

ANTIMICROBIAL AND ANTICANCER CATIONIC PHTHALOCYANINE  
COMPOUNDS

**FIELD OF INVENTION**

- 5     The present invention relates to an antimicrobial compound, antimicrobial surfaces comprising the compound, medical gloves comprising the compound, and medical and non-medical uses of the compound.

**BACKGROUND ART**

- 10    Singlet oxygen generators are known to destroy microorganisms. Singlet oxygen has a greater energy than ground-state, triplet oxygen. The singlet and triplet states of oxygen are distinguished by the singlet state having two electrons of anti-parallel spins and the triplet state having an uncoupled pair of electrons with parallel spins. The singlet oxygen is also distinguished from triplet oxygen because it is a highly reactive species with a lifetime from a  
15    few microseconds to several hundred microseconds. During its lifetime singlet oxygen has the potential to react before being deactivated, and therefore has a wide number of applications, including antimicrobial applications such as in medical gloves.

- Medical gloves are disposable gloves used during medical examinations and procedures that help prevent the spread of infections. They are worn by medical workers at the start of the  
20    examination and discarded and destroyed at the end of the procedure. They function by creating a physical barrier between the medical practitioner and patient that prevents the transfer of infectious microorganisms between the two parties. The gloves themselves are not sterile and there is always a danger that the gloves could tear, allowing microorganisms to be transferred between the patient and the practitioner.

- 25    US2011/0145975 describes how to coat gloves with an anti-bacterial agent. To get the outside of the glove coated, they have to do the coating in an “offline process”, by completing the glove preparation, stripping it from the glove former, then placing it in a tumble dryer equipped with sprayers which coat the glove with the anti-bacterial agent, and then carry out a polymer coating. The polymer coating is required because the anti-bacterial agent is sticky, so there is  
30    a need to coat the glove with something to make it usable. Disadvantages are that the anti-bacterial agent is carcinogenic, and does not stay on the gloves, as it leaches off them in use. It also adds a separate process to the manufacturing.

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The present invention provides a compound according to formula 1:



R=R'(a) or R"(b)  
R' oxygen linked pyridyl  
R" oxygen linked N-alkylated pyridinium

M is selected from aluminium or zinc,

R'' is linked via an oxygen atom to a pyridine group at least 1 of which bears a cationic charge, and the remaining peripheral carbon atoms are an unsubstituted organic radical,

$$a + b = 4$$

b = 1 to 4, preferably 1 to 3.9

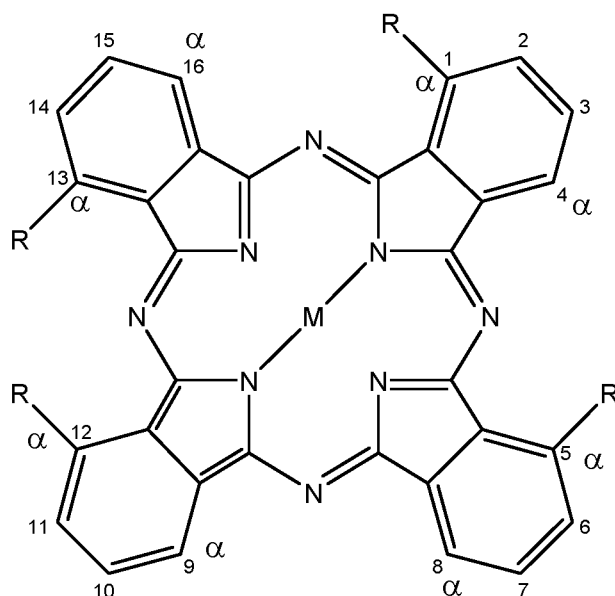
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X = Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, methanesulphonate, ethanesulphonate, formate, acetate or other inorganic or organic counter-ion or mixture thereof;

and wherein alkylation on the pyridine nitrogen is optionally branched C1-C8 alkyl.

