each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to about 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the drug composition,

the drug composition is a gel formed by noncovalent interactions of polymer chains of the block copolymer in the solvent, and

the drug is contained in the gel.

[0009a] In one aspect, there is provided a drug composition, comprising:

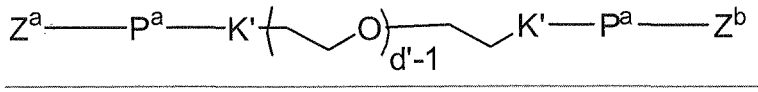
4 wt.% to 10 wt.% of a gel-forming block copolymer;

a solvent; and

0.0001 wt.% to 10 wt.% of a drug;

wherein

the gel-forming block copolymer has a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of 100 to 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the drug composition,

the drug composition is a gel formed by noncovalent interactions of polymer chains of the block copolymer in the solvent, and the drug is contained in the gel.

[0009b] In another aspect, there is provided the drug composition as defined herein for use in treating a cancer.

[0010] Also disclosed is an antimicrobial drug composition, comprising:

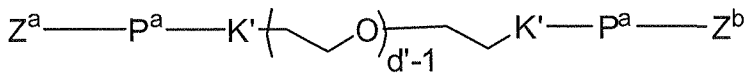
about 4 wt.% to about 10 wt.% of a gel-forming block copolymer;

a solvent; and

about 0.0001 wt.% to about 10 wt.% of an antimicrobial cationic polycarbonate (first drug);

wherein

the gel-forming block copolymer has a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of about 100 to about 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to about 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the antimicrobial drug composition,

the antimicrobial drug composition is a gel formed by noncovalent interactions of polymer chains of the gel-forming block copolymer in the solvent,

the antimicrobial cationic polycarbonate is contained in the gel.

[0010a] In another aspect, there is provided an antimicrobial drug composition, comprising:

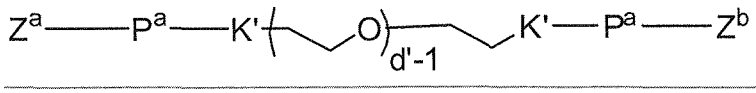
4 wt.% to 10 wt.% of a gel-forming block copolymer;

a solvent; and

0.0001 wt.% to 10 wt.% of an antimicrobial cationic polycarbonate (first drug);

wherein

the gel-forming block copolymer has a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of 100 to 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin, Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the antimicrobial drug composition,

the antimicrobial drug composition is a gel formed by noncovalent interactions of polymer chains of the gel-forming block copolymer in the solvent,

the antimicrobial cationic polycarbonate is contained in the gel.

[0011] Further disclosed is an aqueous solution for killing a microbe, comprising:

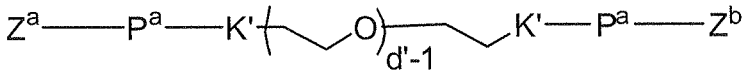
about 0.0001 wt.% to about 10 wt.% of an antimicrobial cationic polycarbonate (first drug); and

about 0.0001 wt.% to about 10 wt.% of an antimicrobial compound (second drug); wherein

weight percent (wt.%) is based on total weight of the aqueous solution,

the first drug and the second drug are associated by noncovalent interactions in the aqueous solution.

[0012] Also disclosed is a gel-forming block copolymer having a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of about 100 to about 600,

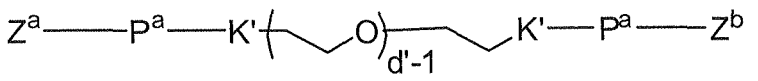
each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to about 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons.

[0012a] In another aspect, there is provided a gel-forming block copolymer having a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of 100 to 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to 15 carbons.

[0013] The above-described and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0014] **Figure 1A** is a graph showing the storage (G') and loss (G'') moduli of blank hydrogels containing 4 wt.% and 8 wt.% VitE1.25-PEG(20k)-VitE1.25 in HPLC water (Example 15 and Example 16, respectively). Herein, weight percent (wt.%) is based on total weight of the hydrogel unless otherwise indicated.

[0015] **Figure 1B** is a graph showing the storage (G') and loss (G'') moduli of blank hydrogels containing 4 wt.% and 8 wt.% VitE2.5-PEG(20k)-VitE2.5 in HPLC water (Example 17 and Example 18, respectively).

[0016] **Figure 1C** is a graph showing the viscosity dependence on shear rate of blank hydrogels containing 4 wt.% and 8 wt.% VitE1.25-PEG(20k)-VitE1.25 in HPLC water (Example 15 and Example 16, respectively).

