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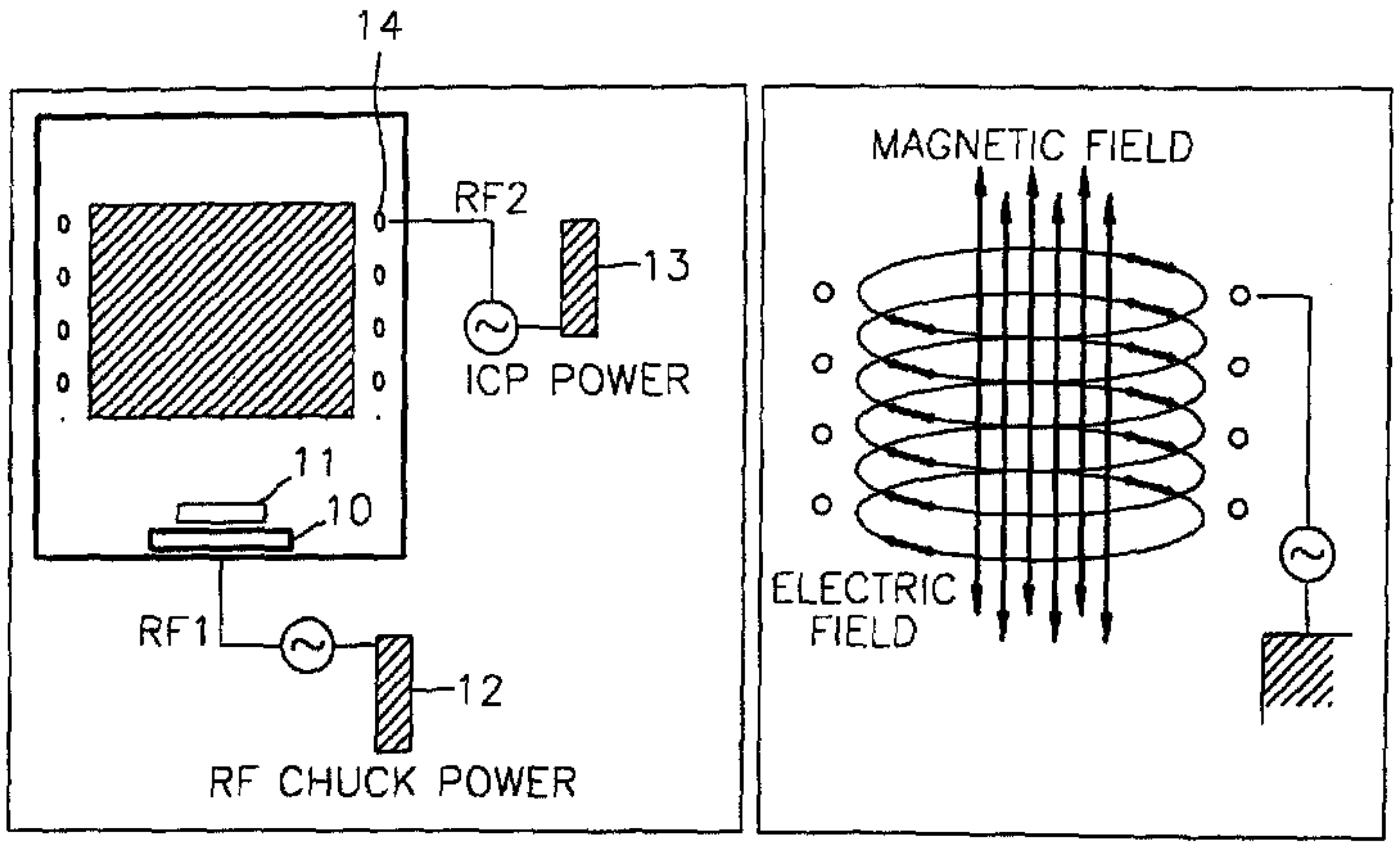
(54) GUIDE D'ONDES OPTIQUES EN MATERIAU POLYMERE ET PROCEDE DE FABRICATION CORRESPONDANT

(54) POLYMER OPTICAL WAVEGUIDE AND METHOD FOR FABRICATING THE SAME



(57) La présente invention se rapporte à un guide d'ondes optiques en matériau polymère et à son procédé de fabrication. Ce guide d'ondes optiques possède une âme fabriquée dans un matériau polymère contenant 12 à 37 % en poids de fluor (F), par rapport au poids total du polymère, et comportant des motifs répétitifs incluant au moins deux groupes fonctionnels -C(=O)-N-C(=O) et au moins quatre groupes fonctionnels -N-C(=O)-, et une gaine optique en contact avec l'âme et fabriquée dans un matériau polymère ayant un indice de réfraction inférieur à celui du polymère constituant l'âme. Si l'on grave une couche de l'âme conformément au procédé de gravure par plasma inductif (ICP), on parvient à graver au moins trois fois plus rapidement que par la technique classique de gravure par ions réactifs (RIE). On améliore ainsi les

(57) The present invention discloses a polymer optical waveguide and a method of fabricating the same. The polymer optical waveguide comprises a core formed of polymer containing fluoride (F) of a 12-37 wt.% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups; and a cladding in contact with the core and formed of polymer having a refractive index lower than the polymer for forming the core. If a core layer is etched according to the ICP etching method, the etch rate becomes at least three times faster than that of the conventional RIE etching method. Also, etching characteristics including uniformity of an etched plane and vertical profile are improved, thereby reducing

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caractéristiques de gravure et notamment l'uniformité du plan gravé et du profil vertical, ce qui permet de réduire les dégâts occasionnés au guide d'ondes optiques. On peut ainsi réduire la perte de diffusion de la lumière du guide d'ondes optiques. L'invention se rapporte également à un procédé de fabrication d'un guide d'ondes optiques en matériau polymère tel que celui décrit ci-dessus, qui est adapté à la fabrication en série de guides d'ondes optiques en matériau polymère.

damage to an optical waveguide. Thus, the light scattering loss of the optical waveguide can be minimized. Also, the method for fabricating of a polymer optical waveguide according to the present invention is useful for mass production of polymer optical waveguides.

PCT

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(54) Title: POLYMER OPTICAL WAVEGUIDE AND METHOD FOR FABRICATING THE SAME

(57) Abstract

The present invention discloses a polymer optical waveguide and a method of fabricating the same. The polymer optical waveguide comprises a core formed of polymer containing fluoride (F) of a 12-37 wt.% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups; and a cladding in contact with the core and formed of polymer having a refractive index lower than the polymer for forming the core. If a core layer is etched according to the ICP etching method, the etch rate becomes at least three times faster than that of the conventional RIE etching method. Also, etching characteristics including uniformity of an etched plane and vertical profile are improved, thereby reducing damage to an optical waveguide. Thus, the light scattering loss of the optical waveguide can be minimized. Also, the method for fabricating of a polymer optical waveguide according to the present invention is useful for mass production of polymer optical waveguides.