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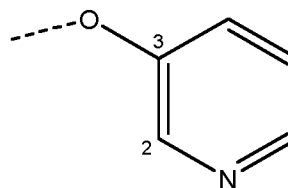
Preferred compounds according to the present invention are:



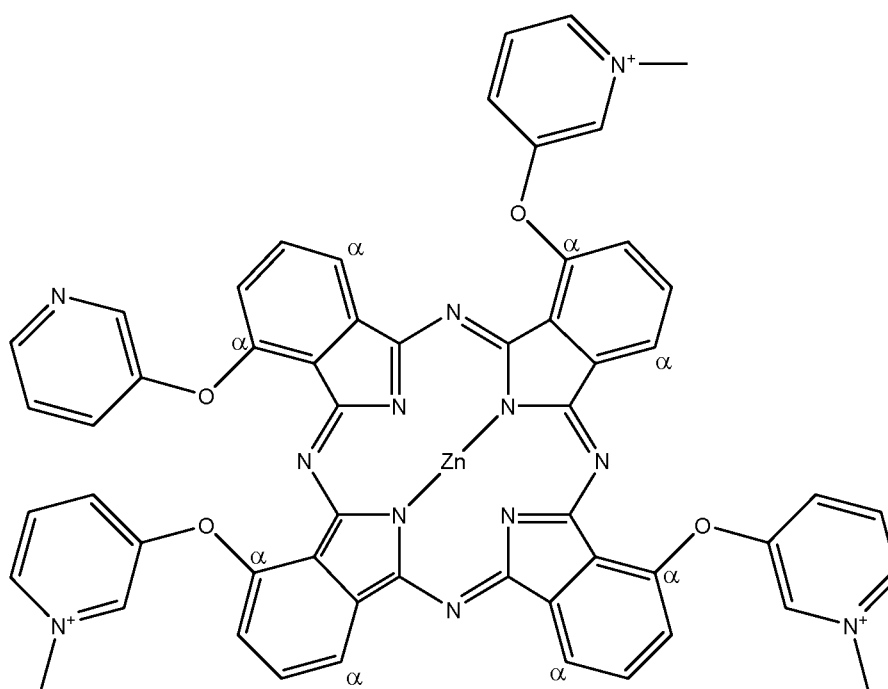
Formula 4

X<sup>-</sup>(b)

R'(a) or R''(b)  
 R' 3-oxygen linked pyridyl  
 R'' 3-oxygen linked N-alkylated pyridinium



and in particular:

X<sup>-</sup>(2-4)

Formula 5

The present invention also provides an antimicrobial surface or nitrile gloves comprising the compounds.

The present invention also provides the compounds for use in therapeutic methods of treatment, such as in skin and subcutaneous cancers.

The present invention further provides a process for removing stains, wherein the method comprises contacting a stained surface with an aqueous composition of the compounds.

Not only do the compounds of the present invention have effective antimicrobial activity for medical examination gloves, they have numerous other applications such as surface disinfection, cleaning and in human health.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention provides novel poly-substituted phthalocyanine compounds which can be used to generate singlet oxygen. The phthalocyanine nucleus may be aluminum or zinc. If aluminium is used, the aluminum may be further substituted by alkyl, aryl, alkoxy, hydroxy or halogen.

Aluminium and zinc are chosen because they are more efficient in generating singlet oxygen than other metals such as copper or nickel, and they are reasonably small and so can be inserted into the phthalocyanine easily, with the reactions occurring under air, in good yield, as opposed to other metals such as using  $\text{SiCl}_4$ , and are easily available in bulk. The central metal atom also influences the position of the absorption maximum of the phthalocyanine, and zinc and aluminium are preferred in the compounds because their absorption is in the visible region of the spectrum especially between 600 - 700nm. The zinc compounds described herein are especially preferred.

For the phthalocyanines of the present invention each of the pendant organic radicals linked via oxygen to the phthalocyanine nucleus is independently selected from N-alkylated pyridinium, such that any one phthalocyanine nucleus may carry two or more different organic radicals. Examples of N-alkylated pyridines are 3-hydroxy-1-methylpyridin-1-ium, 3-hydroxy-1-ethylpyridin-1-ium, 3-hydroxy-1-propylpyridin-1-ium.

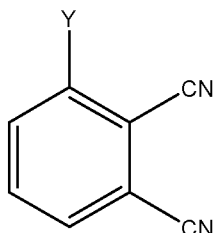
Further, the phthalocyanines used in the present invention have substituents to the phthalocyanine nucleus in the alpha position, adjacent to the phthalocyanine nucleus. This alpha substitution decreases aggregation of the phthalocyanine. Aggregation is known to reduce singlet oxygen generation efficiency, and therefore this structure prevents aggregation and increases efficiency singlet oxygen generation and hence antimicrobial and other activity. In addition, after extensive research the present inventors have realised the molecules described herein have other desirable properties. They are more thermally stable, and stable to radical degradation than commercially available analogs such as Tinolux BBS and Tinolux BMC.

