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Smith

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[54] **MULTI-LAYERED ATTENUATED PHASE SHIFT MASK AND A METHOD FOR MAKING THE MASK**

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[21] Appl. No.: **09/038,973**

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[51] **Int. Cl.**[6] **G03F 9/00**

[52] **U.S. Cl.** **430/5**

[58] **Field of Search** 430/322, 323, 430/324, 5

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(List continued on next page.)

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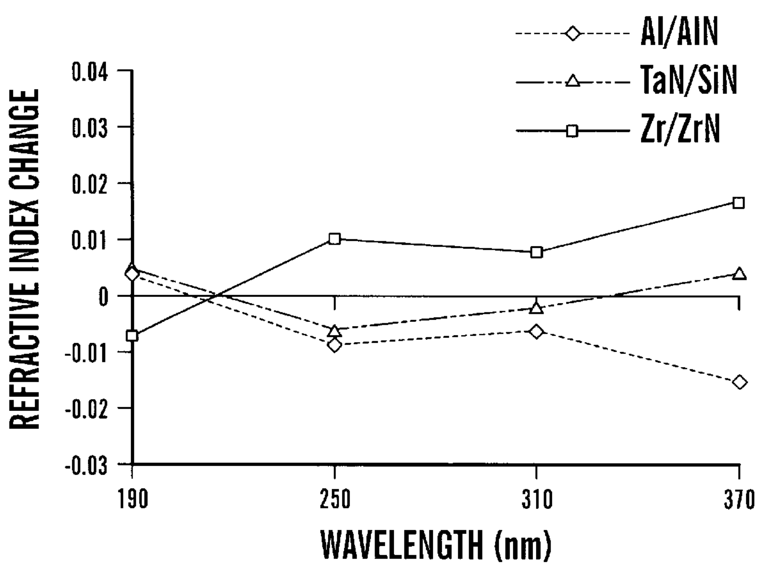
Attorney, Agent, or Firm—Nixon, Hargrave Devans & Doyle LLP

[57] **ABSTRACT**

The attenuated phase shift mask in accordance with one embodiment of the present invention for use in lithography at or below 0.20 μm and for use at wavelengths below 300 nm includes a substrate, a first layer disposed on the substrate, and a second layer disposed on the first layer. The first layer is a group IV, V or VI transitional metal nitride and the second layer is Si_xN_y or the first layer is Si_xN_y and the second layer is a group IV, V or VI transitional metal nitride. The mask may include a third layer disposed on the second layer and a fourth layer disposed on the second layer. The third layer is a group IV, V or VI transitional metal nitride if the second layer is Si_xN_y and is Si_xN_y if the second layer is a group IV, V or VI transitional metal. The fourth layer is a group IV, V or VI transitional metal nitride if the third layer is Si_xN_y and is Si_xN_y if the third layer is a group IV, V or VI transitional metal. The attenuated phase shift mask has a thickness between about 500 angstroms and 2000 angstroms, with the ratio of the thickness of the Si_xN_y to the group IV, V or VI transitional metal nitride being about 85 to 15.

20 Claims, 6 Drawing Sheets



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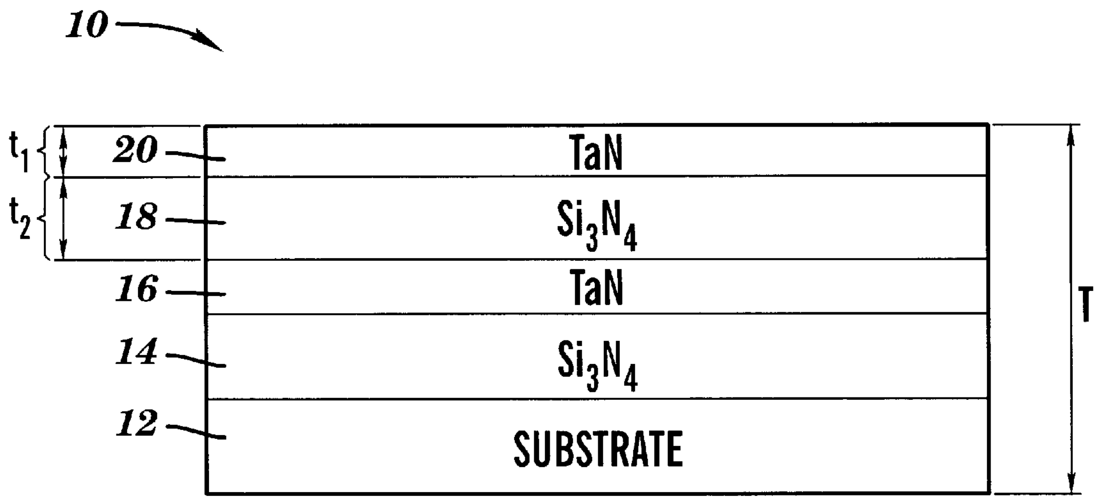

10
t1
t2
20
18
16
14
12
TaN
Si3N4
TaN
Si3N4
SUBSTRATE
T

FIG. 1

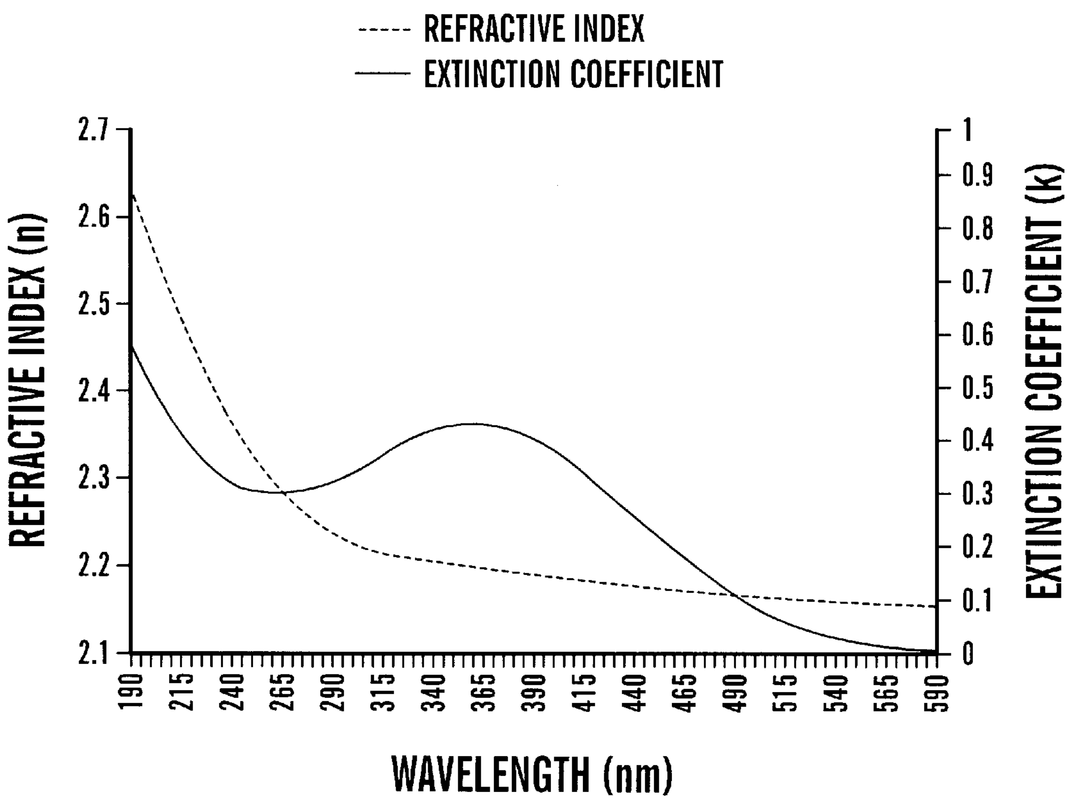

REFRACTIVE INDEX
EXTINCTION COEFFICIENT
REFRACTIVE INDEX (n)
EXTINCTION COEFFICIENT (k)
2.7
2.6
2.5
2.4
2.3
2.2
2.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
190 215 240 265 290 315 340 365 390 415 440 465 490 515 540 565 590
WAVELENGTH (nm)

