

**TITLE OF INVENTION: A PEPTIDE CAPABLE OF FORMING A GEL FOR USE
IN TISSUE ENGINEERING AND BIOPRINTING**

5

The present invention relates to peptides capable of forming a gel and to their use(s), e.g. in tissue engineering and bioprinting. The present invention furthermore relates to a gel comprising a peptide in accordance with the present invention, to a method of preparing such gel and to the use of such gel. In one embodiment, such gel is a hydrogel. The present invention furthermore relates to a wound dressing or wound healing agent comprising a gel according to the present invention and to a surgical implant or stent comprising a peptide scaffold formed by a gel according to the present invention. Moreover, the present invention also relates to a pharmaceutical and/or cosmetic composition, to a biomedical device or an electronic device comprising peptide(s) according to the present invention. Furthermore, the present invention relates to a kit comprising a first container containing a peptide according to the present invention, and a second container containing an aqueous or organic solution. Moreover, the present invention relates to a method of tissue regeneration, using a gel in accordance with the present invention. Furthermore, the present invention also relates to a method of printing using the peptide(s) and/or the gel(s) according to the present invention. Furthermore, the present invention relates to a method of treatment of a wound and/or for wound healing involving the use of a gel and/or peptide(s) according to the present invention.

BACKGROUND

3D printing technologies can be applied to build tissue-like structures, e.g. in the field of medicine and tissue engineering. Generally, these methods are referred to as 3D bioprinting. Typically, printing inks are used that are synthetic, e.g. polymers, or natural. Also materials from plants, such as alginate, can be used. In particular, with natural materials there can be significant batch-to-batch variations which has an impact on reproducibility and sustainability of the bio-printed 3D structures.

In 3D bioprinting, usually a pre-polymer viscous solution is used to print in 3D, and after printing, either an initiator or (UV or visible) light is used for the polymerization of the 3D construct. Alternatively, a polymer or other macromolecular structure may form by self-

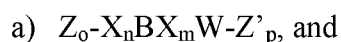
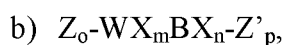
assembly. The solution(s), that is (are) used for bioprinting are also referred to as “bioinks”. Several factors are important for bioinks to be suitable for 3D bioprinting. These include ease of handling, biocompatibility, biomimetic structure, biodegradability, porosity and mechanical strength. Bioinks need to be prepared with ease and form macromolecular structures at the
 5 desired point in space and time. Accordingly, there is a continued need for useful bioinks that can be used in printing and tissue engineering methodologies.

Gels are used for many biomedical applications, such as salves, ointments, wound dressings etc. In many instances, they are formed by naturally derived compounds, such as gelatin or
 10 alginates or carrageenans, and thus are subject to naturally inherent variations in quality and composition. Hence there exists a need in the art for novel materials capable of forming gels.

SUMMARY OF THE INVENTION

15 It was therefore an object of the present invention to provide means to prepare a suitable bio-ink. It was furthermore an object of the present invention to provide means that are suitable to be used in tissue engineering. It was also an object of the invention to provide materials capable of forming a gel that are easy to synthesise and that are not subject to natural variations.

20 In a first aspect, the present invention therefore relates to a peptide capable of forming a gel by self-assembly, said peptide having a general formula selected from:



25 wherein Z is an N-terminal protecting group and Z' is a C-terminal protecting group, with o and p being independently selected from 0 and 1;

wherein X is, independently at each occurrence, an aliphatic amino acid selected from
 30 isoleucine, norleucine, leucine, valine, alanine, glycine, homoallylglycine and homopropargylglycine with n and m being integers being independently selected from 0, 1 and 2, with the proviso that $m+n \leq 2$,

wherein B is an aromatic amino acid selected from phenylalanine and tryptophan, or is an aliphatic counterpart of said aromatic amino acid, said aliphatic counterpart being

selected from cyclohexylalanine, 4-hydroxy-cyclohexylalanine, 3,4-dihydroxycyclohexylalanine.