In the preferred group of compounds the total number of cationic substituents (b) is 2 to 3.9 , and more preferably 2.5 to 3.5. The compounds described herein may have a charge of at least +1, and up to +3.9, preferably +2 to +3.9 and most preferably +2.5 to +3.5. Suitable counter-

ions for the N-alkylated pyridines include, but are not limited to, iodide, chloride, bromide, methanesulphonate, toluenesulphonate, acetate and hexafluorophosphate.

The phthalocyanines of Formula 1 can be prepared by reacting:

(1) a substituted 1,2-dicyanobenzene of Formula 2:



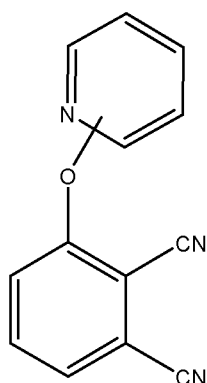
Y=F,Cl,Br,I,NO<sub>2</sub>

Formula 2

wherein Z is selected from chloro, bromo and iodo or nitro and is in the 3 position (alpha) to one of the CN groups,

with

(2) a compound pyridine-OH whereby the group Z, is replaced by pyridine-O groups to form a compound of Formula (3):



Formula 3

This can then be followed by reaction of one or more 1,2-dicyanobenzene compounds of Formula 3, or a combination of one or more compounds of Formula 3 and 1,2-dicyanobenzene,

with an appropriate metal or metal salt optionally in an inert liquid at an elevated temperature to form a phthalocyanine of Formula 1.

Such reactions are fully described in GB 1489394, GB 2200650 and DE 2455675.

5 In the manufacturing process, the alkylation of the pyridine groups is done last. If the process is not done to completion, some of the pyridyl substituents can remain unalkylated and uncharged. The process can be modified by temperature and stoichiometry to give higher or lower degrees of final alkylation.

10 The present invention also provides a process for the generation of singlet oxygen by irradiation in the presence of oxygen of the substituted phthalocyanine compounds of the present invention, in which at least one of the peripheral carbon atoms in the 1 or 4, 5 or 8, 9 or 12, 13 or 16 (alpha) positions of the phthalocyanine nucleus, such as shown in Formula 1, is cationic. Suitable sources of electromagnetic radiation include sunlight, tungsten light, fluorescent light, LED lights and lasers with emissions in the 600 to 800 nm region.

15 Preferable phthalocyanines of the present invention are those which promote the generation of singlet oxygen when exposed to radiation from the 600 to 800 nm region, especially the 630 to 770 nm region of the electromagnetic spectrum.

20 The reactivity of the singlet oxygen may be utilised in a wide range of applications which includes photobleaching, photodeodorising, photodynamic therapy (PDT), photodynamic inactivation of bacteria, virus, yeasts and other microorganisms, treatment of visible stains on a range of material surfaces, surfaces include fabric, cement, stone, brick, glass, etc., biocidal, degradation of plastics, paper and pulp bleaching, environmental clean-up, anti-microbial action on fibres, incorporation into various products for example in fabrics as deodorisers, into paints or film treatments to destroy micro-organisms or contaminants, into cement products, glass products and paints to confer self-cleaning properties, sterilising swimming pools and as  
25 a surface treatment to prevent yellowing/discoloration of paper. For photobleaching and photodeodorising application the phthalocyanine compound of the present invention can be incorporated into detergent formulations which are used in a wide range of cleaning applications.

The compound of the present invention can also be used for creating an antimicrobial polymer, especially an elastomer, especially by coagulating a natural or synthetic latex on a former. A process for making an antimicrobial glove can comprise dissolving the compound in an aqueous coagulant and then dipping in a nitrile dispersion.

5    Gloves are manufactured by dipping glove formers shaped like hands into tanks of liquid latex and admixed chemicals. The latex may contain vulcanization agents that are used to cure the rubber, and a dry rubber film is produced. The formers are first precoated with a coagulant to gel the latex and to facilitate the subsequent removal of the glove from the former. The precoated formers are then dipped in the tanks of chemicals to make the gloves. While still on  
10   the formers, the latex gloves can also go through one or more rinses to leach out proteins and residual chemicals. The wet gel is dried and cured in a heated oven and the latex glove cures on the former before they are reversed stripped off the former, packaged, and/or sterilized.