POLYMER OPTICAL WAVEGUIDE
AND METHOD FOR FABRICATING THE SAME

Technical Field

The present invention relates to a polymer optical waveguide and a method for fabricating the same, and more particularly, to a polymer optical waveguide which can minimize damage to an optical waveguide by improving the etch rate, uniformity and vertical profile of an etched plane, and a method for fabricating the polymer optical waveguide.

Background Art

In an optical waveguide formed of an optical polymer having a low light loss in an optical communication wavelength region containing a near infrared region, it is necessary to minimize light scattering loss at a boundary between a core and a cladding. In order to minimize light scattering loss, it is imperative to appropriately control characteristics such as the uniformity of a side wall of an etched waveguide, the vertical profile of the side wall of an etched waveguide and the etch rate, when etching an optical waveguide. Since such characteristics are directly affected by the plasma density and ion energy during etching and are optimized under contrary conditions, the plasma density and the ion energy must be independently controlled. Particularly, in the case of etching an optical waveguide formed of polymer containing halogen atoms, it is important to reduce damage of an optical waveguide by increasing the etch rate to minimize the exposure to the plasma. Thus, it is necessary to independently control the plasma density and ion energy.

A general method for fabricating an optical waveguide will now be described.

First, a lower cladding layer is formed on a substrate and then a core layer is formed on the lower cladding layer. Subsequently, a photoresist layer is formed on the core layer, exposed and then developed the resultant, to form a photoresist pattern. The core layer is etched using the photoresist pattern and then patterned. Then, an upper cladding layer is formed on the patterned core layer, thereby completing the optical waveguide.

As an etching method of the core layer, a reactive ion etching (RIE) method is widely used, in view of processing stability, preciseness and productivity.

However, according to the RIE method, the etch rate is very low, i.e., not more than 500 nm/min, which causes the substrate to be exposed to plasma for a long time to be damaged. In addition to damage to the etched plane, the vertical profile thereof is nonuniform. And, in the case of increasing the plasma density for the purpose of enhancing the etch rate, the ion energy increases, which causes to damage the etched plane. Also, in the case of decreasing the plasma density for the purpose of reducing damage to the etched plane, the etch rate is lowered, and the substrate is exposed to the plasma for a long time to bring about a film damage.

Disclosure of the Invention

To solve the above problems, it is an objective of the present invention to provide a polymer optical waveguide which can minimize damage to an optical waveguide by improving the etch rate, uniformity, etching ratio and vertical profile of an etched plane of the optical waveguide and a method for fabricating the same.

In order to achieve the above-mentioned object, there is provided a polymer optical waveguide comprises a core formed of polymer containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups; and

a cladding in contact with the core and formed of polymer having a refractive index lower than the polymer for forming the core.

According to another of the present invention, there is provided a method for fabricating a polymer optical waveguide comprising the steps of: forming a lower cladding layer on a substrate; forming a core layer on the lower cladding layer; patterning the core layer by etching the core layer in a predetermined pattern; forming an upper cladding layer on the patterned core layer, wherein etching of the core layer is performed by an inductively coupled plasma (ICP) process on condition that ICP power and RF chuck power are 170-750 W and 20-340 W, respectively, and the core layer is formed of a polymer containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups.

Brief Description of the Drawings

The above objective and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. 1 is a conceptual diagram of an inductively coupled plasma (ICP) etching device used in the present invention;

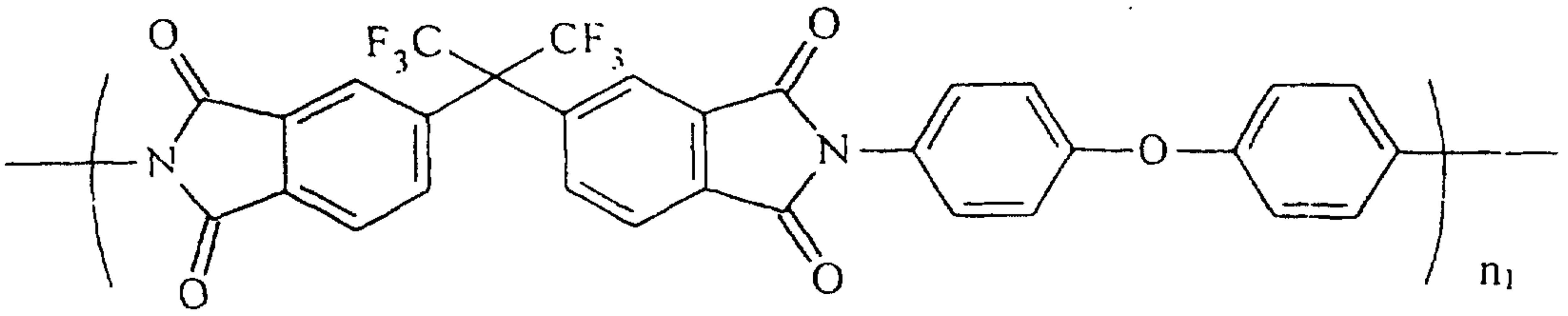
FIGs. 2 and 4 illustrate changes in the etch rate and ion energy (DC-bias) depending on the ICP power of polymers, according to a preferred embodiment of the present invention; and

FIGs. 3 and 5 illustrate changes in the etch rate and ion energy (DC-bias) depending on the RF chuck power of polymers, according to a preferred embodiment of the present invention.

Best mode for carrying out the Invention

A polymer optical waveguide of the present invention includes a core and a cladding in contact with the core. The core is formed of polymer containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups. Here, the cladding is formed of polymer having a refractive index lower than of the core. In the polymer optical waveguide having the above-mentioned structure, a light loss is low in an optical communication wavelength region containing a near infrared region and light scattering loss at a boundary between a core and a cladding can be minimized.