FIG. 2A

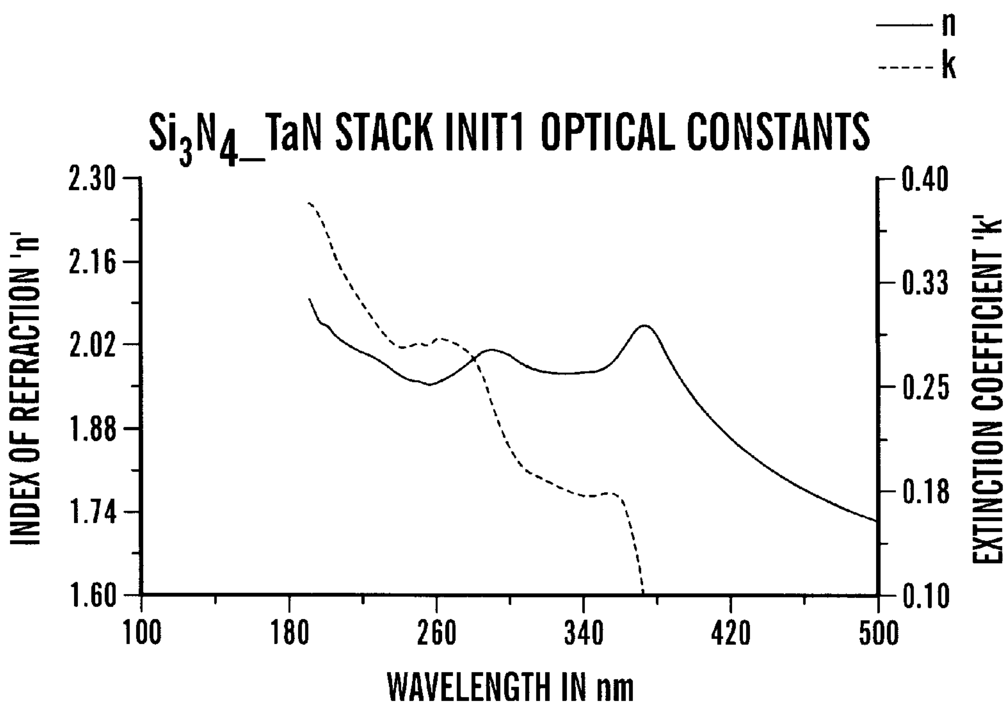

n
k
Si3N4_TaN STACK INIT1 OPTICAL CONSTANTS
2.30
2.16
2.02
1.88
1.74
1.60
INDEX OF REFRACTION 'n'
0.40
0.33
0.25
0.18
0.10
EXTINCTION COEFFICIENT 'k'
100
180
260
340
420
500
WAVELENGTH IN nm