Wherein W is a polar amino acid selected from aspartic acid, glutamic acid, asparagine, glutamine, lysine, 5-N-ethyl-glutamine (theanine), citrulline, thio-citrulline, cysteine, homocysteine, methionine, ethionine, selenomethionine, telluromethionine, threonine, allothreonine, serine, homoserine, tyrosine, histidine, arginine, homoarginine, ornithine, lysine, N(6)-carboxymethyllysine, histidine, 2,4-diaminobutyric acid (Dab), 2,3-diaminopropionic acid (Dap), and N(6)-carboxymethyllysine, wherein said polar amino acid is preferably selected from the group consisting of aspartic acid, asparagine, glutamic acid, glutamine, serine, threonine, methionine, arginine, histidine, lysine, ornithine (Orn), 2,4-diaminobutyric acid (Dab), and 2,3-diaminopropionic acid (Dap).

In one embodiment, o and p are each 1.

In one embodiment, Z has the general formula $-C(O)-R$, wherein R is selected from the group consisting of H, unsubstituted or substituted alkyls, and unsubstituted or substituted aryls,

wherein R is preferably selected from the group consisting of methyl, ethyl, propyl, isopropyl, butyl and isobutyl, and

wherein Z' is $-NR_1R_2$, R_1 and R_2 being independently selected from H and C_1-C_{10} alkyl, said- NR_1R_2 thus forming an amide group at the C-terminus of said peptide, wherein preferably Z is an acetyl group, and wherein preferably Z' is NH_2 .

In one embodiment, said amino acids in said peptide are either L-amino acids or D-amino acids.

In one embodiment, each of the hydrophilic amino acids has a polar group which is independently selected from a hydroxyl, an ether, a carboxyl, an imido, an amido, an ester, an amino, a guanidine, a thio, a thioether, a seleno and a telluro group.

In one embodiment, said gel is a hydrogel or is an organogel.

In one embodiment, the peptide consists of a sequence selected from

	IVFK	(SEQ ID NO:1)
	IVOK	(SEQ ID NO:2)
	IFVK	(SEQ ID NO:3)
5	IOVK	(SEQ ID NO:4)
	FIVK	(SEQ ID NO:5)
	OIVK	(SEQ ID NO:6)
	FVIK	(SEQ ID NO:7)
	OVIK	(SEQ ID NO:8)
10		
	IVFD	(SEQ ID NO:9)
	IVOD	(SEQ ID NO:10)
	IFVD	(SEQ ID NO:11)
	IOVD	(SEQ ID NO:12)
15	FIVD	(SEQ ID NO:13)
	OIVD	(SEQ ID NO:14)
	FVID	(SEQ ID NO:15)
	OVID	(SEQ ID NO:16)
20	IVFE	(SEQ ID NO:17)
	IVOE	(SEQ ID NO:18)
	IFVE	(SEQ ID NO:19)
	IOVE	(SEQ ID NO:20)
	FIVE	(SEQ ID NO:21)
25	OIVE	(SEQ ID NO:22)
	FVIE	(SEQ ID NO:23)
	OVIE	(SEQ ID NO:24)
30		
	IVFS	(SEQ ID NO:25)
	IVOS	(SEQ ID NO:26)
	IFVS	(SEQ ID NO:27)
	IOVS	(SEQ ID NO:28)
	FIVS	(SEQ ID NO:29)
	OIVS	(SEQ ID NO:30)

	FVIS	(SEQ ID NO:31)
	OVIS	(SEQ ID NO:32)
	IVFR	(SEQ ID NO:33)
5	IVOR	(SEQ ID NO:34)
	IFVR	(SEQ ID NO:35)
	IOVR	(SEQ ID NO:36)
	FIVR	(SEQ ID NO:37)
	OIVR	(SEQ ID NO:38)
10	FVIR	(SEQ ID NO:39)
	OVIR	(SEQ ID NO:40)
	IVF(Dab)	(SEQ ID NO:41)
	IVO(Dab)	(SEQ ID NO:42)
15	IFV(Dab)	(SEQ ID NO:43)
	IOV(Dab)	(SEQ ID NO:44)
	FIV(Dab)	(SEQ ID NO:45)
	OIV(Dab)	(SEQ ID NO:46)
	FVI(Dab)	(SEQ ID NO:47)
20	OVI(Dab)	(SEQ ID NO:48)
	IVF(Dap)	(SEQ ID NO:49)
	IVO(Dap)	(SEQ ID NO:50)
	IFV(Dap)	(SEQ ID NO:51)
25	IOV(Dap)	(SEQ ID NO:52)
	FIV(Dap)	(SEQ ID NO:53)
	OIV(Dap)	(SEQ ID NO:54)
	FVI(Dap)	(SEQ ID NO:55)
	OVI(Dap)	(SEQ ID NO:56)
30		
	IVF(Orn)	(SEQ ID NO:57)
	IVO(Orn)	(SEQ ID NO:58)
	IFV(Orn)	(SEQ ID NO:59)
	IOV(Orn)	(SEQ ID NO:60)

