition surface having surface roughness (Ra) of 0.1
μm or less.