FIG. 2B

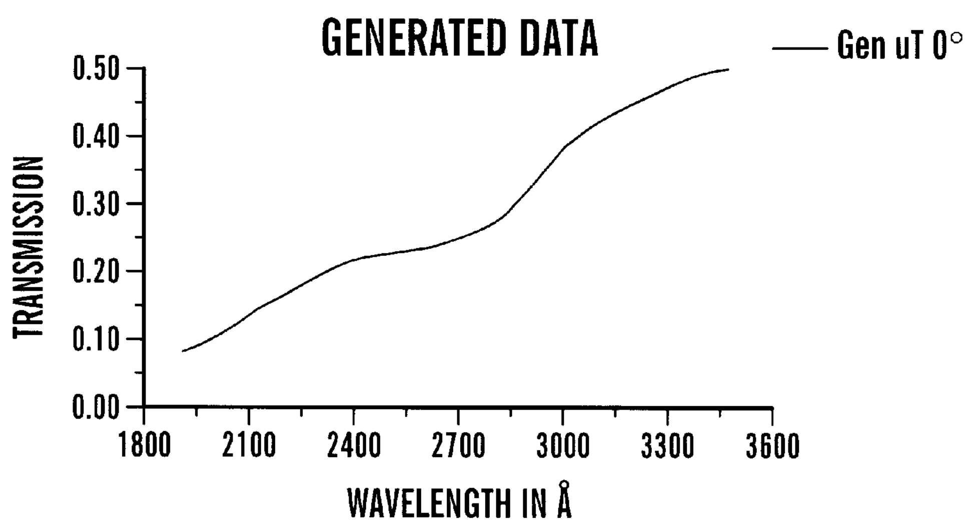

GENERATED DATA
Gen uT 0°
0.50
0.40
0.30
0.20
0.10
0.00
TRANSMISSION
1800
2100
2400
2700
3000
3300
3600
WAVELENGTH IN Å

FIG. 2C

FIG. 3A

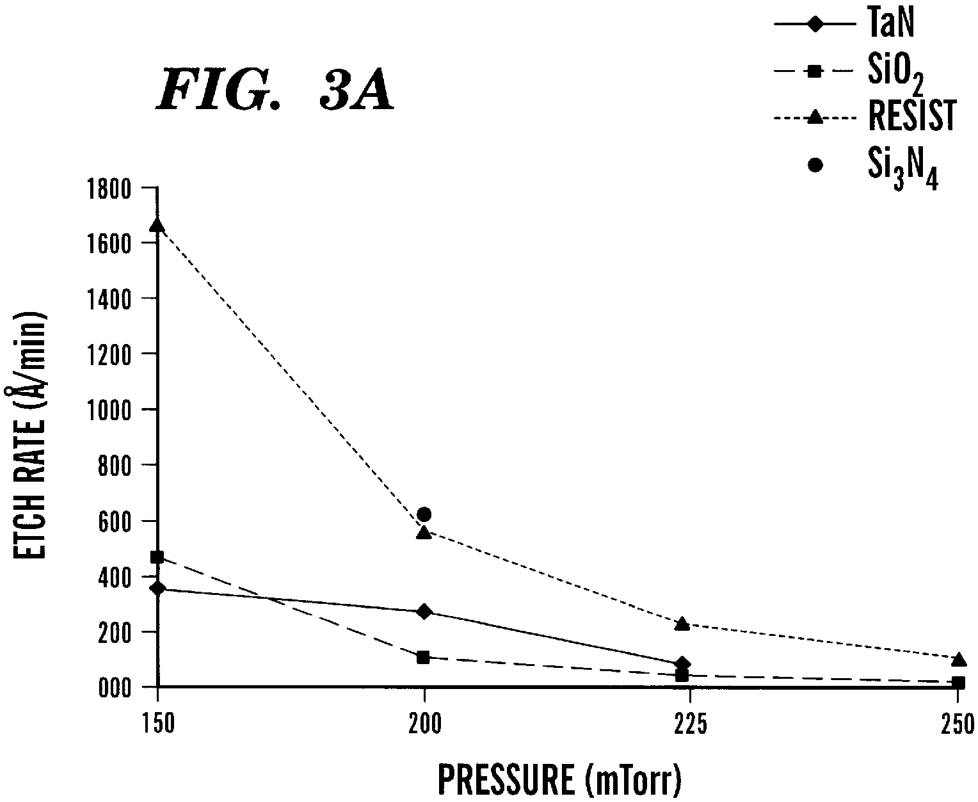
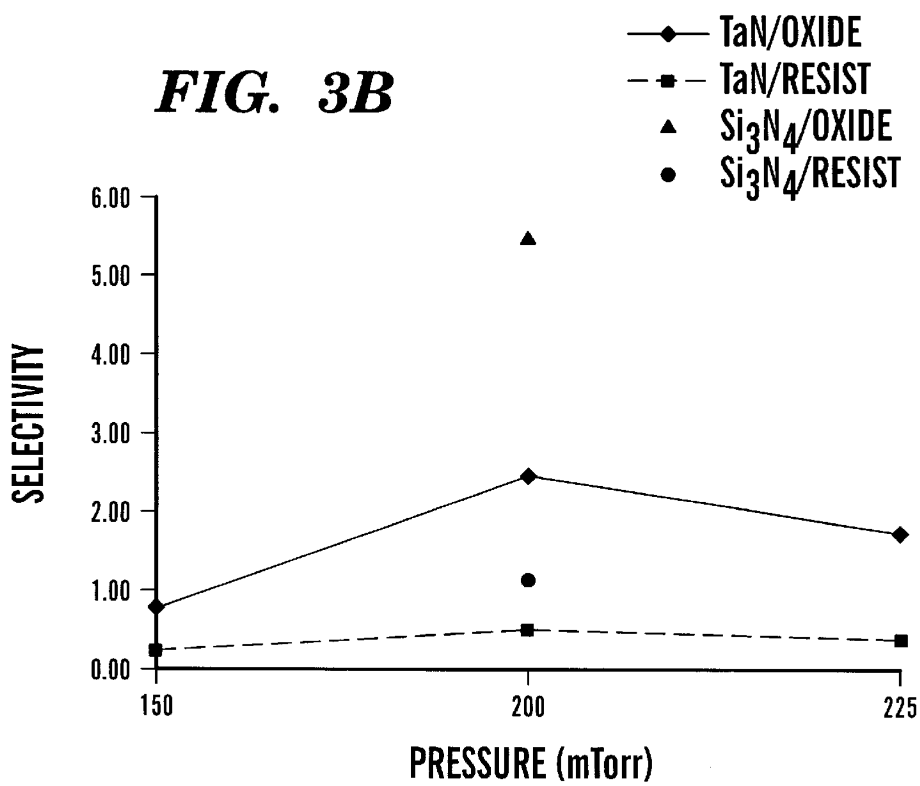

TaN
SiO_2
RESIST
Si_3N_4
1800
1600
1400
1200
1000
800
600
400
200
000
ETCH RATE (Å/min)
150
200
225
250
PRESSURE (mTorr)

FIG. 3B


TaN/OXIDE
TaN/RESIST
Si_3N_4/OXIDE
Si_3N_4/RESIST
6.00
5.00
4.00
3.00
2.00
1.00
0.00
SELECTIVITY
150
200
225
PRESSURE (mTorr)

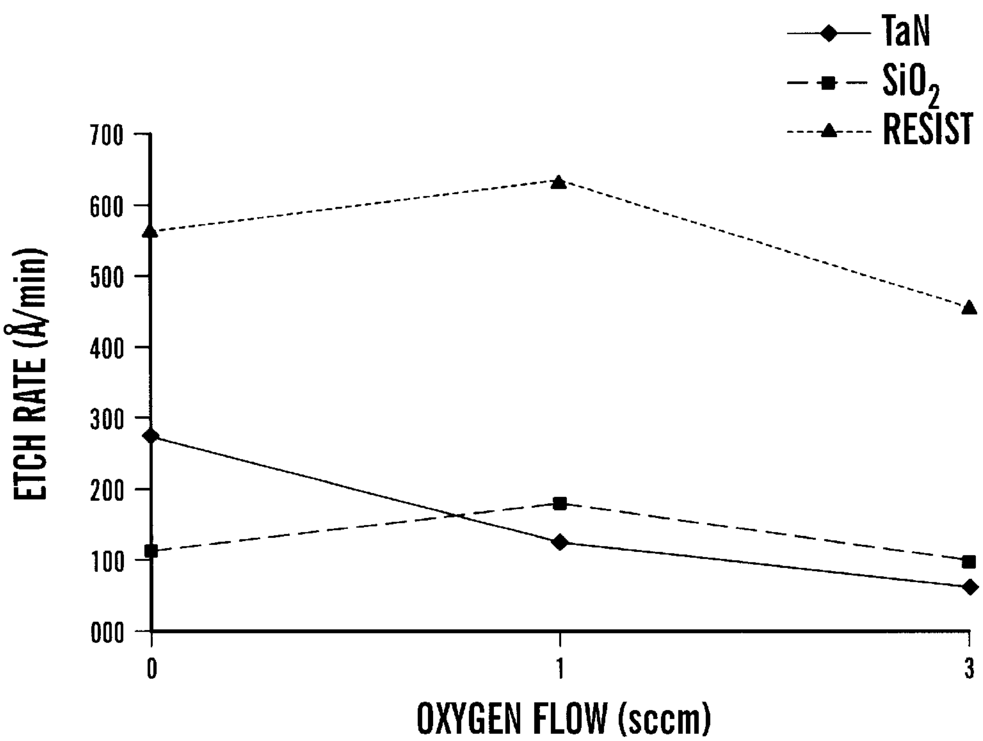

TaN
SiO2
RESIST
700
600
500
400
300
200
100
000
ETCH RATE (Å/min)
0
1
3
OXYGEN FLOW (sccm)