[0017] **Figure 1D** is a graph showing the viscosity dependence on shear rate of blank hydrogels containing 4 wt.% and 8 wt.% VitE2.5-PEG(20k)-VitE2.5 in HPLC water (Example 17 and Example 18, respectively).

[0018] **Figure 1E** is a graph showing viscosity dependence on shear rate of blank organogels containing 10 wt.% VitE6.5-PEG(20k)-VitE6.5 and 10 wt.% VitE8.5-PEG(20k)-VitE8.5 organogels in KOLLIPHOR RH40 (Example 19 and Example 20, respectively).

[0019] **Figure 2** is a graph showing the dynamic step strain amplitude test ($\gamma = 0.2$ or 100%) of blank hydrogel Example 15 containing 4 wt.% VitE1.25-PEG(20k)-VitE1.25, and a herceptin-loaded hydrogel Example 24 containing 4 wt.% VitE1.25-PEG(20k)-VitE1.25 and 1 wt.% herceptin.

CLAIMS

What is claimed is:

1. A drug composition, comprising:

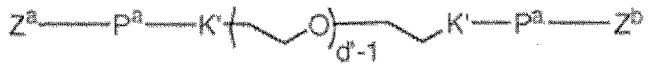
~~about~~ 4 wt.% to ~~about~~ 10 wt.% of a gel-forming block copolymer;

a solvent; and

~~about~~ 0.0001 wt.% to ~~about~~ 10 wt.% of a drug;

wherein

the gel-forming block copolymer has a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of ~~about~~ 100 to ~~about~~ 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to ~~about~~ 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the drug composition,

the drug composition is a gel formed by noncovalent interactions of polymer chains of the block copolymer in the solvent, and

the drug is contained in the gel.

2. The drug composition of claim 1, wherein each P^a consists essentially of 1 to ~~about~~ 8 vitamin-bearing subunits.

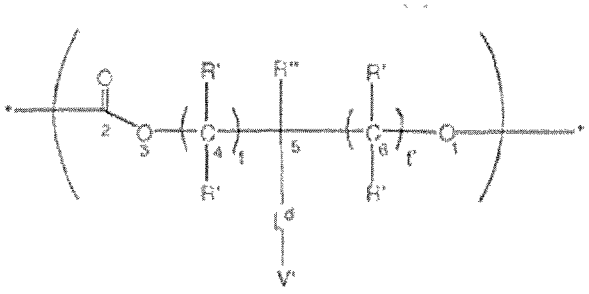
3. The drug composition of claim 1, wherein the vitamin is selected from the group

consisting of vitamin E compounds, vitamin D compounds, and combinations thereof.

4. The drug composition of claim 1, wherein each of the vitamin-bearing subunits comprises an alpha-tocopheryl moiety.

5. The drug composition of claim 1, wherein each of the vitamin-bearing subunits comprises an ergocalcipheryl moiety.6. The drug composition of claim 1, wherein Z^a is hydrogen and Z^b is hydrogen.

7. The drug composition of claim 1, wherein the vitamin-bearing subunits of have a structure in accordance with formula (2):



(2).

wherein

the carbonate backbone atoms are numbered 1 to 6,

L^d is a single bond or a divalent linking group comprising 1 to ~~about~~ 15 carbons,

V is a moiety comprising a covalently bound form of a vitamin,

each R' is an independent monovalent radical selected from the group consisting of hydrogen, halogens, methyl, and ethyl,

R" is a monovalent radical selected from the group consisting of hydrogen and alkyl groups comprising 1 to 6 carbons,

t is a positive integer having a value of 0 to 2,

t' is a positive integer having a value of 0 to 2, and

t and t' cannot both be zero.

8. The drug composition of claim 1, wherein the vitamin-bearing subunits of the gel- forming block copolymer have the structure:

15. The drug compositionuse of claim 14, wherein the cancer is a breast cancer.

16. An antimicrobial drug composition, comprising:

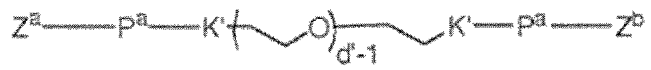
about 4 wt.% to about 10 wt.% of a gel-forming block copolymer;

a solvent; and

about 0.0001 wt.% to about 10 wt.% of an antimicrobial cationic polycarbonate (first drug);

wherein

the gel-forming block copolymer has a structure in accordance with formula (1):



(I),

wherein

d' is a positive number having a value of about 100 to about 600,

each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to about 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to about 15 carbons;

and wherein

weight percent (wt.%) is based on total weight of the antimicrobial drug composition,

the antimicrobial drug composition is a gel formed by noncovalent interactions of polymer chains of the gel-forming block copolymer in the solvent,

the antimicrobial cationic polycarbonate is contained in the gel.