	FIV(Orn)	(SEQ ID NO:61)
	OIV(Orn)	(SEQ ID NO:62)
	FVI(Orn)	(SEQ ID NO:63)
	OVI(Orn)	(SEQ ID NO:64)
5		
	KFVI	(SEQ ID NO:65)
	KOVI	(SEQ ID NO:66)
	KVFI	(SEQ ID NO:67)
	KVOI	(SEQ ID NO:68)
10	KVIF	(SEQ ID NO:69)
	KVIO	(SEQ ID NO:70)
	KIVF	(SEQ ID NO:71)
	KIVO	(SEQ ID NO:72)
15		
	DFVI	(SEQ ID NO:73)
	DOVI	(SEQ ID NO:74)
	DVFI	(SEQ ID NO:75)
	DVOI	(SEQ ID NO:76)
	DVIF	(SEQ ID NO:77)
20	DVIO	(SEQ ID NO:78)
	DIVF	(SEQ ID NO:79)
	DIVO	(SEQ ID NO:80)
25		
	EFVI	(SEQ ID NO:81)
	EOVI	(SEQ ID NO:82)
	EVFI	(SEQ ID NO:83)
	EVOI	(SEQ ID NO:84)
	EVIF	(SEQ ID NO:85)
	EVIO	(SEQ ID NO:86)
30	EIVF	(SEQ ID NO:87)
	EIVO	(SEQ ID NO:88)
	SFVI	(SEQ ID NO:89)
	SOVI	(SEQ ID NO:90)

	SVFI	(SEQ ID NO:91)
	SVOI	(SEQ ID NO:92)
	SVIF	(SEQ ID NO:93)
	SVIO	(SEQ ID NO:94)
5	SIVF	(SEQ ID NO:95)
	SIVO	(SEQ ID NO:96)
	RFVI	(SEQ ID NO:97)
	ROVI	(SEQ ID NO:98)
10	RVFI	(SEQ ID NO:99)
	RVOI	(SEQ ID NO:100)
	RVIF	(SEQ ID NO:101)
	RVIO	(SEQ ID NO:102)
	RIVF	(SEQ ID NO:103)
15	RIVO	(SEQ ID NO:104)
	(Dab)FVI	(SEQ ID NO:105)
	(Dab)OVI	(SEQ ID NO:106)
	(Dab)VFI	(SEQ ID NO:107)
20	(Dab)VOI	(SEQ ID NO:108)
	(Dab)VIF	(SEQ ID NO:109)
	(Dab)VIO	(SEQ ID NO:110)
	(Dab)IVF	(SEQ ID NO:111)
	(Dab)IVO	(SEQ ID NO:112)
25		
	(Dap)FVI	(SEQ ID NO:113)
	(Dap)OVI	(SEQ ID NO:114)
	(Dap)VFI	(SEQ ID NO:115)
	(Dap)VOI	(SEQ ID NO:116)
30	(Dap)VIF	(SEQ ID NO:117)
	(Dap)VIO	(SEQ ID NO:118)
	(Dap)IVF	(SEQ ID NO:119)
	(Dap)IVO	(SEQ ID NO:120)

	(Orn)FVI	(SEQ ID NO:121)
	(Orn)OVI	(SEQ ID NO:122)
	(Orn)VFI	(SEQ ID NO:123)
	(Orn)VOI	(SEQ ID NO:124)
5	(Orn)VIF	(SEQ ID NO:125)
	(Orn)VIO	(SEQ ID NO:126)
	(Orn)IVF	(SEQ ID NO:127)
	(Orn)IVO	(SEQ ID NO:128)

10 Wherein I = isoleucine, L = leucine, V = valine, F = phenylalanine, K = lysine, D = aspartic acid, O = cyclohexylalanine, (Dab) = 2,4-diaminobutyric acid, (Dap) = 2,3-diaminopropionic acid, and (Orn) = ornithine;

wherein each of the sequences may be protected or unprotected at the N-terminus, preferably acetylated or non—acetylated, and may be amidated or non-amidated at the C-terminus,