In the manufacturing process of the invention, the singlet oxygen generating compound is designed to dissolve in the aqueous coagulant phase of the above process. The coagulant may  
15   contain 10 to 20% of calcium nitrate to coagulate the latex. Typical dyes have several disadvantages in this process, for example they often lack solubility in strong solutions of calcium 2+ ions. The above dye compounds of the present invention, such as recited in Formulas 1, 4 and 5, contain a number of features to allow them to operate in this environment. They are soluble in calcium salts, by virtue of multiple cationic charges. In addition, many  
20   latexes, especially nitrile latex are stabilised by anionic carboxyl groups. The dye compounds of the present invention can cross link into the anionic nitrile polymers, bonding to them very strongly, rendering them non leachable. In addition the latex is cured by radical curing at high temperature and many known phthalocyanine dyes, such as Tinolux BBS and Tinolux BMC degrade by radical reactions under these conditions. The dye compounds of the present  
25   invention are more thermally stable, and more stable to radical conditions than the Tinolux molecules and therefore are not degraded by the glove forming process.

The dyes of Formula 1 can also be simply dissolved in the aqueous coagulant solution of the glove forming process, by which they are transferred to the surface of the former to the elastomer on dipping, bind irreversibly with it, and create a photo activated antimicrobial  
30   surface after curing and drying.

The medical gloves of the present invention can be made of natural or preferably nitrile rubber latex.

The compounds of the present invention can also be used in therapeutic treatment of a human or an animal body, in particular the treatment of skin, subcutaneous cancers, microbial infections or other disease by photodynamic therapy. In such treatment the compound of the present invention can be introduced into the affected tissue and then irradiated with electromagnetic radiation in the region from 600 to 800 nm, preferably 650 to 770 nm in order to generate singlet oxygen which destroys the affected cells. As described above, the phthalocyanine compounds of the present invention can promote the formation of singlet oxygen under the influence of electromagnetic radiation, particularly in the 600 to 770 nm region and are capable of promoting singlet oxygen formation in localised areas.

Measurement of triplet oxygen yields after laser excitation and singlet oxygen emission yields allows calculation of singlet oxygen generating efficiency ( $S\Delta$ ). The experimental details for these measurements are more fully described in Gorman et al, Journal of the American Chemical Society [1987], 109, 3091; Gorman et al, Journal of the American Chemical Society [1989], 111, 1876 and Gorman et al, Photochemistry and Photobiology [1987] 45(2), 215.

In the synthesis of these materials, a mixture of isomeric structures is obtained, even from a single phthalonitrile. The point group symmetries are  $C_{4h}$ ,  $D_{2h}$ ,  $C_{2v}$  and  $C_s$ , (*J. Mater. Chem. C*, 2015,**3**, 10705-10714). Those shown below are typically produced in the ratios 1:1:2:4. All of these structures are incorporated herein.

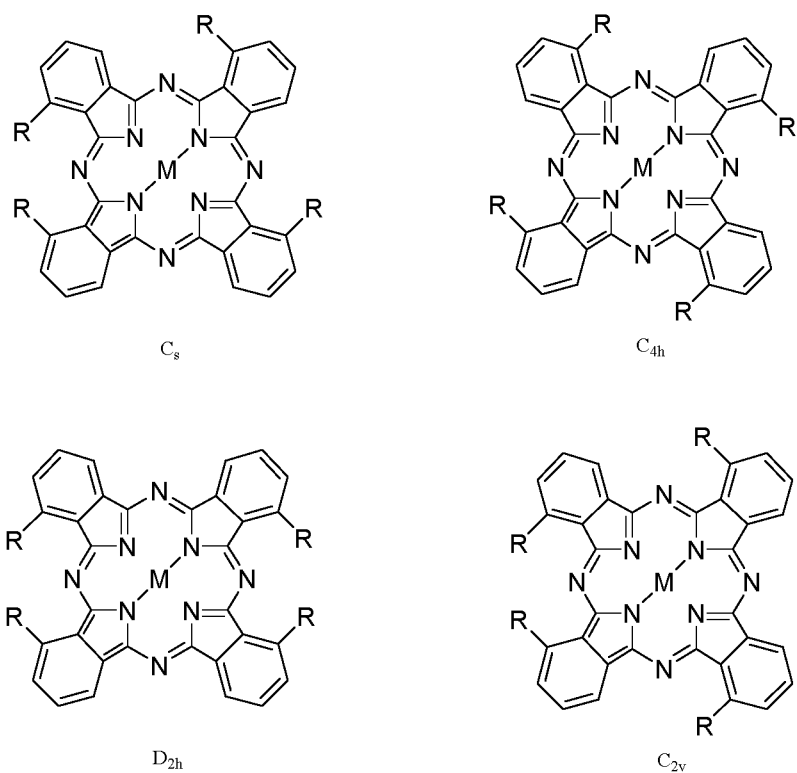


Figure 2

The present invention will now be illustrated, but in no way limited, by reference to the following examples.