Preferably, the polymer for forming the core is a compound represented by the formula 1 or 2:



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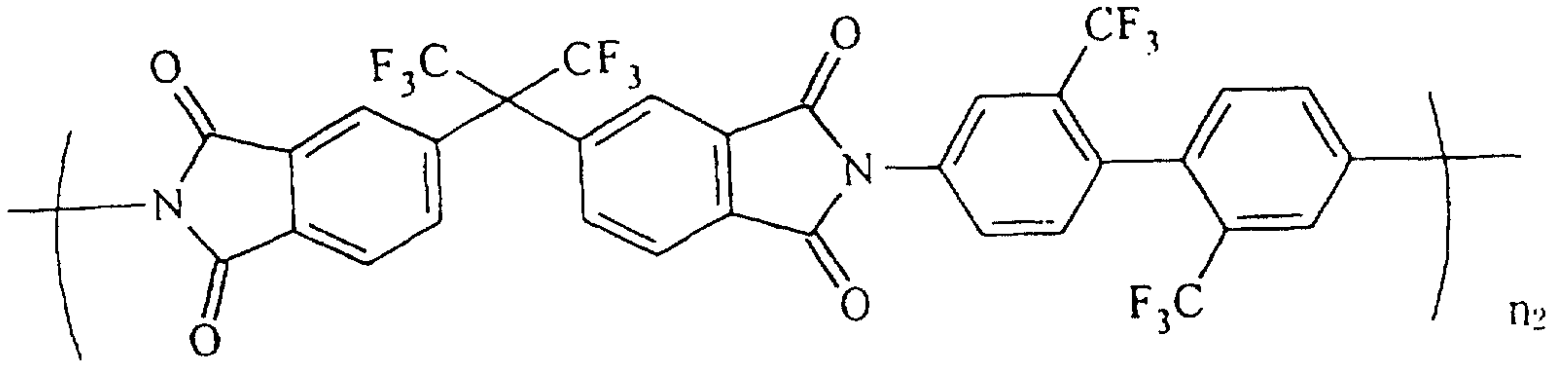

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where n_1 is an integer between 10 and 500, and n_2 is an integer between 10 and 500.

The method of fabricating the polymer optical waveguide of the present invention will now be described in detail with reference to the accompanying drawings

The method of fabricating the polymer optical waveguide of th present invention is characterized in that a core layer is etched by a inductively plasma (ICP) etching process under a predetermined ICP power and RF chuck power conditions. As a result, the etch rate becomes at least three times faster than that of the conventional method for etching core layer. Also, etching characteristics including uniformity of an etched plane and vertical profile of an etched plane are improved

According to an inductively coupled plasma (ICP) etching method, a non-polarized discharge plasma is generated by flowing current in a coil placed in a gas flow of an inert gas and an object disposed in the gas is etched. According to this method, since the plasma density and ion energy are independently controlled by using two RF power sources, the vertical profile, etch rate and uniformity of an etched plane of an optical waveguide can be optimized. Also, as an etching gas, only one kind of gas, i.e., oxygen, can be used. In the case of using an inert gas such as helium, argon or nitrogen together with oxygen, the etch rate can be more easily controlled.

As a polymer for the polymer optical waveguide of the present invention, an optical polymer having low light loss in an optical communication wavelength region can be used. It is preferable to use a polymer having polyimide, polyetherimide, polyesterimide, polysulfoneimide or polyamideimide as a basic unit, containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups. Here, the F content is above the range, the light loss slightly change according to the F content in the polymer.

In other words, when the F content in the polymer is low, i.e., greater than or equal to 12 wt% and less than 25 wt%, ICP power is 170-1000 W, preferably 500±150 *W*, and RF chuck power is 30-310 W, preferably 180±80 *W*. If the optical waveguide is etched under such conditions, the etch rate is greater than or equal to 500 nm/min, especially greater than or equal to 1500 nm/min and uniform etching planes can be obtained in both horizontal and vertical directions.

When the F content in the polymer is greater than or equal to 25 wt% and less than 37 wt%, ICP power is 190-750 W, preferably 440±180 *W*, and the RF chuck power is 20-340 W, preferably 200±60 *W*. If the optical waveguide is etched under such conditions, the etch rate is greater than or equal to 500 nm/min, especially greater than or equal to 2000 nm/min and uniform etching planes can be obtained in both horizontal and vertical directions.

The pressure of a chamber and the flow rate of an etching gas are the same irrespective of the F content in the polymer. The pressure of the chamber and the flow amount of the etching gas are preferably controlled to be 2-20 mtorr and 15-50 sccm, respectively. And, the etch rate is preferably controlled to be greater than or equal to 500 nm/min.

FIG. 1 is a conceptual diagram of an inductively coupled plasma (ICP) etching device used in the present invention.

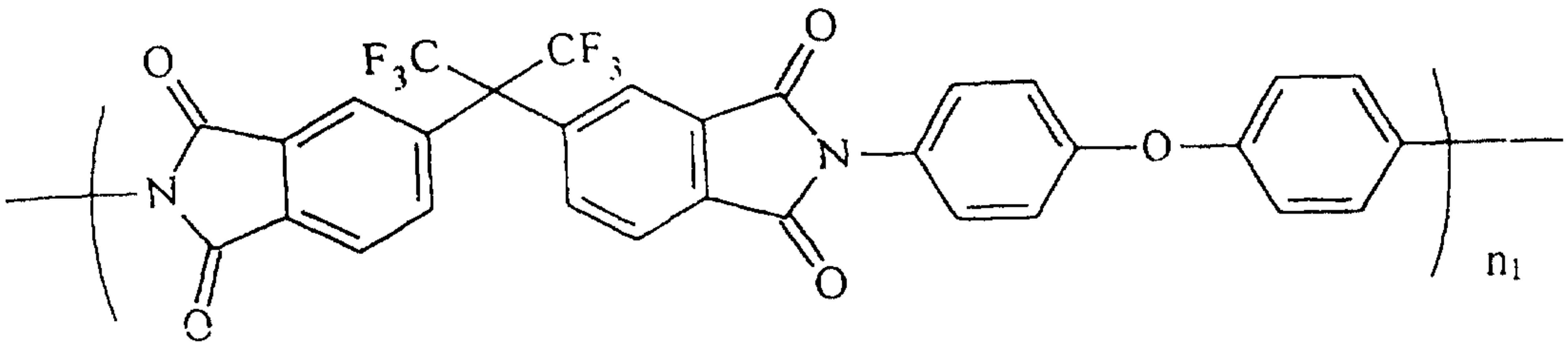
Referring to FIG. 1, two RF power sources are employed in the ICP etching device, that is, RF chuck power source 12 and ICP power source 13.

As seen from the FIG. 1, RF_1, is applied to a chuck 10 on which etched subjected is displaced from the RF chuck power source 12 and, RF_2 is applied to RF coils 14 from the ICP power source 13, respectively.

If a voltage is applied to the RF coils from the ICP power source 13, a magnetic field is induced along the flow of current. The thus-induced magnetic field changes the movement of electrons in the plasma. The electrons give rise to linear movement and spiral movement. Accordingly, collisions between electrons, atoms and ions occur more frequently. The plasma density increases due to collisions between electrons, and the number of ions, radicals (neutral atoms) and electrons increases in the plasma.