15 wherein, preferably, said sequence is selected from

	Ac-IVFK-NH ₂	(SEQ ID NO:1)
	Ac-IVOK-NH ₂	(SEQ ID NO:2)
	Ac-IFVK-NH ₂	(SEQ ID NO:3)
20	Ac-IOVK-NH ₂	(SEQ ID NO:4)
	Ac-FIVK-NH ₂	(SEQ ID NO:5)
	Ac-OIVK-NH ₂	(SEQ ID NO:6)
	Ac-FVIK-NH ₂	(SEQ ID NO:7)
	Ac-OVIK-NH ₂	(SEQ ID NO:8)

25

	Ac-IVFD-COOH	(SEQ ID NO:9)
	Ac-IVOD-COOH	(SEQ ID NO:10)
	Ac-IFVD-COOH	(SEQ ID NO:11)
	Ac-IOVD-COOH	(SEQ ID NO:12)
30	Ac-FIVD-COOH	(SEQ ID NO:13)
	Ac-OIVD-COOH	(SEQ ID NO:14)
	Ac-FVID-COOH	(SEQ ID NO:15)
	Ac-OVID-COOH	(SEQ ID NO:16)

	Ac-IVFE-COOH	(SEQ ID NO:17)
	Ac-IVOE-COOH	(SEQ ID NO:18)
	Ac-IFVE-COOH	(SEQ ID NO:19)
	Ac-IOVE-COOH	(SEQ ID NO:20)
5	Ac-FIVE-COOH	(SEQ ID NO:21)
	Ac-OIVE-COOH	(SEQ ID NO:22)
	Ac-FVIE-COOH	(SEQ ID NO:23)
	Ac-OVIE-COOH	(SEQ ID NO:24)
10	Ac-IVFS- -NH ₂	(SEQ ID NO:25)
	Ac-IVOS- -NH ₂	(SEQ ID NO:26)
	Ac-IFVS- -NH ₂	(SEQ ID NO:27)
	Ac-IOVS- -NH ₂	(SEQ ID NO:28)
	Ac-FIVS- -NH ₂	(SEQ ID NO:29)
15	Ac-OIVS- -NH ₂	(SEQ ID NO:30)
	Ac-FVIS- -NH ₂	(SEQ ID NO:31)
	Ac-OVIS- -NH ₂	(SEQ ID NO:32)
	Ac-IVFR-NH ₂	(SEQ ID NO:33)
20	Ac-IVOR-NH ₂	(SEQ ID NO:34)
	Ac-IFVR-NH ₂	(SEQ ID NO:35)
	Ac-IOVR-NH ₂	(SEQ ID NO:36)
	Ac-FIVR-NH ₂	(SEQ ID NO:37)
	Ac-OIVR-NH ₂	(SEQ ID NO:38)
25	Ac-FVIR-NH ₂	(SEQ ID NO:39)
	Ac-OVIR-NH ₂	(SEQ ID NO:40)
	Ac-IVF(Dab)-NH ₂	(SEQ ID NO:41)
	Ac-IVO(Dab) -NH ₂	(SEQ ID NO:42)
30	Ac-IFV(Dab)-NH ₂	(SEQ ID NO:43)
	Ac-IOV(Dab) -NH ₂	(SEQ ID NO:44)
	Ac-FIV(Dab) -NH ₂	(SEQ ID NO:45)
	Ac-OIV(Dab) -NH ₂	(SEQ ID NO:46)
	Ac-FVI(Dab) -NH ₂	(SEQ ID NO:47)