FIG. 3C

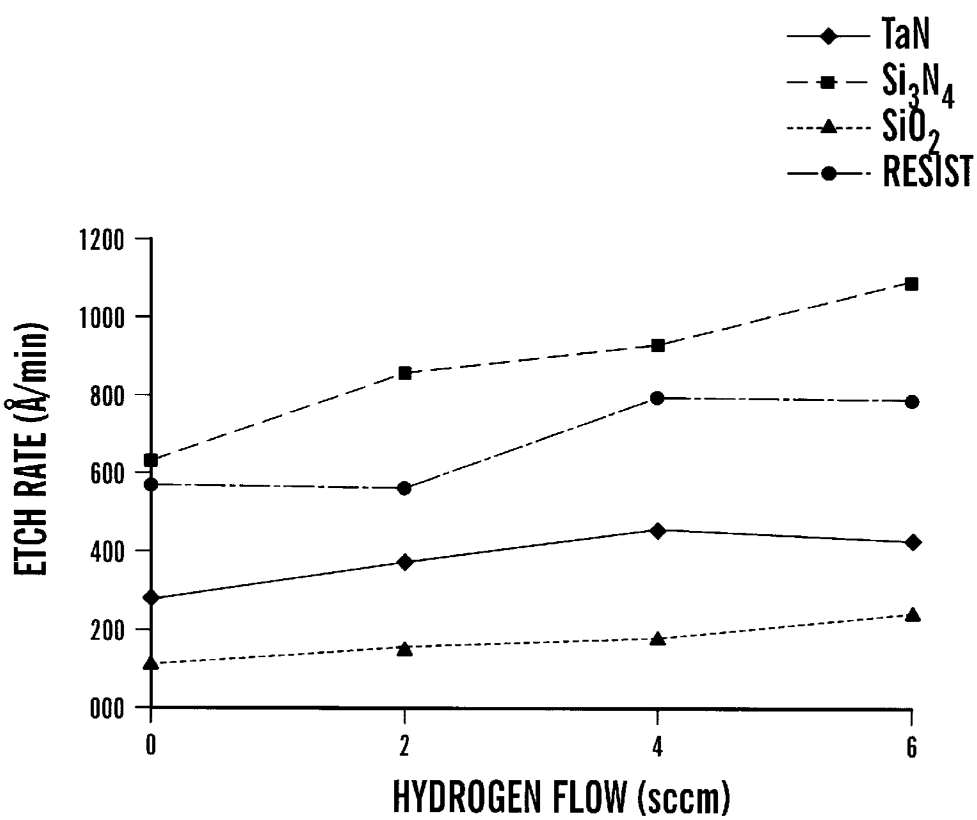
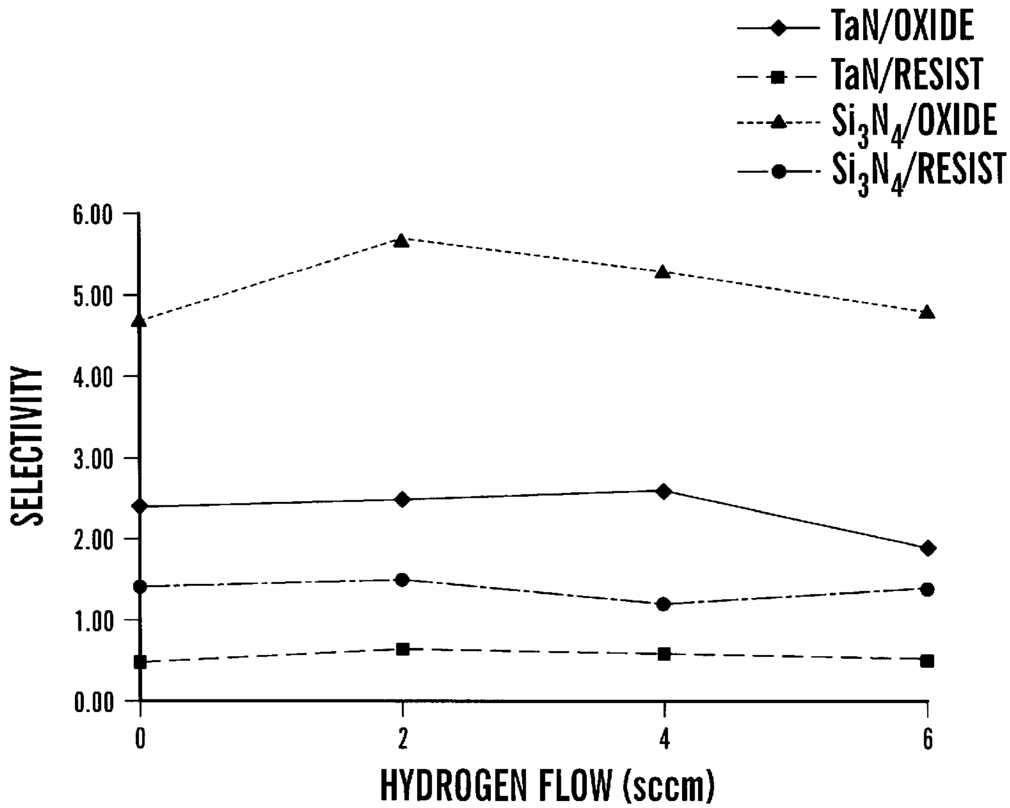

TaN
Si3N4
SiO2
RESIST
1200
1000
800
600
400
200
000
ETCH RATE (Å/min)
0
2
4
6
HYDROGEN FLOW (sccm)

FIG. 3D


TaN/OXIDE
TaN/RESIST
Si_3N_4/OXIDE
Si_3N_4/RESIST
6.00
5.00
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1.00
0.00
SELECTIVITY
0
2
4
6
HYDROGEN FLOW (sccm)

FIG. 3E

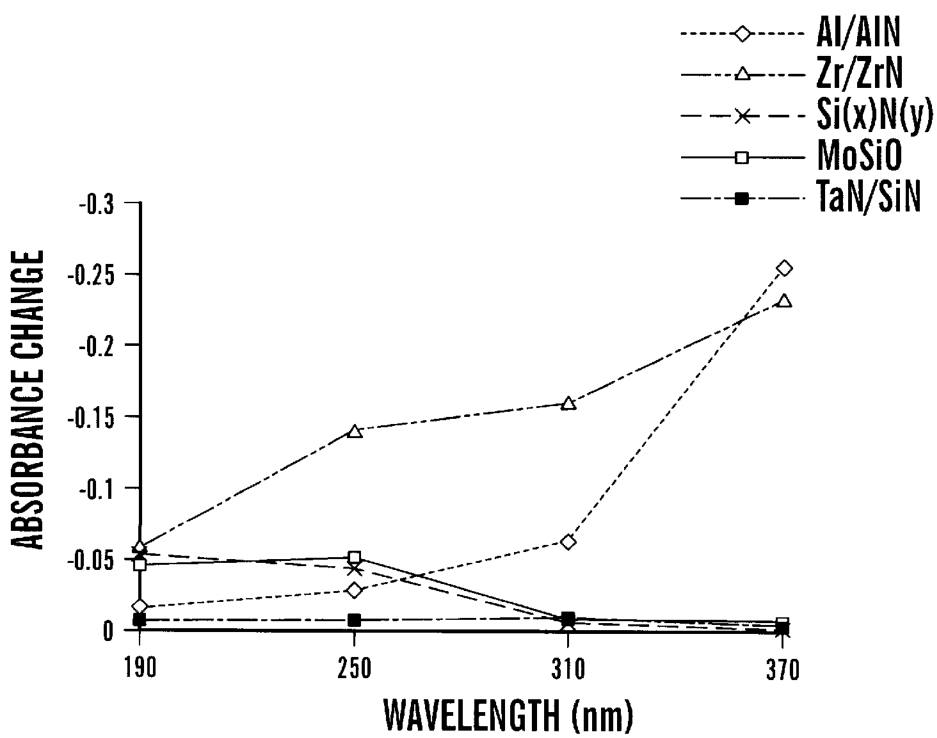
Al/AlN
Zr/ZrN
Si(x)N(y)
MoSiO
TaN/SiN
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
ABSORBANCE CHANGE
190
250
310
370
WAVELENGTH (nm)