Hereinbelow, an etching process of a polymer optical waveguide according to a preferred embodiment of the present invention will be described.

An optical waveguide formed of polyimide represented by the formula 1 (F content: 25wt%) was etched using an ICP etching method. Here, oxygen was used as an etching gas. Changes in etching characteristics of the optical waveguide depending on RF chuck power, ICP power, chamber pressure, a change in flow rates of the etching gas were observed. The result showed that the RF chuck power and the ICP power greatly affected on the etching characteristics of the optical waveguide, but the chamber pressure and the flow rate were hardly affected.



1

where n_1 is an integer between 50 and 300.

First, in order to observe changes in etching characteristics of the optical waveguide depending on the ICP power, the ICP power was changed while the RF chuck power, the chamber pressure, the flow rate of oxygen were maintained at 150 W, 5 mtorr and 40 sccm, respectively. Changes in etch rates (▼) and ion energies (DC-bias) (○) depending on changes in the ICP power were observed and the results are shown in FIG. 2.

Referring to FIG. 2, when the ICP power increased from 0 to 750 W, the etch rate increased linearly from 450 nm/min to 2160 nm/min. On the other hand, the DC-bias decreased from 551 V to 220 V.

Observation of the states of the etched optical waveguide under various conditions showed that an optical waveguide having a good uniformity and vertical profile of the etched plane could be obtained when the ICP power was set to 500 W.

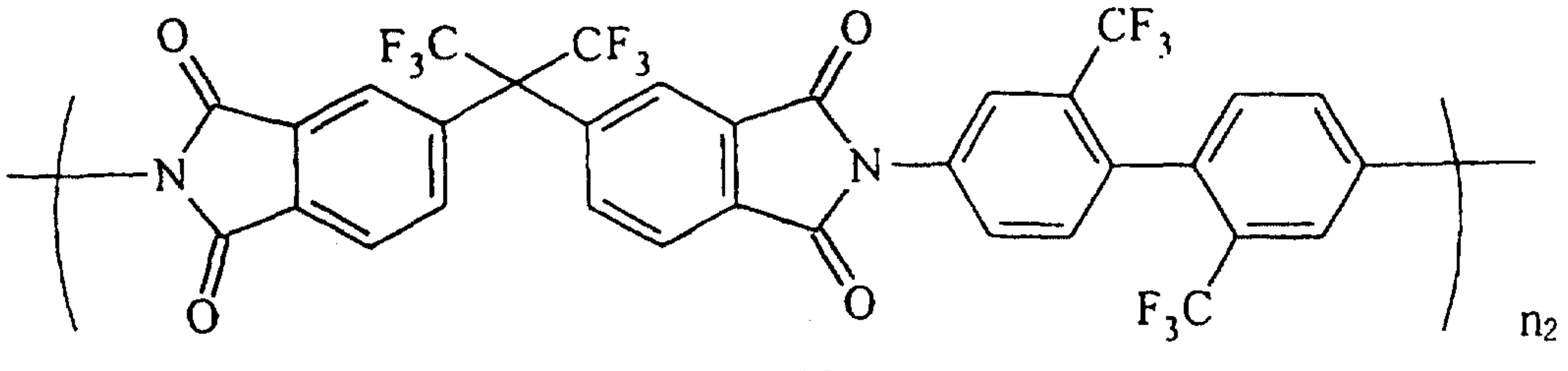
Next, in order to observe changes in etching characteristics of the optical waveguide depending on the RF chuck power, the RF chuck power was changed while the ICP power, the chamber pressure, the flow rate of oxygen were maintained at 500 W, 5 mtorr and 40 sccm, respectively. Changes in etch rates (▼) and ion energies (DC-bias) (○) depending on changes in the RF chuck power were observed and the results are shown in FIG. 3.

Referring to FIG. 3, when the RF chuck power was increased from 0 to 50 W, 150W, 250 W and 350 W, the etch rate increased linearly from 30 nm/min to 1060 nm/min, 1500nm/min, 1735 nm/min and 1950 nm/min, respectively. The DC-bias increased linearly from 0 V to 500 V.

Observation of the phases of the etched optical waveguide under various conditions showed that an optical waveguide having a good uniformity and vertical profile of the etched plane could be obtained when the RF chuck power was greater than or equal to 150 W.

Hereinbelow, an etching process of a polymer optical waveguide according to another embodiment of the present invention will be described.

An optical waveguide comprised of polyimide represented by the formula 2 (F content: 37wt%) was etched using an ICP etching method. Here, oxygen was used as an etching gas. Changes in etching characteristics of the optical waveguide depending on RF chuck power, ICP power, chamber pressure, a change in flow rates of the etching gas were observed. The result showed that the RF chuck power and the ICP power affected greatly on the etching characteristics of the optical waveguide, but the chamber pressure and the flow rate were hardly affected.



2

where n_2 is an integer between 40 and 200.

First, in order to observe changes in etching characteristics of the optical waveguide depending on the ICP power, the ICP power was changed while the RF chuck power, the chamber pressure, the flow rate of oxygen were maintained at 150 W, 5 mtorr and 40 sccm, respectively. Changes in etch rates (▼) and ion energies

(DC-bias) (○) depending on changes in ICP power were observed and the results are shown in FIG. 4.

Referring to FIG. 4, when the ICP power was increased from 0 to 750 W, the etch rate increased linearly from 540 nm/min to 2030 nm/min. On the other hand, the DC-bias decreased from 550 V to 220 V.

Observation of the phases of the etched optical waveguide under various conditions showed that an optical waveguide having a good uniformity and vertical profile of the etched plane could be obtained when the ICP power was set to 500 W.

Therefore, it was concluded that when the ICP power increased, the ion energy decreased while the etch rate increased. When the ion energy (DC-bias) was very large, the etching characteristic of the optical waveguide was poor, which is due to a damaged optical waveguide by the large ion energy (DC-bias).

Next, in order to observe changes in etching characteristics of the optical waveguide depending on the RF chuck power, the RF chuck power was changed while the ICP power, the chamber pressure, the flow rate of oxygen were maintained at 500 W, 5 mtorr and 40 sccm, respectively. Changes in etch rates (▼) and ion energies (DC-bias) (○) depending on changes in the RF chuck power were observed and the results are shown in FIG. 5.

Referring to FIG. 5, when the RF chuck power increased from 0 to 50 W, 150W, 250 W and 350 W, the etch rate increased linearly from 30 nm/min to 980 nm/min, 1530 nm/min, 1620 nm/min and 1870 nm/min, respectively. The DC-bias increased linearly from 0 V to 500 V.

Observation of the phases of the etched optical waveguide under various conditions showed that an optical waveguide having a good uniformity and vertical profile of the etched plane could be obtained when the RF chuck power was greater than or equal to 150 W.