	Ac-OVI(Dab) -NH ₂	(SEQ ID NO:48)
	Ac-IVF(Dap) -NH ₂	(SEQ ID NO:49)
	Ac-IVO(Dap) -NH ₂	(SEQ ID NO:50)
5	Ac-IFV(Dap) -NH ₂	(SEQ ID NO:51)
	Ac-IOV(Dap) -NH ₂	(SEQ ID NO:52)
	Ac-FIV(Dap) -NH ₂	(SEQ ID NO:53)
	Ac-OIV(Dap) -NH ₂	(SEQ ID NO:54)
	Ac-FVI(Dap) -NH ₂	(SEQ ID NO:55)
10	Ac-OVI(Dap) -NH ₂	(SEQ ID NO:56)
	Ac-IVF(Orn) -NH ₂	(SEQ ID NO:57)
	Ac-IVO(Orn) -NH ₂	(SEQ ID NO:58)
	Ac-IFV(Orn) -NH ₂	(SEQ ID NO:59)
15	Ac-IOV(Orn) -NH ₂	(SEQ ID NO:60)
	Ac-FIV(Orn) -NH ₂	(SEQ ID NO:61)
	Ac-OIV(Orn) -NH ₂	(SEQ ID NO:62)
	Ac-FVI(Orn) -NH ₂	(SEQ ID NO:63)
	Ac-OVI(Orn) -NH ₂	(SEQ ID NO:64)
20		
	Ac-KFVI-NH ₂	(SEQ ID NO:65)
	Ac-KOVI-NH ₂	(SEQ ID NO:66)
	Ac-KVFI-NH ₂	(SEQ ID NO:67)
	Ac-KVOI-NH ₂	(SEQ ID NO:68)
25	Ac-KVIF-NH ₂	(SEQ ID NO:69)
	Ac-KVIO-NH ₂	(SEQ ID NO:70)
	Ac-KIVF-NH ₂	(SEQ ID NO:71)
	Ac-KIVO-NH ₂	(SEQ ID NO:72)
30		
	Ac-DFVI-NH ₂	(SEQ ID NO:73)
	Ac-DOVI-NH ₂	(SEQ ID NO:74)
	Ac-DVFI-NH ₂	(SEQ ID NO:75)
	Ac-DVOI-NH ₂	(SEQ ID NO:76)
	Ac-DVIF-NH ₂	(SEQ ID NO:77)

	Ac-DVIO-NH ₂	(SEQ ID NO:78)
	Ac-DIVF-NH ₂	(SEQ ID NO:79)
	Ac-DIVO-NH ₂	(SEQ ID NO:80)
5	Ac-EFVI-NH ₂	(SEQ ID NO:81)
	Ac-EOVI-NH ₂	(SEQ ID NO:82)
	Ac-EVFI-NH ₂	(SEQ ID NO:83)
	Ac-EVOI-NH ₂	(SEQ ID NO:84)
	Ac-EVIF-NH ₂	(SEQ ID NO:85)
10	Ac-EVIO-NH ₂	(SEQ ID NO:86)
	Ac-EIVF-NH ₂	(SEQ ID NO:87)
	Ac-EIVO-NH ₂	(SEQ ID NO:88)
	Ac-SFVI-NH ₂	(SEQ ID NO:89)
15	Ac-SOVI-NH ₂	(SEQ ID NO:90)
	Ac-SVFI-NH ₂	(SEQ ID NO:91)
	Ac-SVOI-NH ₂	(SEQ ID NO:92)
	Ac-SVIF-NH ₂	(SEQ ID NO:93)
	Ac-SVIO-NH ₂	(SEQ ID NO:94)
20	Ac-SIVF-NH ₂	(SEQ ID NO:95)
	Ac-SIVO-NH ₂	(SEQ ID NO:96)
	Ac-RFVI-NH ₂	(SEQ ID NO:97)
	Ac-ROVI-NH ₂	(SEQ ID NO:98)
25	Ac-RVFI-NH ₂	(SEQ ID NO:99)
	Ac-RVOI-NH ₂	(SEQ ID NO:100)
	Ac-RVIF-NH ₂	(SEQ ID NO:101)
	Ac-RVIO-NH ₂	(SEQ ID NO:102)
	Ac-RIVF-NH ₂	(SEQ ID NO:103)
30	Ac-RIVO-NH ₂	(SEQ ID NO:104)
	Ac-(Dab)FVI –NH ₂	(SEQ ID NO:105)
	Ac- (Dab)OVI -NH ₂	(SEQ ID NO:106)
	Ac- (Dab)VFI –NH ₂	(SEQ ID NO:107)