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## EXAMPLES

### Example 1 - Preparation of tetrapyrrolium zinc phthalocyanine

#### (i) Preparation of 3-(pyridin-3-yloxy)phthalonitrile

3-nitroptalonitrile (1.82 parts) was stirred in DMF 10 parts with 3 hydroxypyridine and potassium carbonate (2.9 parts), heating to 90°C for 1 hour. The mixture was poured into water, and the greenish solid filtered off.

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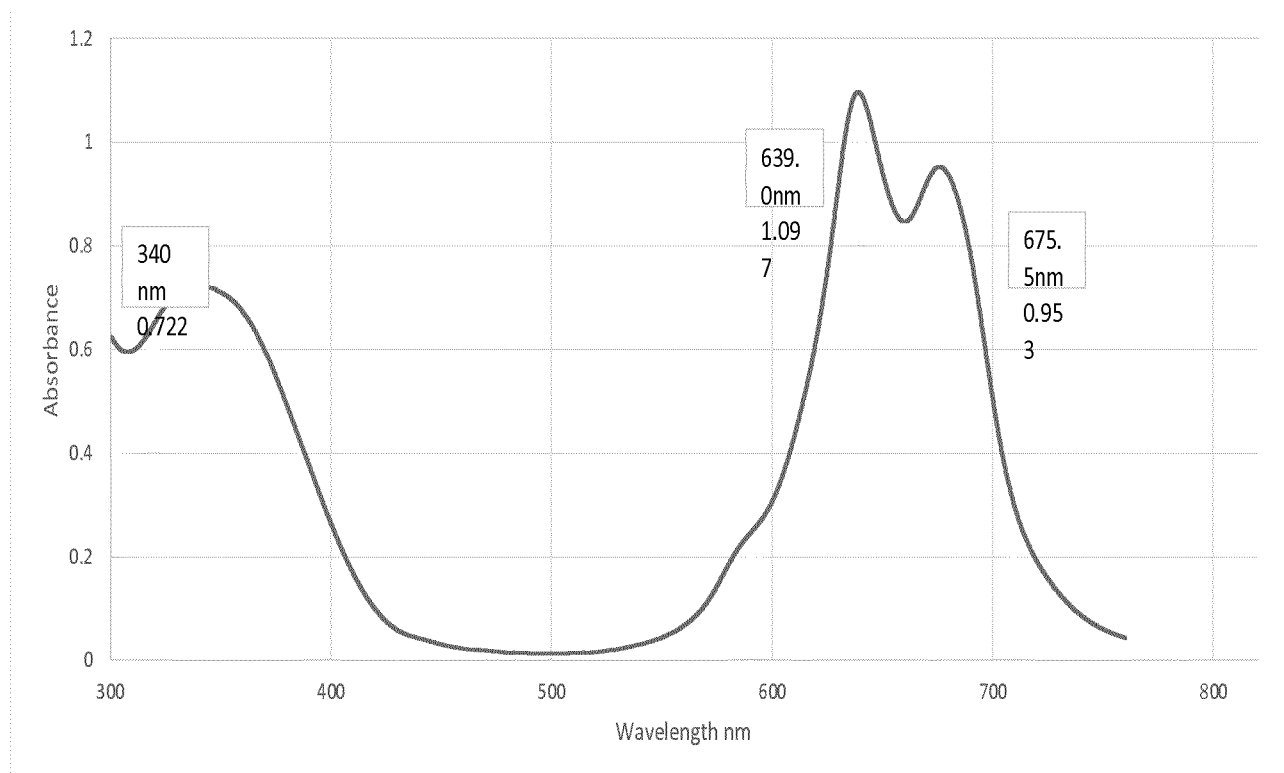
(ii) Preparation of tetrapyrroline zinc phthalocyanine

3-(pyridin-3-yloxy)phthalonitrile (22 parts) was mixed thoroughly with zinc chloride (3.4 parts), urea (1.5 parts), ammonium molybdate (0.04 parts), and DBU (3 parts). The mixture was heated to 180°C for 30 minutes with stirring, poured into water and the green solid filtered and washed with water.