It was found from the above result that the optical waveguide formed of polymer represented by the formula 1 or 2 was etched at a rate of 1500-2000 nm/min with the ICP power at 500 W and the RF chuck power at 150-300 W. Here, there was little damage to the optical waveguide, and the uniformity of the etched plane was very good.

The above-described embodiments have been described by way of examples only and the present invention is not limited thereto.

If a core layer is etched according to the ICP etching method of the present invention, the etch rate becomes at least three times faster than that of the conventional RIE etching method. Also, etching characteristics including uniformity of an etched plane and vertical profile of an etched plane are improved, thereby reducing damage to an optical waveguide. Thus, the light scattering loss of the optical waveguide can be minimized.

The method for fabricating a polymer optical waveguide according to the present invention is useful for mass production of polymer optical waveguides.

Industrial Applicability

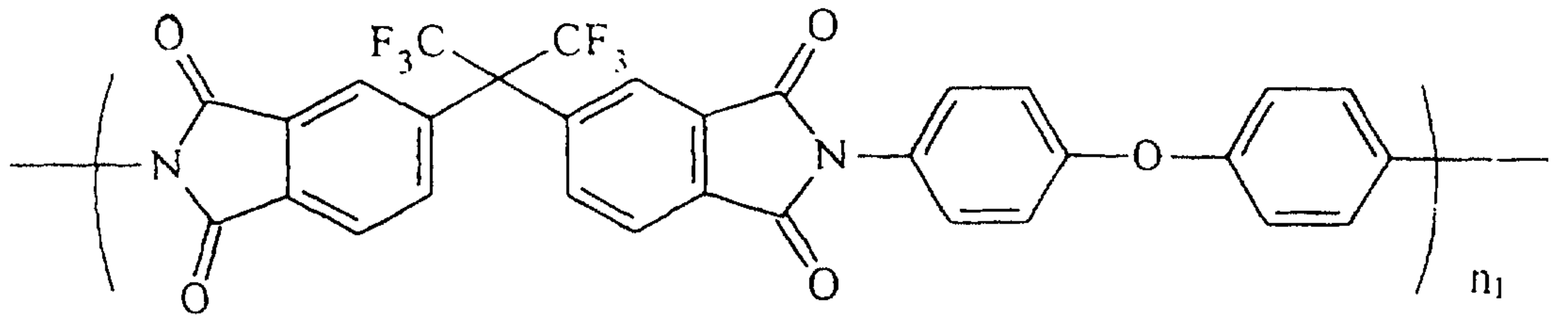
The polymer optical waveguide according to the present invention can be applied in fabricating optical communication devices such as plastic optical fibers, multi-chip modules or hybrid integrated devices.

What is claimed is:

1. A polymer optical waveguide comprises a core formed of polymer containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups; and

a cladding in contact with the core and formed of polymer having a refractive index lower than the polymer for forming the core.

2. The polymer optical waveguide according to claim 1, the polymer for forming the core is a compound represented by the formula 1 or 2:



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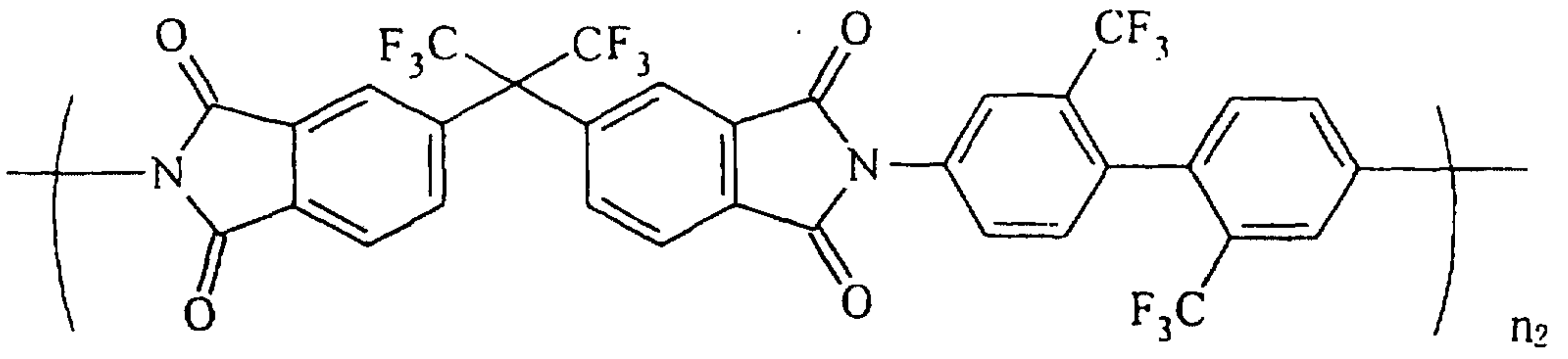


2

where n_1 is an integer between 10 and 500, and n_2 is an integer between 10 and 500.

3. A method for fabricating a polymer optical waveguide comprising the steps of:

forming a lower cladding layer on a substrate;

forming a core layer on the lower cladding layer;

patterning the core layer by etching the core layer in a predetermined pattern;

forming an upper cladding layer on the patterned core layer,

wherein etching of the core layer is performed by an inductively coupled plasma (ICP) process on condition that ICP power and RF chuck power are 170-750

W and 20-340 W, respectively, and the core layer is formed of a polymer containing fluoride (F) of a 12-37 wt% on the basis of total weight of the polymer, and having repeating units with at least two -C(=O)-N-C(=O) functional groups or at least four -N-C(=O)- functional groups.

4. The method according to claim 3, wherein when the fluoride content in the polymer is greater than or equal to 12 wt% and less than 25 wt%, the ICP power and the RF chuck power are controlled to be 190-750 W and 20-340 W, respectively.

5. The method according to claim 3, wherein when the fluorine content of the polymer is greater than or equal to 25 wt% and less than 37 wt%, the ICP power and the RF chuck power are controlled to be 170-1000 W and 30-310 W, respectively.

6. The method according to claim 3, wherein the chamber pressure is maintained at 2-20 mtorr during the ICP etching process.

7. The method according to claim 3, wherein the flow rate of an etching gas is maintained at 15-50 sccm during the ICP etching process.

8. The method according to claim 3, wherein the etching gas is at least one selected from the group consisting of argon, helium, nitrogen and oxygen during the ICP etching process.