	Ac- (Dab)VOI –NH ₂	(SEQ ID NO:108)
	Ac- (Dab)VIF –NH ₂	(SEQ ID NO:109)
	Ac- (Dab)VIO –NH ₂	(SEQ ID NO:110)
	Ac- (Dab)IVF –NH ₂	(SEQ ID NO:111)
5	Ac- (Dab)IVO –NH ₂	(SEQ ID NO:112)
	Ac-(Dap)FVI –NH ₂	(SEQ ID NO:113)
	Ac-(Dap)OVI –NH ₂	(SEQ ID NO:114)
	Ac-(Dap)VFI –NH ₂	(SEQ ID NO:115)
10	Ac-(Dap)VOI –NH ₂	(SEQ ID NO:116)
	Ac-(Dap)VIF –NH ₂	(SEQ ID NO:117)
	Ac-(Dap)VIO –NH ₂	(SEQ ID NO:118)
	Ac-(Dap)IVF –NH ₂	(SEQ ID NO:119)
	Ac-(Dap)IVO –NH ₂	(SEQ ID NO:120)
15		
	Ac-(Orn)FVI –NH ₂	(SEQ ID NO:121)
	Ac-(Orn)OVI –NH ₂	(SEQ ID NO:122)
	Ac-(Orn)VFI –NH ₂	(SEQ ID NO:123)
	Ac-(Orn)VOI –NH ₂	(SEQ ID NO:124)
20	Ac-(Orn)VIF –NH ₂	(SEQ ID NO:125)
	Ac-(Orn)VIO –NH ₂	(SEQ ID NO:126)
	Ac-(Orn)IVF –NH ₂	(SEQ ID NO:127)
	Ac-(Orn)IVO –NH ₂	(SEQ ID NO:128)
25	wherein Ac = acetyl acetylates the N-terminus, NH ₂ = amine, thus amidates the C-terminus, and –COOH = unprotected C-terminus.	

In one embodiment, said N-terminal protecting group Z is a peptidomimetic molecule, including natural and synthetic amino acid derivatives, wherein the N-terminus of said peptidomimetic molecule may be modified with a functional group selected from the group consisting of carboxylic acid, amide, alcohol, aldehyde, amine, imine, nitrile, an urea analog, phosphate, carbonate, sulfate, nitrate, maleimide, vinyl sulfone, azide, alkyne, alkene, carbohydrate, imide, peroxide, ester, aryl, ketone, sulphite, nitrite, phosphonate, and silane.

In one embodiment, said C-terminal group Z' is selected from the group of small molecules, functional groups and linkers.

In one embodiment, said C-terminal group Z' is selected from

- 5 - functional groups, such as polar or non-polar functional groups,
 such as (but not limited to)
 -COOH, -COOR, -COR, -CONHR or -CONRR' with R and R' being
 selected from the group consisting of H, unsubstituted or substituted alkyls,
 and unsubstituted or substituted aryls,
- 10 -NH₂, -OH, -SH, -CHO, maleimide, imidoester, carbodiimide ester, iso-
 cyanate;
- small molecules,
 such as (but not limited to) sugars, alcohols, hydroxy acids, amino acids, vita-
 mins, biotin;
- 15 - linkers terminating in a polar functional group,
 such as (but not limited to) ethylenediamine, PEG, carbodiimide ester, im-
 idoester;
- linkers coupled to small molecules or vitamins,
 such as biotin, sugars, hydroxy acids.
- 20
- In one embodiment, said C-terminal group Z' is suitable to be used for chemical conjugation
or coupling of at least one compound selected from
 bioactive molecules or moieties,
 such as growth factors, cytokines, lipids, cell receptor ligands, hormones, pro-
25 drugs, drugs, vitamins, antigens, antibodies, antibody fragments, oligonucleo-
 tides (including but not limited to DNA, messenger RNA, short hairpin RNA,
 small interfering RNA, microRNA, peptide nucleic acids, aptamers), saccha-
 rides;
- label(s), dye(s),
- 30 such as fluorescent or radioactive label(s), imaging contrast agents;
- pathogens,
 such as viruses, bacteria and parasites;
- micro- and nanoparticles
 or combinations thereof

wherein said chemical conjugation can be carried out before or after self-assembly of the peptide.

In one embodiment, the C-terminus of the peptide is functionalized, such as by chemical conjugation or coupling of at least one compound selected from

bioactive molecules or moieties,

such as growth factors, cytokines, lipids, cell receptor ligands, hormones, prodrugs, drugs, vitamins, antigens, antibodies, antibody fragments, oligonucleotides (including but not limited to DNA, messenger RNA, short hairpin RNA, small interfering RNA, microRNA, peptide nucleic acids, aptamers), saccharides;

label(s), dye(s),

such as fluorescent or radioactive label(s), imaging contrast agents;

pathogens,

such as viruses, bacteria and parasites;

micro- and nanoparticles

or combinations thereof

wherein said chemical conjugation can be carried out before or after self-assembly of the peptide and/or peptidomimetic.