FIG. 4A

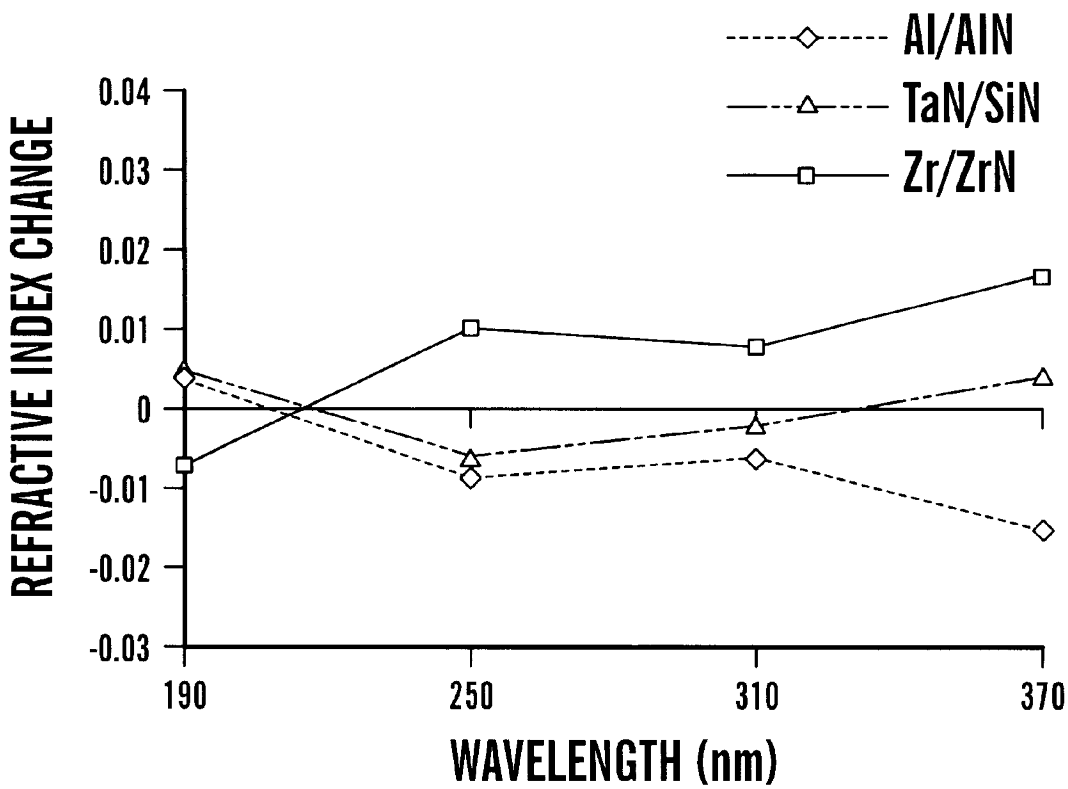
Al/AlN
TaN/SiN
Zr/ZrN
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
REFRACTIVE INDEX CHANGE
190
250
310
370
WAVELENGTH (nm)

FIG. 4B

MULTI-LAYERED ATTENUATED PHASE SHIFT MASK AND A METHOD FOR MAKING THE MASK

FIELD OF INVENTION

This invention relates generally to an attenuated phase-shift mask, and more particularly, to an attenuated phase shift mask comprising one or more alternating layers of tantalum nitride and silicon nitride suitable for use in lithography at or below 0.20 μm for wavelengths below 300 nm.

BACKGROUND OF THE INVENTION

Lithography is a process for producing a pattern on a semiconductor wafer. The pattern is produced by first exposing a pattern etched into a mask onto a semiconductor wafer coated with a resist material. The projected image of the pattern changes the composition of the resist material on the semiconductor wafer which is then removed to leave a matching pattern on the semiconductor wafer for further processing.

Typically, the masks used in lithography each include a substrate which is coated with a film. Depending upon the particular lithography application, the mask needs to satisfy several different requirements. The challenge is in finding a material or materials for use as the film which will satisfy these requirements.

For lithography at or below 0.20 μm and for use at wavelengths at or below 300 nm, an attenuated phase shift mask must have certain optical properties. These optical properties include a transmission between about 1% and 90%, an appropriate phase shift, e.g. a phase shift of about 180 degrees, a refractive index of between about 1.5 and 30, and extinction coefficient between about 0.1 and 1.0 and reflectivity below about 20 percent.

Additionally, the attenuated phase shift mask must have suitable plasma etch characteristics with selectivity to the underlying substrate and to the resist material. In other words, the film on the substrate of the attenuated phase shift mask must be made of a material or materials which can be etched to form the pattern to be replicated on semiconductor wafers without significant loss to the underlying substrate or to the resist material.

Since the intended application of the attenuated phase shift mask is for use with energetic ultra violet (UV) radiation from an excimer laser, the film on the substrate of the attenuated phase shift mask must be able to withstand both short and long term exposure to the UV radiation without significant optical degradation. Typically, damage to the film from exposure to radiation from the excimer laser can be shown to correlate with spatial and temporal peak power density as well as maximum power density and total energy density. Since single laser pulse energy levels from the excimer laser for lithography at or below 0.20 μm are typically low, damage to the attenuated phase shift mask generally results from total energy density from the excimer laser. Damage from long term or cumulative exposure can result from thermo-chemicals effects, the migration of defects, damage to microscopic defects, or surface particle formation. This damage can detrimentally effect the optical properties of the attenuated phase shift mask. Under stoichiometric films on substrates are particularly vulnerable to damage from exposure to radiation.

As yet, an appropriate material or materials for use as the film on the substrate of the attenuated phase shift mask for lithography at or below 0.20 μm and for use at wavelengths below 300 nm has not been found.

SUMMARY OF THE INVENTION

The attenuated phase shift mask in accordance with one embodiment of the present invention for use in lithography at or below 0.20 μm and for use at wavelengths below 300 nm includes a substrate, a first layer disposed on the substrate, and a second layer disposed on the first layer. The first layer is a group IV, V or VI transitional metal nitride and the second layer is Si_xN_y or the first layer is Si_xN_y and the second layer is a group IV, V or VI transitional metal nitride. The mask may include a third layer disposed on the second layer and a fourth layer disposed on the second layer. The third layer is a group IV, V or VI transitional metal nitride if the second layer is Si_xN_y and is Si_xN_y if the second layer is a group IV, V or VI transitional metal. The fourth layer is a group IV, V or VI transitional metal nitride if the third layer is Si_xN_y and is Si_xN_y if the third layer is a group IV, V or VI transitional metal. The attenuated phase shift mask has a thickness between about 500 angstroms and 2000 angstroms with the ratio of the thickness of the Si_xN_y to the group IV, V or VI transitional metal nitride being about 85 to 15.