17. The antimicrobial drug composition of claim 16, wherein the antimicrobial cationic polycarbonate has a structure in accordance with formula (8):

Z'-P'-Z' (8),

wherein

Z' is a monovalent C_1-C_{15} first end group, wherein Z' is linked to a backbone carbonyl group of P',

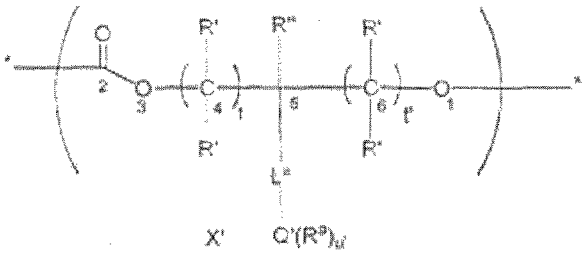
Z" is a monovalent second end group selected from the group consisting of hydrogen and C_1-C_{15} moieties,

P' is a polymer chain consisting essentially of cationic carbonate subunits, wherein i) P' has a degree of polymerization (DP) of ~~about~~ 5 to ~~about~~ 45, ii) each of the cationic carbonate subunits comprises a backbone portion and a C_6-C_{25} cationic side chain linked to the backbone portion, and iii) the cationic side chain comprises a positive-charged heteroatom Q' of a quaternary ammonium group and/or quaternary phosphonium group,

~~about~~ 25% to ~~about~~ 100% of the cationic carbonate subunits, designated first cationic carbonate subunits, have a cationic side chain comprising 13 to ~~about~~ 25 carbons, and

~~about~~ 0% to ~~about~~ 75% of the cationic carbonate subunits, designated second cationic carbonate subunits, have a cationic side chain comprising 6 to 12 carbons.

18. The antimicrobial drug composition of claim 17, wherein each of the cationic carbonate subunits of the antimicrobial cationic polycarbonate has a structure in accordance with formula (9):



(9),

wherein

L^a-$Q'(R^a)_{u'}$ is a C_6-C_{25} cationic side chain comprising a quaternary ammonium group and/or quaternary phosphonium group, wherein L^a is a divalent linking group comprising at least 3 carbons, Q' is a tetravalent positive-charged nitrogen or phosphorus, u' has a value of 1 to 3, each R^a is an independent radical having a valency of 1 to 3, and each R^a comprises at least 1 carbon,

of hydrogen and C_1-C_{15} moieties,

each polymer chain P^b consists essentially of cationic carbonate subunits, wherein i) the cationic polymer comprises a total of 5 to ~~about~~ 45 cationic carbonate subunits, ii) each of the cationic carbonate subunits comprises a backbone portion of the polymer chain and a cationic side chain linked to the backbone portion, and iii) the cationic side chain comprises a positive-charged heteroatom Q' of a quaternary ammonium group and/or quaternary phosphonium group,

~~about~~ 25% to 100% of all the cationic carbonate subunits of the cationic polymer, designated first cationic carbonate subunits, have a cationic side chain comprising 10 to ~~about~~ 25 carbons, and

0% to ~~about~~ 75% of the cationic carbonate subunits of the cationic polymer, designated second cationic carbonate subunits, have a cationic side chain comprising 6 to 9 carbons.

22. The antimicrobial drug composition of claim 21, wherein each of the first cationic carbonate subunits of the antimicrobial cationic polycarbonate has a cationic side chain comprising 13 to ~~about~~ 25 carbons, and each of the second cationic carbonate subunits has a cationic side chain comprising 6 to 12 carbons.

23. The antimicrobial drug composition of claim 16, further comprising a second drug that is an antimicrobial compound.

24. The antimicrobial drug composition of claim 23, wherein the antimicrobial compound is selected from the group consisting of fluconazole, doxycycline, and combinations thereof.