9. The method according to claim 3, wherein the etch rate is greater than or equal to 500nm/min.

FIG. 1

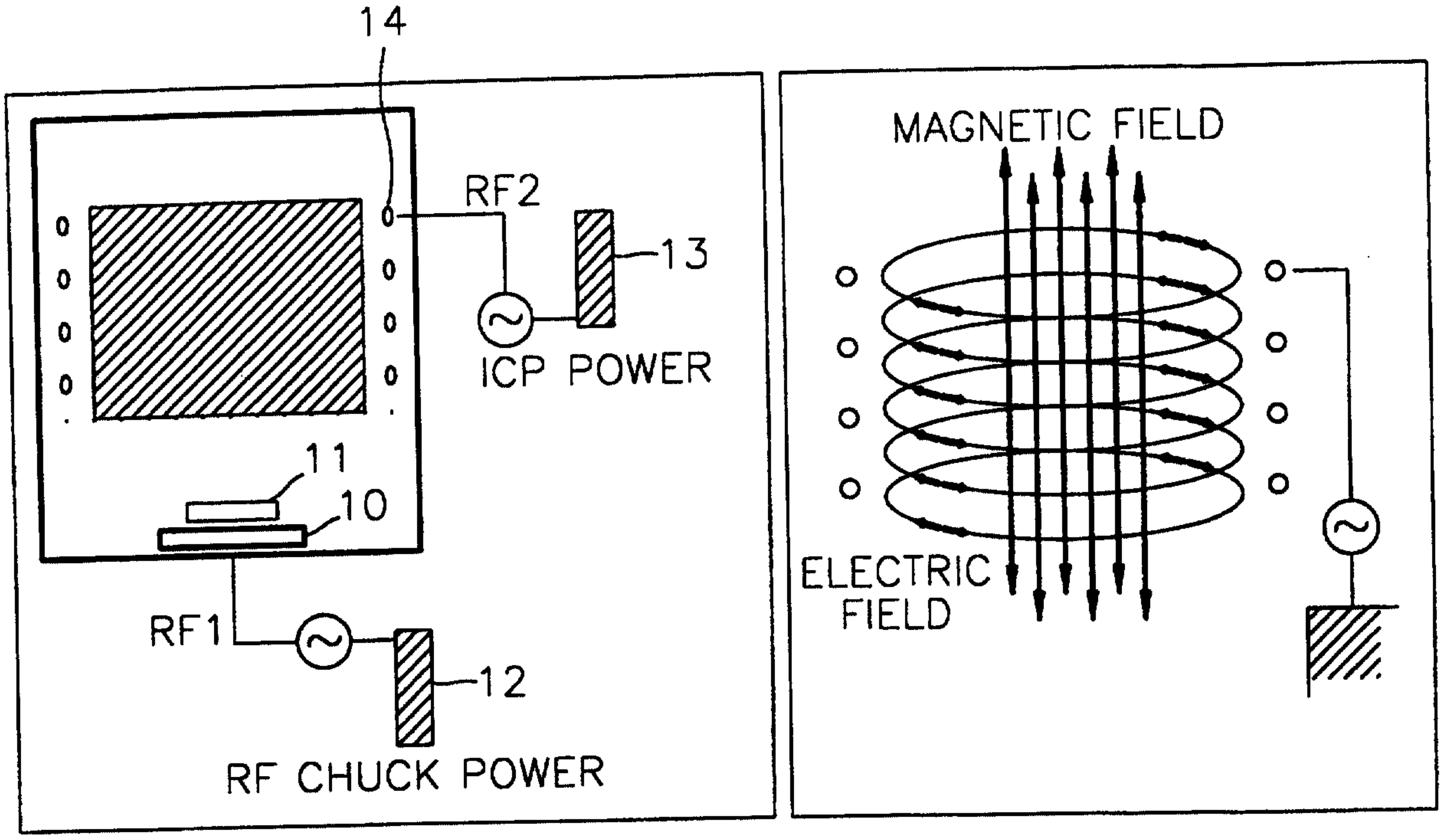

14
RF2
13
ICP POWER
11
10
RF1
12
RF CHUCK POWER
MAGNETIC FIELD
ELECTRIC FIELD