The attenuated phase shift mask in accordance with the present invention provides a number of advantages including providing a mask with multiple layers with appropriate optical properties for use at deep ultraviolet wavelengths, i.e. wavelengths at or below about 300 nm. More specifically, the attenuated phase shift mask provides a transmission between about 1% and 90%, an appropriate phase shift, e.g. a phase shift of about 180 degrees, and a refractive index between about 1.5 and 3.0. Even though the attenuated phase shift mask has multiple alternating layers, the use of sub-wavelength thicknesses for the film comprised of the multiple layers allows the mask to closely approach the optical properties of a mask with a homogeneous layer of material.

The attenuated phase shift mask also provides suitable etch rates and selectivity. The alternating layers of Si_xN_y and a group IV, V or VI transitional metal nitride on the substrate can be etched using techniques, such as plasma reactive ion etching, without significant loss of the underlying substrate or the resist material.

Further, the attenuated phase shift mask is able to withstand both the short and long term effects of exposure to radiation from and excimer laser at or below 300 nm without significant optical degradation. When exposed to prolonged radiation, the attenuated phase shift mask in accordance with the present invention only experiences a phase shift change of only about +/− one degree or less, a transmission modification of only about 0.5 percent or less, and a change in refractive index of only about 0.6 percent or less. The stoichiometric nature of the alternating layers of Si_xN_y and TaN on the substrate, makes the attenuated phase shift mask inherently less prone to damage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of an attenuated phase shift mask in accordance with one embodiment of the present invention;

FIG. **2A** is a graph illustrating the refractive index and extinction for the attenuated phase shift mask shown in FIG. **1**;

FIG. **2B** is a graph illustrating the index of refraction for the attenuated phase shift mask shown in FIG. **1** as a function of wavelength;

FIG. 2C is a graph illustrating the index of transmission for the attenuated phase shift mask shown in FIG. **1** as a function of wavelength;

FIG. **3**A is a graph illustrating the etch rates of TaN, SiO_2, Si_3N_4, and a resist material as a function of pressure;

FIG. **3**B is a graph illustrating the selectivity of TaN and Si_3N_4 to SiO_2 and to resist as a function of pressure;

FIG. **3**C is a graph illustrating the etch rates of TaN, SiO_2 and a resist material as a function of oxygen flow;

FIG. **3**D is a graph illustrating the etch rates of TaN, Si_3N_4, SiO_2 and a resist material as a function of hydrogen flow;

FIG. **3**E is a graph illustrating the selectivity of TaN and Si_3N_4 to SiO_2 and to a resist material as a function of hydrogen flow;

FIG. **4**A is a graph illustrating the absorbance change in the attenuated phase shift mask shown in FIG. **1** as a function of wavelength; and

FIG. **4**B is a graph illustrating the refractive index change in the attenuated phase shift mask shown in FIG. **1** as a function of wavelength.

DETAILED DESCRIPTION

An attenuated phase shift mask **10** in accordance with one embodiment of the present invention for use in lithography is illustrated in FIG. **1**. The attenuated phase shift mask **10** includes a substrate **12**, a first layer **14** disposed on the substrate, and a second layer **16** disposed on the first layer **14**. The first layer **14** is a group IV, V or VI transitional metal nitride and the second layer **16** is Si_xN_y or the first layer **14** is Si_xN_y and the second layer **16** is a group IV, V or VI transitional metal nitride. The mask may include a third layer **18** disposed on the second layer **16** and a fourth layer **20** disposed on the second layer **16**. The third layer **18** is a group IV, V or VI transitional metal nitride if the second layer **16** is Si_xN_y and is Si_xN_y if the second layer **16** is a group IV, V or VI transitional metal. The fourth layer **20** is a group IV, V or VI transitional metal nitride if the third layer **18** is Si_xN_y and is Si_xN_y if the third layer **18** is a group IV, V or VI transitional metal. The attenuated phase shift mask **10** in accordance with the present invention provides a number of advantages including providing a mask with appropriate optical characteristics, excellent etch selectivity with respect to the substrate and resist material, and the ability to withstand radiation at or below 300 nm with out significant optical degradation.

Referring to FIG. **1**, the attenuated phase shift mask **10** includes the substrate **12**. In this particular embodiment, the substrate **12** is made of fused silica, although other types of materials, such as quartz, fluorides, or other glasses, can be used as the substrate **12** as needed or desired. Preferably, the substrate **12** has a thickness between about 500 angstroms and 2000 angstroms.

A stacked approach of layers made of radiation stable and good etch selectivity materials has been taken to form a TaN/Si_xN_y film on the substrate **12**, where stoichiometric nitrides allow for appropriate optical properties. In this particular embodiment, the film includes a first layer **14** of silicon nitride is disposed on the substrate **12**, a second layer **16** of tantalum nitride is disposed on the first layer **14** of silicon nitride, a third layer **18** of silicon nitride is disposed on the second layer **16** of tantalum nitride, and a fourth layer **20** of tantalum nitride is disposed on the third layer **18** of silicon nitride. Although in this particular embodiment four alternating layers **14**, **16**, **18**, and **20** of silicon nitride and tantalum nitride are illustrated, the mask could have more than four layers or could have as few as one layer of each material as needed or desired. Additionally, the order in which the silicon nitride and tantalum nitride are formed on the substrate can be switched as needed or desired. Further, although tantalum nitride (TaN) and silicon nitride Si_3N_4) are shown, any group IV, V or VI transitional metal nitride can be used and any silicon nitride (Si_xN_y) can be used. One of the advantages the present invention is that the layers **14**, **16**, **18**, and **20** of the mask **10** not only have the appropriate optical properties for lithography at or below 0.20 μm and for use at wavelengths below 300 nm, but also are made from materials which are radiation stable and etch selective. In other words, the materials for the layers **14**, **16**, **18**, and **20** remain optically stable even when exposed to the short and long terms effects of radiation from a source, such as an excimer laser, under which the mask **10** is normally exposed during their useful life and do not experience a significant loss to the underlying substrate or to the resist material when etched. By way of example only, radiation stable materials for the mask **10** do not experience a transmission change of more than about 0.5% during the useful life of the mask **10** and have an etch selectivity of about 5:1 or more with respect to the substrate **12** and 2:1 or more with respect to the resist material.

The optical properties of the attenuated phase shift mask with the substrate **12** and the alternating four layers **14**, **16**, **18** and **20** are illustrated in FIGS. **2**A–**2**C and are set forth in the table below:

Film	n(193)	k(193)	thickness (Å)	Transmission	Reflectivity
TaN/SiN	2.62	0.57	595	11%	19%

Although reflectivity of the film for the attenuated phase shift mask **10** in this example is 19%, this number can be reduced simply by placing the lower index layer at the top surface, i.e. the surface opposite from the substrate **12**.

Preferably, the attenuated phase shift mask **10** has a thickness T ranging between about 500 angstroms and 2000 angstroms. More preferably, the attenuated phase shift mask **10** has a thickness F of about 600 angstrom. The use of a sub-wavelength thickness for the combined thickness of the layers **14**, **16**, **18**, and **20** of the attenuated phase shift mask **10** allows the mask **10** to approach the optical properties of a mask with a homogeneous layer of material. Each layer **16** and **20** of tantalum nitride has a thickness t_1 and each layer **14** and **18** of silicon nitride as a thickness of t_2. In this particular embodiment, the thickness t_1 ranges between about five angstroms and fifty angstroms and the thickness t_2 ranges between about thirty angstroms and three-hundred angstroms. Preferably, the ratio of the thickness of the silicon nitride layer to the tantalum nitride is about 85 to 15 (85:15).