(iii) Preparation of tetrapyrroline zinc phthalocyanine iodide salt

The tetrapyrroline zinc phthalocyanine produced above (12.5 parts) was heated in DMSO at 70°C for 3 hours with an excess (10 parts) of methyl tosylate. The reaction mass was added to water producing a sticky mass. The reaction mass was stirred with lithium iodide (8 parts) to give the iodide salt which was filtered off as a green solid. NMR showed approximately 3:1 quaternised to non-quaternised pyridines.

The UV visible spectrum was taken by dissolving 24mg of the compound in 1000ml of water, and measuring in a 1 cm path length cell on a Hach-Lange DR3900, as shown below:



## Example 2 - Preparation of tetrapyridinium Aluminium phthalocyanine

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### (i) Preparation of 3-(pyridin-3-yloxy)phthalonitrile

The 3-(pyridin-3-yloxy)phthalonitrile was prepared as above.

### 10 (ii) Preparation of tetrapyridine aluliminium phthalocyanine

3-(pyridin-3-yloxy)phthalonitrile (3 parts) was mixed thoroughly with an excess of Aluminium chloride (1 part), and DBU (0.5 parts) in n-pentanol (10 parts). The mixture was heated to reflux at 140°C for 12 hours with stirring, poured into water : methanol 1:1 (10 parts) and the  
15 green solid filtered.

### (iii) Preparation of tetrapyridinium aluminium phthalocyanine iodide salt

The tetrapyridine aluminium phthalocyanine produced above (12.5 parts) was heated in DMSO  
20 at 70°C for 3 hours with an excess (10 parts) of methyl tosylate. The reaction mass was added to water producing a sticky mass. The reaction mass was stirred with lithium iodide (8 parts) to give the iodide salt which was filtered off as a green solid. NMR showed approximately 3:1 quaternised to non-quaternised pyridines.

## 25 Example 3 - Preparation of an antimicrobial elastomer

0.25 parts of the compounds from example 1 were dissolved in 5100 parts of water, containing 1500 parts of calcium nitrate. To the mixture was added 0.8 part of a calcium stearate mold release agent. A porcelain former heated to 150°C was dipped in the coagulant and dried in an  
30 oven at 150°C for 15 minutes. The dried former was dipped in a nitrile latex suspension (Nantex 672), cured and dried. The glove was stripped from the former and the glove surface was tested according to ASTM D7907. Staphylococcus aureus was reduced by > log 5 in 5 minutes. The glove making process is described more fully in US patent 8936843 B2 and references disclosed therein.

**Example 4 - Alternative Preparation of tetrapyrindinium zinc phthalocyanine**

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(i) Preparation of 3-(pyridin-3-yloxy)phthalonitrile

The 3-(pyridin-3-yloxy)phthalonitrile was prepared as described in J Organomet Chem. 2009 May 1; 694(11): 1607–1611.

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(ii) Preparation of tetrapyrindine zinc phthalocyanine

To 2-ethylhexanol (242 parts) was added to 3-(pyridin-3-yloxy)-phthalonitrile (145 parts) followed by zinc chloride (21 parts) and DBU (parts Kg). The reaction was heated to 150°C to effect cyclisation, then cooled and crystallised with iso-propanol (1600 parts). The product was filtered, washed with further iso-propanol and dried to give the pyridyloxy zinc phthalocyanine.

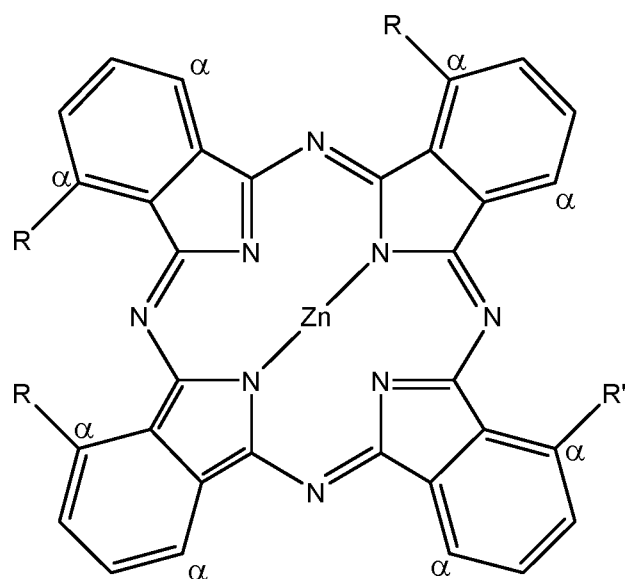
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(iii) Preparation of tetrapyrindinium zinc phthalocyanine iodide salt

To N-Methyl-2-pyrrolidone (NMP) was added the pyridyloxy zinc phthalocyanine (140 parts) and methyl tosylate (120 parts). The mixture was heated to effect quaternisation, then cooled and mixed with iso-propanol (3100 parts) containing lithium iodide (160 parts). The product was filtered, washed with further iso-propanol and dried to give the quaternised zinc phthalocyanine as predominantly the iodide salt.