FIG. 2

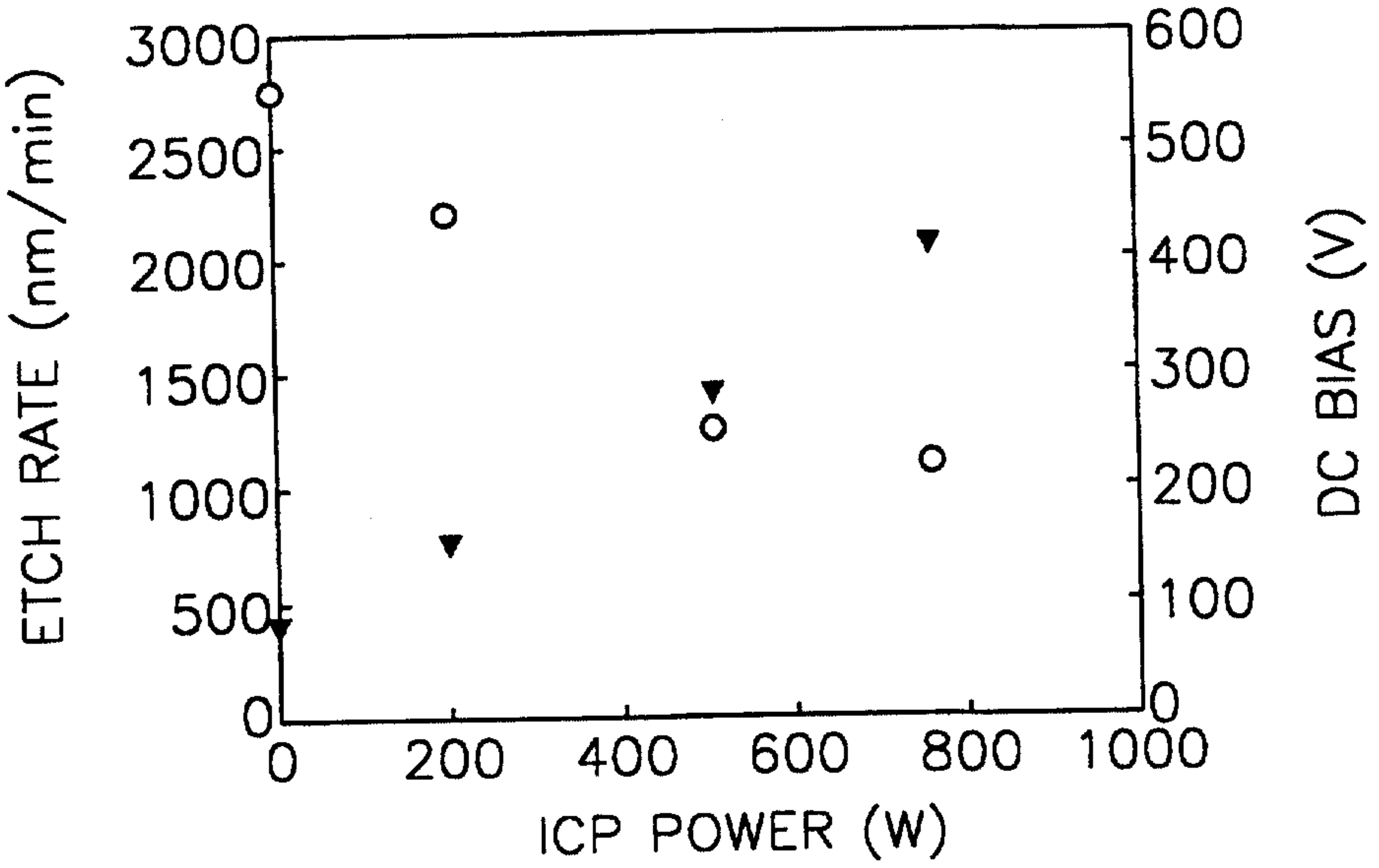
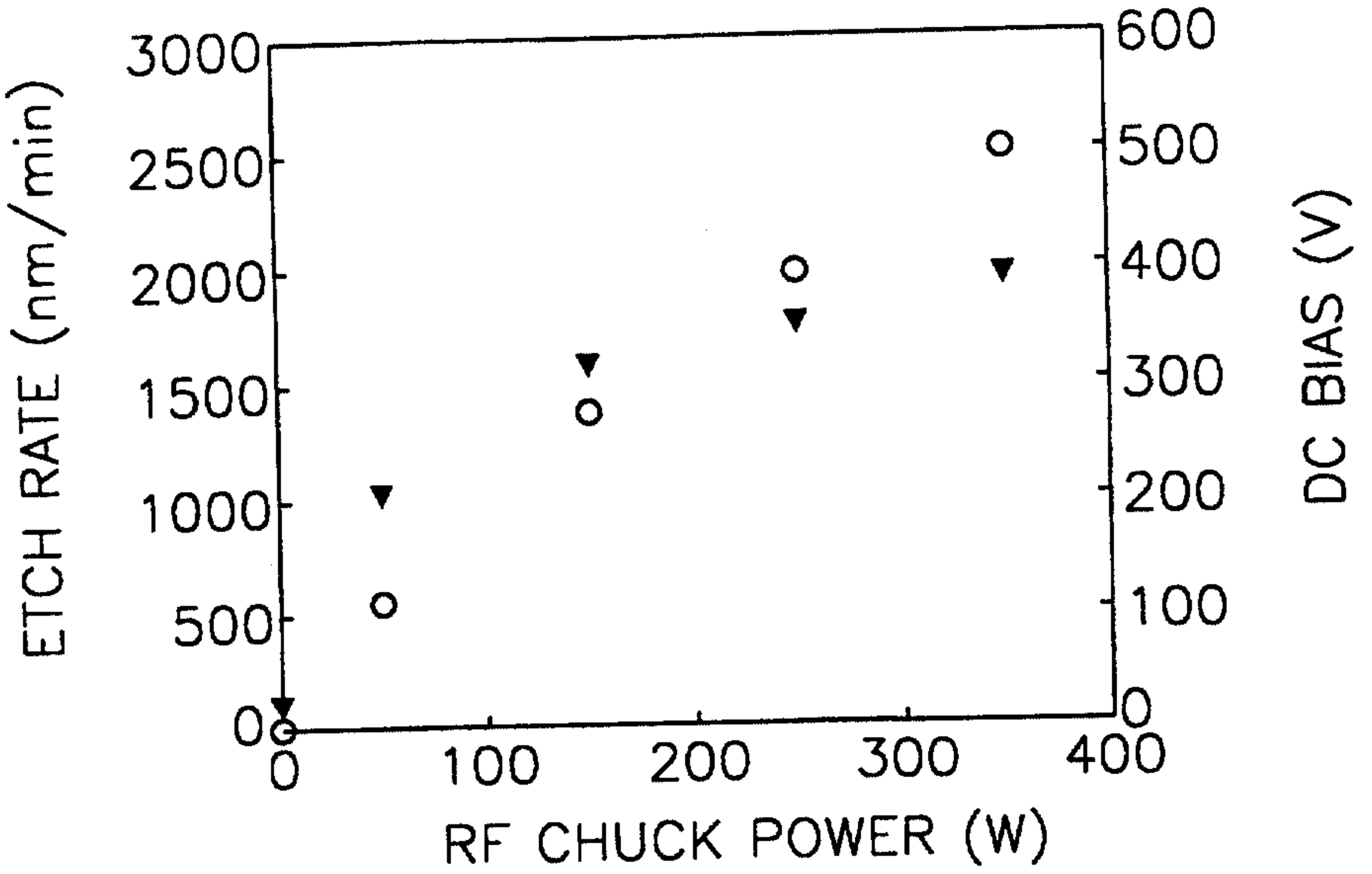

ETCH RATE (nm/min)
0
500
1000
1500
2000
2500
3000
DC BIAS (V)
0
100
200
300
400
500
600
ICP POWER (W)
0
200
400
600
800
1000