The attenuated phase shift mask **10** in accordance with the present invention provides several advantages, including providing appropriate optical properties for lithography at or below 0.20 μm for wavelengths below 300 nm. The attenuated phase shift mask **10** also provides a suitable etch rate and selectivity. Preferably, the mask **10** is etched with a fluorine-based etching plasma, such as SF_6 or CF_4 combined with oxygen or hydrogen which allows for maximum etch rate, selectivity, and anisotropy for the attenuated phase shift mask **10**. The attenuated phase shift mask **10** is also able to withstand both the short and long term effects of exposure to radiation from an excimer laser at or below 300 nm without significant optical degradation. These advantages are illustrated in the experiments discussed below.

EXPERIMENTS

Background for Experiments

Deposition of materials to from the films on the substrates was carried out by rf magnetrom sputtering of 8" targets in argon with nitrogen or oxygen. Films were sputtered at power levels between 500W and 1500 W with an evacuated pressure of $\sim 1\times10^{-7}$ Torr onto fused silica substrates approximately 1.5×1.5×0.090". Prior to sputtering, substrates were cleaned and dehydrated to reduce reactivity with oxygen. Films were deposited without additional substrate heating.

Optical evaluation of reflectance and transmittance was carried out with UV/visible spectrophotometry at wavelengths from 190 to 900 nm using a Perkin Elmer Lambda 11 spectrophotometer. From these measurements, refractive index and extinction coefficient data was extracted through solution of Fresnel equations. Additionally, spectroscopic ellipsometry was conducted on TaN and Si_3N_4 films using a Woollam WVASE system. Thickness measurement was performed using profilometry (Dektak) and atomic force microscopy.

Plasma etching was carried out in a modified Plasma Therm RIE system utilizing a single wafer parallel plate chamber. The lower electrode is 15.2 cm in diameter and was not cooled during operation. The electrode was modified to allow for uniform etching of small fused silica samples. The chamber was not load locked and was pumped down typically below 10^{-5} torr before processing. Samples of thermal silicon dioxide (SiO_2 over silicon) were etched for evaluation of selectivity. Etch rates were determined by measuring etch step heights on a Dektak profilometer. Etch gases studied included fluorine, chlorine, and bromine chemistries (Cl_2 CCl_4, HBr, Cl_2/CF_4, BCl_3, SF_6, CF_4, and combinations with Ar and H).

Examination of Etch Rates and Selectivity

An investigation of the etching properties of the film of layers **14**, **16**, **18**, and **20** on a substrate **12** for attenuated phase shift mask **10** was conducted by evaluating the etch properties of TaN and Si_3N_4 and etch selectivity to SiO_2 and resist material when etched with SF_6. In this experiment, the power was held constant at about 200 Watts and the flow of SF_6 was 30 sccm.

Referring to FIGS. **3**A and **3**B, the etch rates of TaN, SiO_2, and resist material as a function of pressure from 150 to 250 mTorr and the etch rate of Si_3N_4 at 200 mTorr and the selectivity of TaN to SiO_2 and TaN to resist material are illustrated. As these graphs illustrate, the etch rates of TaN, SiO_2 and resist decrease with pressure, but selectivity of TaN to SiO_2 and TaN to resist material is maximum near 200 mTorr at 2.5:1 and 0.5:1 respectively.

Referring to FIG. **3**C, the contribution of oxygen to etching the film of layers **14**, **16**, **18**, and **20** for attenuated phase shift mask **10** was investigated next. As illustrated, the addition of oxygen, increases the etch rate of SiO_2, but decreases the etch rate of tantalum nitride TaN. The increase in the etch rate of SiO_2 can be attributed to an increase in fluorine radicals. The detrimental decrease in the etch rate of tantalum nitride may be due to dilution and the lower volatility of tantalum oxifluorides compared to tantalum fluorides.

Referring to FIG. **3**D, the addition of hydrogen to the fluorine etch process was also investigated for Si_3N_4, TaN, resist material, and SiO_2 for hydrogen flow from 0 to 6 sccm at 200 W, 200 m Torr, and 30 sccm SF6. When etching SiO_2, the addition of hydrogen can be offset by the liberation of oxygen and thus has little effect on etch rate. However, the etching of other films can be impacted as hydrogen (H_2) scavenges fluorine. This can modify the availability of other gas constituents and help increase physical etch activity.

Referring to FIG. **3**E, the selectivity ratios of TaN and Si_3N_4 to resist material and to SiO_2 are illustrated. As the graph illustrates, selectivity values are maximized at a hydrogen flow of 2 sccm.

Etch results for the film of layers **14**, **16**, **18**, and **20** on a substrate **12** for attenuated phase shift mask **10** are summarized in the table below:

Film	Etch chemistry	Fused silica	Resist	Comments
TaN/SiN	SF_6/H	>5:1	>2:1	Good selectivity

As this investigation illustrates, an attenuated phase shift mask **10** with a film of alternating layers **14**, **16**, **18**, and **20** of tantalum nitride and silicon nitride on a substrate **12** can allow for high etch rates in SF_6/H plasma chemistries with adequate selectivity to both fused silica and resist material. The etching process and testing results of the film of layers **14**, **16**, **18**, and **20** on a substrate **12** for attenuated phase shift mask **10** described above along with other tests are explained in greater detail in Bruce Smith, et al., "Plasma reactive ion etching of 193 nm attenuated phase shift mask materials," J. Vac. Sci. Technol. B. (1997), which is herein incorporated by reference.

Examination of Optical Degradation From Exposure

An investigation of the stability of attenuated phase shift masks, including an attenuated phase shift mask **10** with a film of alternating layers **14**, **16**, **18**, and **20** of tantalum nitride and silicon nitride on a substrate **12**, was conducted. A Cymer CS2LS excimer laser running at 193 nm with ArF with pulse width near 20 ns at 100 Hz repetition rate was used as the source of radiation. Radiation at 193 nm was selected because it was likely to lead to the greatest extent of modification to the masks via cumulative damage mechanisms and oxidative effects. The attenuated phase shift masks were subjected to cumulative exposure levels that would typically be experienced during the lifetime of an attenuated phase shift mask. Using a 25 mJ/cm^2 resist sensitivity value and 40% throughout for a five times (5×) reduction optical system, a 2.5 mW/cm^2 nominal mask plane irradiance is required for 100 pulse wafer exposures. Films were subjected to 25 mW/cm^2 at 100 Hz to deliver exposure energy density values up to $3\times10^3 J/cm^2$. Transmission, reflectance, and ellipsometric measurements were made on the attenuated phase shift masks before and after exposure to 193 nm radiation.