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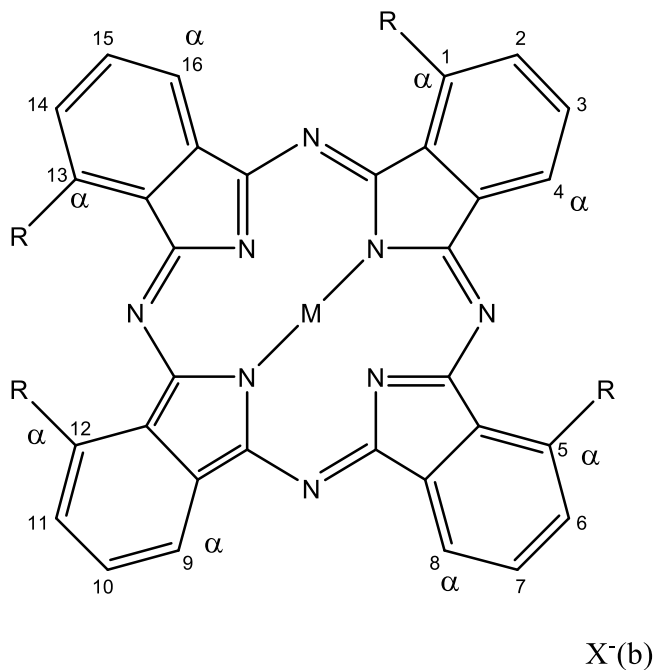
Further examples as shown below were also prepared:



| Example | 4        | 5        | 6        | 7        | 8        | 9        |
|---------|----------|----------|----------|----------|----------|----------|
| Metal   | Zn       | Zn       | Zn       | Al       | Al       | Al       |
| R       |          |          |          |          |          |          |
| R'      |          |          |          |          |          |          |
|         | a=1, b=3 | a=1, b=3 | a=1, b=3 | a=1, b=3 | a=1, b=3 | a=1, b=3 |

**CLAIMS**

1. Compounds according to the following formula:



Formula 1

R=R'(a) or R''(b)

R' oxygen linked pyridyl

R'' oxygen linked N-alkylated pyridinium

in which:

- 5 M is selected from aluminium or zinc,

R'' is linked via an oxygen atom to a pyridine group at least 1 of which bears a cationic charge, and the remaining peripheral carbon atoms are an unsubstituted organic radical,

$$a + b = 4$$

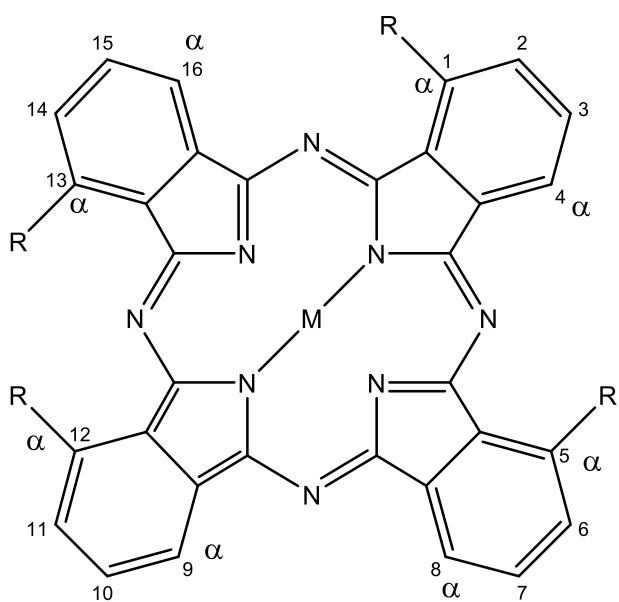
$$b = 1 \text{ to } 3.9$$

- 10 X = Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, methanesulphonate, ethanesulphonate, formate, acetate or other inorganic or organic counter-ion or mixture thereof;

and

in which alkylation on the pyridine nitrogen is optionally branched C1-C8 alkyl.