FIG. 3


ETCH RATE (nm/min)
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DC BIAS (V)
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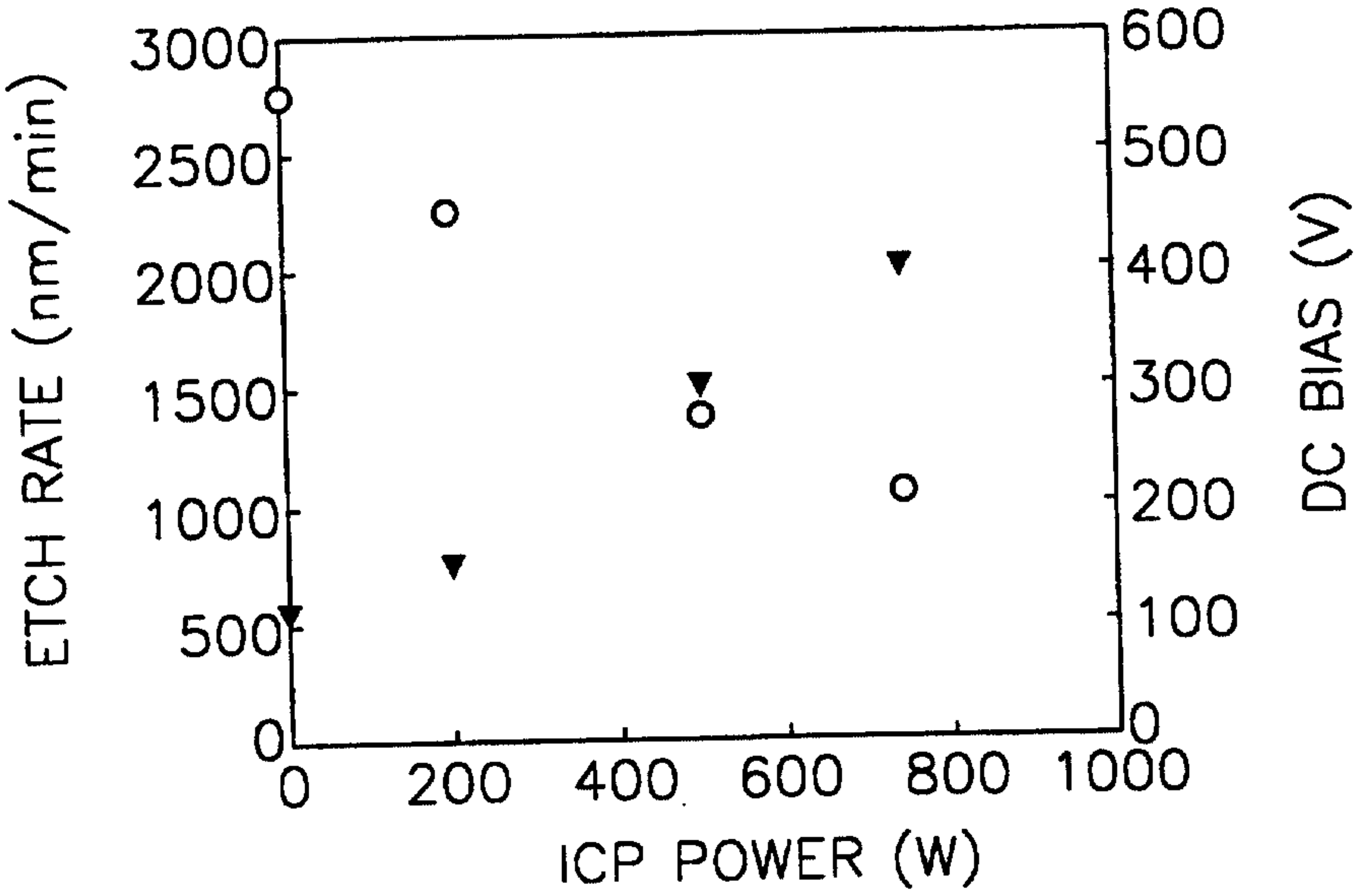
200
300
400
RF CHUCK POWER (W)

FIG. 4


ETCH RATE (nm/min)
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DC BIAS (V)
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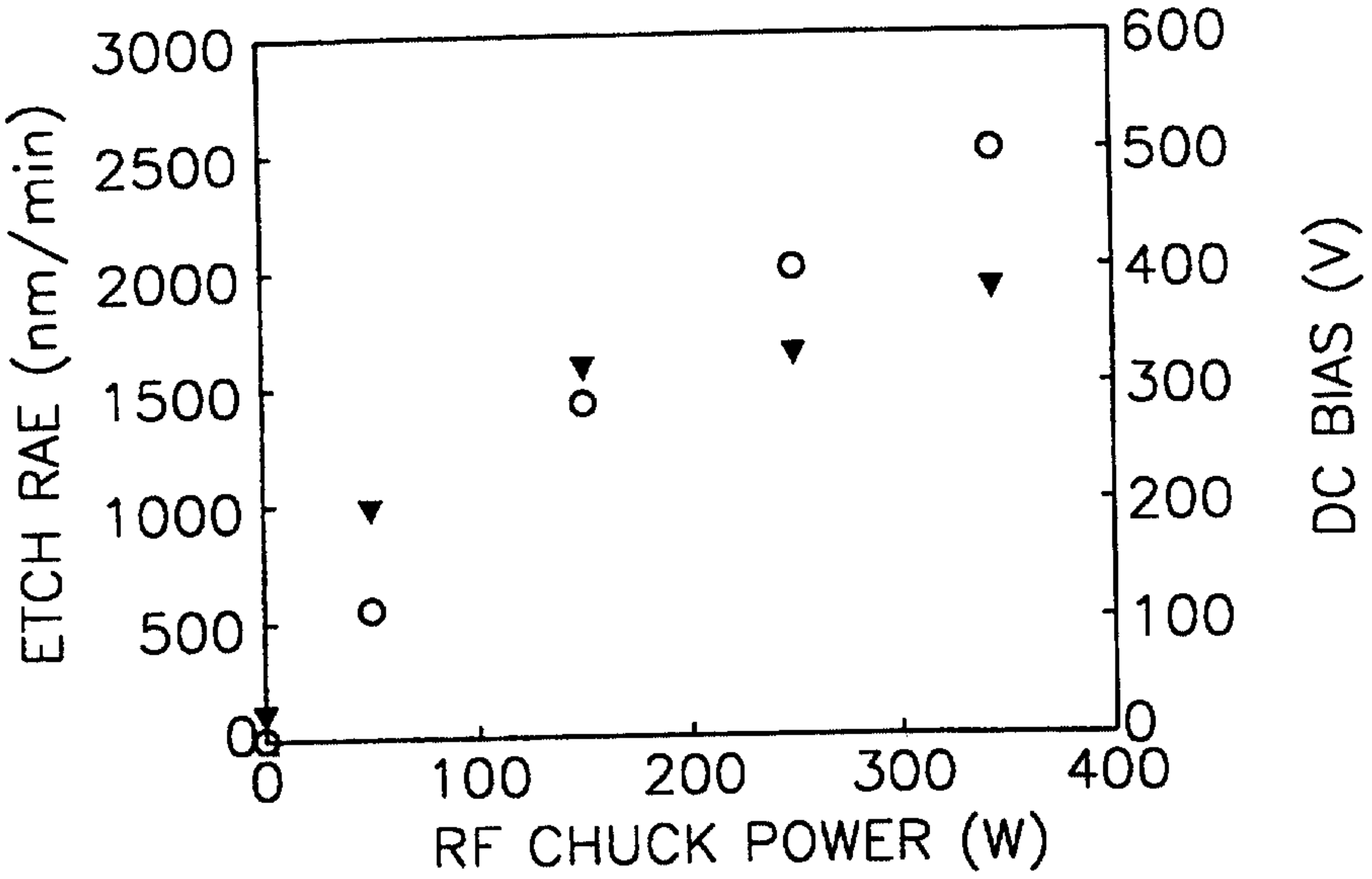
ICP POWER (W)

FIG. 5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ETCH RAE (nm/min)
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RF CHUCK POWER (W)