~~25. An aqueous solution for use in killing a microbe, comprising:~~

~~about 0.0001 wt.% to about 10 wt.% of an antimicrobial cationic polycarbonate (first drug); and~~

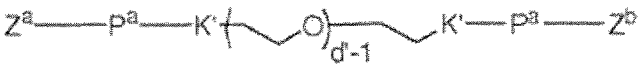
~~about 0.0001 wt.% to about 10 wt.% of an antimicrobial compound (second drug); wherein~~

~~weight percent (wt.%) is based on total weight of the aqueous solution,~~

~~the first drug and the second drug are associated by noncovalent interactions in the aqueous solution.~~

~~26. The aqueous solution of claim 25, wherein the aqueous solution is suitable for eradicating a microbial biofilm.~~

~~27~~25. A gel-forming block copolymer having a structure in accordance with formula (1):



(1),

wherein

d' is a positive number having a value of ~~about~~ 100 to ~~about~~ 600,

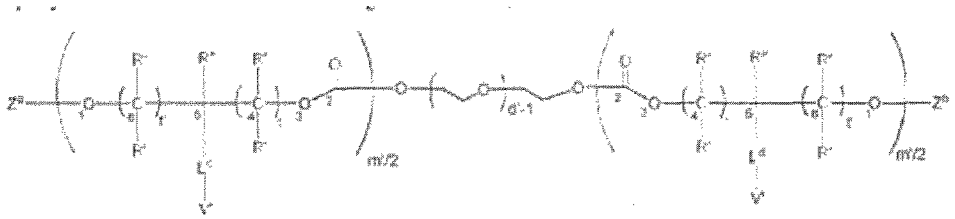
each K' is an independent divalent linking group selected from the group consisting of O, NH, S, and combinations thereof,

each P^a is an independent monocarbonate or polycarbonate chain comprising 1 to ~~about~~ 10 vitamin-bearing subunits, wherein each of the vitamin-bearing subunits comprises a carbonate backbone portion and a side chain linked to the carbonate backbone portion, the side chain comprising a covalently bound form of a vitamin,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons.

~~28~~26. The gel-forming block copolymer of claim ~~27~~25, wherein the gel-forming block copolymer has a structure according to formula (1-A):



(1-A),

wherein

the carbonate backbone atoms are numbered 1 to 6 in each carbonate subunit, d' is a positive number having a value of ~~about~~ 100 to ~~about~~ 600,

each m' is an independent positive number having a value of 2 to ~~about~~ 20, each L^d is independently a single bond or a divalent linking group comprising 1 to ~~about~~ 15 carbons,

each V' is an independent moiety comprising a covalently bound form of a vitamin,

each R' is an independent monovalent radical selected from the group consisting of hydrogen, halogens, methyl, and ethyl,

each R" is an independent monovalent radical selected from the group consisting of hydrogen and alkyl groups comprising 1 to 6 carbons,

each t is an independent positive integer having a value of 0 to 2,

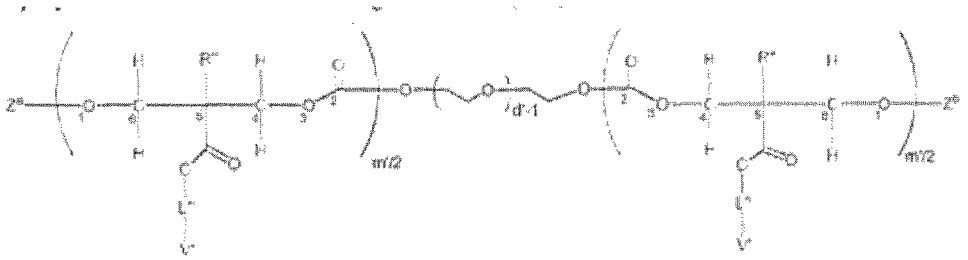
each t' is an independent positive integer having a value of 0 to 2,

no carbonate subunit has t = 0 and t' = 0,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons.

~~29~~27. The gel-forming block copolymer of claim ~~27~~25, wherein the gel-forming block copolymer has a structure according to formula (1-B):



(1-B),

wherein

the carbonate backbone atoms are numbered 1 to 6 in each carbonate subunit,

d' is a positive number having a value of ~~about~~ 100 to ~~about~~ 600, each m' is an independent positive number having a value of 2 to ~~about~~ 20, each L^e is independently a single bond or a divalent linking group comprising 1 to ~~about~~ 15 carbons,

each V' is an independent moiety comprising a covalently bound form of a vitamin,

each R' is an independent monovalent radical selected from the group consisting of hydrogen, halogens, methyl, and ethyl,

each R" is an independent monovalent radical selected from the group consisting of hydrogen and alkyl groups comprising 1 to 6 carbons,

Z^a is a first end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons, and

Z^b is a second end group selected from the group consisting of hydrogen and groups comprising 1 to ~~about~~ 15 carbons.