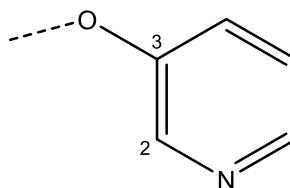
2. Compounds according to Claim 1 with the following formula:



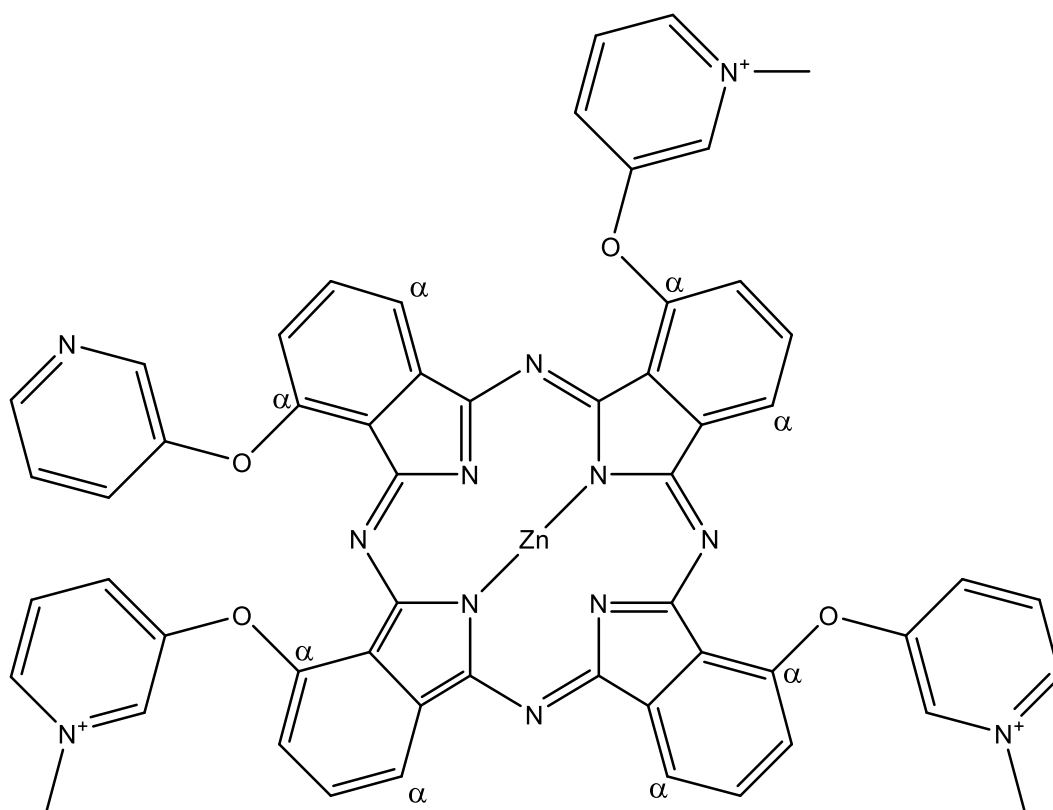
Formula 4

X<sup>-</sup>(b)

R'(a) or R''(b)  
 R' 3-oxygen linked pyridyl  
 R'' 3-oxygen linked N-alkylated pyridinium



3. Compounds according to Claim 1 or 2 with the following formula:

X<sup>-</sup>(2-4)

Formula 5

in which the mean average total number of alkylated pyridines is 2 to 3, preferably 2.5 to 3.

4. Compounds according to Claim 1, 2 or 3, in which the compounds absorb
- 5 electromagnetic radiation at a wavelength from 600 to 800 nm.
5. An antimicrobial surface comprising the compounds according to any preceding claim.
6. An antimicrobial surface according to Claim 5, in which the compounds are contained in a polymer, metal or textile comprised by the surface.
7. A surface according to Claim 6, in which the surface is an elastomer or nitrile latex
- 10 surface.
8. A nitrile glove comprising the compounds according to any of Claims 1 to 4.

9. A method of manufacturing a nitrile glove according to Claim 8, in which the method comprises dissolving the compounds in an aqueous coagulant and then dipping in a nitrile dispersion.
10. A process for removing stains on a surface, in which the method comprises contacting a  
5 stained surface with an aqueous composition of the compounds according to any of Claims 1 to 4, and exposing the surface to light, preferably sunlight, during or after the contacting step.
11. A process according to Claim 10, in which the surface is of any of fabric, cement, stone, brick or glass.