Referring to FIG. **4**A, a plot of the resulting changes in absorbance of five different films on substrates, including a film of alternating layers **14**, **16**, **18**, and **20** of tantalum nitride and silicon nitride on a substrate **12**, is illustrated. The values in the graph were determined from n and k values fitted to measured data. For a 10% transmitting film in an attenuated phase shift mask, an absorbance change of 0.049 corresponds to a 0.5% transmission change. As illustrated in the graph, the stoichiometric TaN/Si_3N_4 film (i.e. the film of alternating layers **14**, **16**, **18**, and **20** of tantalum nitride and silicon nitride on a substrate **12**) exhibits no optical degradation at the levels of radiation tested.

Referring to FIG. **4**B, a plot of the resulting changes in absorbance of five different films on substrates, including a film of alternating layers **14**, **16**, **18**, and **20** of tantalum nitride and silicon nitride on a substrate **12**, is illustrated. As illustrated in the graph, the film of alternating layers **14**, **16**, 18, and 20 of tantalum nitride and silicon nitride on a substrate 12 only experienced a refractive index change of 0.0056. Accordingly, when exposed to short and long term radiation from an excimer laser, the attenuated phase shift mask 10 with a film of alternating layers 14, 16, 18, and 20 of tantalum nitride and silicon nitride on a substrate 12 shows no significant modification to optical properties and is attractive as a stable material for mask application.

The investigation of the effects short and long term radiation from an excimer laser on the attenuated phase shift mask 10 with a film of alternating layers 14, 16, 18, and 20 of tantalum nitride and silicon nitride on a substrate 12 as well as on other attenuated phase shift masks is explained in greater detail in Bruce Smith, et al., "Plasma reactive ion etching of 193 nm attenuated phase shift mask materials" J. Vac. Sci. Technol. B 15 [6] p. 2444 (1997) and Bruce Smith, et al., "The Effects of Excimer Laser Radiation on Attenuated Phase-Shift Masking Materials" Id. at 2259 which are herein incorporated by reference.

Summary

For an attenuated phase shift mask for use in lithography at or below 0.20 μm and for use at wavelengths below 300 nm to be considered viable, the mask must have appropriate optical properties, suitable plasma etch characteristics and selectivities, and the ability to withstand short and long term exposure to radiation from an excimer laser without significant optical degradation. As illustrated in the examples above, an attenuated phase shift mask with a film comprising alternating layers of TaN and Si_3N_4 on a substrate satisfies each of these requirements.

Having thus described the basic concept of the invention, it will be rather apparent to those skilled in the art that the foregoing detailed disclosure is intended to be presented by way of example only, and is not limiting. Various alterations, improvements, and modifications will occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested hereby, and are within the spirit and scope of the invention. Accordingly, the invention is limited only by the following claims and equivalents thereto.

What is claimed is:

1. An attenuated phase shift mask for use in lithography comprising:

a substrate;

a first layer disposed on the substrate; and

a second layer disposed on the first layer, wherein the first layer is a group IV, V or VI transitional metal nitride and the second layer is silicon nitride Si_xN_y or the first layer is silicon nitride Si_xN_y and the second layer is a group IV, V or VI transitional metal nitride.

2. The attenuated phase shift mask according to claim I further comprising a third layer disposed on the second layer, the third layer is a group IV, V or VI transitional metal nitride if the second layer is silicon nitride Si_xN_y and is silicon nitride Si_xN_y if the second layer is a group IV, V or VI transitional metal.

3. The attenuated phase shift mask according to claim 2 further comprising a fourth layer disposed on the third layer, the fourth layer is a group IV, V or VI transitional metal nitride if the third layer is silicon nitride Si_xN_y and is silicon nitride Si_xN_y if the third layer is a group IV, V or VI transitional metal.

4. The attenuated phase shift mask according to claim 3 wherein the group IV, V or VI transitional metal nitride comprises TaN and the silicon nitride Si_xN_y comprises Si_3N_4.

5. The attenuated phase shift mask according to claim 1 wherein the mask has a thickness between about 500 angstroms and 2000 angstroms.

6. The attenuated phase shift mask according to claim 1 wherein the ratio of the thickness of the silicon nitride Si_xN_y to the group IV, V or VI transitional metal nitride is about 85:15.

7. A method for making a multi-layered attenuated phase shift mask for use in lithography, the method comprising:

providing a substrate;

disposing a first layer on the substrate; and

disposing a second layer on the first layer, wherein the first layer is a group IV, V or VI transitional metal nitride and the second layer is silicon nitride Si_xN_y or the first layer is silicon nitride Si_xN_y and the second layer is a group IV, V or VI transitional metal nitride and the first and second materials are radiation stable and etch selective.

8. The method according to claim 7 further comprising disposing a third layer on the second layer, the third layer is a group IV, V or VI transitional metal nitride if the second layer is silicon nitride Si_xN_y and is silicon nitride Si_xN_y if the second layer is a group IV, V or VI transitional metal.

9. The method according to claim 8 further comprising disposing a fourth layer on the third layer, the fourth layer is a group IV, V or VI transitional metal nitride if the third layer is Si_xN_y and is silicon nitride Si_xN_y if the third layer is a group IV, V or VI transitional metal.

10. The method according to claim 9 wherein the group IV, V or VI transitional metal nitride comprises TaN and the silicon nitride Si_xN_y comprises Si_3N_4.

11. The method according to claim 8 wherein the mask is formed to have a thickness between about 500 angstroms and 2000 angstroms.

12. The method according to claim 9 wherein the mask is formed so that the ratio of the thickness of the Si_xN_y to the group IV, V or VI transitional metal nitride is about 85:15.

13. A lithography system for producing a pattern on a semiconductor wafer, the lithography system comprising:

a source of radiation;

a mask comprising a substrate, a first layer disposed on the substrate; and a second layer disposed on the first layer, wherein the first layer is a group IV, V or VI transitional metal nitride and the second layer is silicon nitride Si_xN_y or the first layer is silicon nitride Si_xN_y and the second layer is a group IV, V or VI transitional metal nitride; and

a projection system positioned between the mask and the wafer.

14. The lithography system according to claim 13 wherein the mask further comprises:

a third layer disposed on the second layer, the third layer is a group IV, V or VI transitional metal nitride if the second layer is silicon nitride Si_xN_y and is silicon nitride Si_xN_y if the second layer is a group IV, V or VI transitional metal; and

a fourth layer disposed on the third layer, the fourth layer is a group IV, V or VI transitional metal nitride if the third layer is silicon nitride Si_xN_y and is silicon nitride Si_xN_y if the third layer is a group IV, V or VI transitional metal.

15. The lithography system according to claim 14 wherein the group IV, V or VI transitional metal nitride comprises TaN and the silicon nitride Si_xN_y comprises Si_3N_4.

16. The lithography system according to claim 14 wherein the mask has a thickness between about 500 angstroms and 2000 angstroms.

17. The lithography system according to claim 14 wherein the ratio of the thickness of the silicon nitride Si_xN_y to the group IV, V or VI transitional metal nitride is about 85:15.

18. The attenuated phase shift mask according to claim 1 wherein the first and the first and second materials are radiation stable and etch selective.

19. The attenuated phase shift mask according to claim 18 wherein the etch selective first and second materials have an etch selectivity of about 5:1 or more to the substrate and 2:1 or more to the resist material.

20. The attenuated phase shift mask according to claim 18 wherein the radiation stable first and second materials experience a transmission change of no more than about 0.5% during the useful life of the mask.

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