In one embodiment, said C-terminal group Z' is a peptidomimetic molecule, including natural and synthetic amino acid derivatives, wherein the C-terminus of said peptidomimetic molecule may be modified with a functional group selected from the group consisting of carboxylic acid, amide, alcohol, aldehyde, amine, imine, nitrile, an urea analog, phosphate, carbonate, sulfate, nitrate, maleimide, vinyl sulfone, azide, alkyne, alkene, carbohydrate, imide, peroxide, ester, aryl, ketone, sulphite, nitrite, phosphonate, and silane.

In one embodiment, the peptide according to the present invention is stable in aqueous solution at physiological conditions at ambient temperature for a period of time in the range from 1 day to at least 6 months, preferably to at least 8 months, more preferably to at least 12 months.

In one embodiment, the peptide according to the present invention is stable in aqueous solution at physiological conditions, at a temperature up to 90 °C, for at least 1 hour.

In a further aspect, the present invention relates to a hydrogel or organogel comprising a peptide according to the present invention, as defined above.

- 5 In one embodiment, the hydrogel is stable in aqueous solution at ambient temperature for a period of at least 1 month, preferably at least 2 to 4 months, more preferably at least 6 to 12 months.

In one embodiment, the hydrogel is characterized by a storage modulus G' to loss modulus G'' ratio that is greater than 2 to 5.

In one embodiment, the hydrogel or organogel is characterized by a storage modulus G' from 500Pa to 200,000 Pa at a frequency in the range of from 0.1 Hz to 100 Hz.

- 15 In one embodiment, the hydrogel or organogel has a higher mechanical strength than collagen or its hydrolyzed form (gelatin).

In one embodiment, the hydrogel or organogel according to the present invention comprises fibers of the peptide according to the present invention, as defined above, said fibers defining a network that is capable of entrapping at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a micro-or nanoparticle, a small organic molecule or a pharmaceutically active compound.

- 25 In one embodiment, the hydrogel comprises at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a small organic molecule, a micro-or nanoparticle, or a pharmaceutically active compound entrapped by the network of fibers.

- 30 In one embodiment, the fibers are coupled to the at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a small organic molecule, a micro-or nanoparticle, or a pharmaceutically active compound entrapped by the network of fibers.

In one embodiment, the hydrogel or organogel is comprised in at least one of a fuel cell, a solar cell, an electronic cell, a biosensing device, a medical device, an implant, a pharmaceutical composition and a cosmetic composition.

- 5 In one embodiment, the hydrogel or organogel according to the present invention is injectable.

In a further aspect, the present invention relates to the use of a peptide or of hydrogel or organogel according to the present invention, as defined above, in at least one of the following:

- 10 medical tool kit,
a fuel cell,
a solar cell,
an electronic cell,
regenerative medicine and tissue regeneration,
15 implantable scaffold
disease model
wound healing,
2D and 3D synthetic cell culture substrate,
stem cell therapy,
20 injectable therapies,
biosensor development,
high-throughput screening,
biofunctionalized surfaces,
printing
25 biofabrication, such as bio-printing, and
gene therapy.

- In a further aspect, the present invention also relates to a method of preparing a hydrogel or organogel, the method comprising dissolving a peptide according to the present invention in
30 an aqueous solution or an organic solution, respectively.

In one embodiment, the dissolved peptide in aqueous or organic solution is further exposed to temperature, wherein the temperature is in the range from 20 °C to 90 °C, preferably from 20 °C to 70 °C.

In one embodiment, the peptide is dissolved at a concentration from 0.01 µg/ml to 100 mg/ml, preferably at a concentration from 1 mg/ml to 50 mg/ml, more preferably at a concentration from about 1 mg/ml to about 20 mg/ml.

5

In a further aspect, the present invention also relates to a cell or tissue graft or device comprising a hydrogel or organogel according to the present invention.

10 In a further aspect, the present invention also relates to a wound dressing or wound healing agent comprising a hydrogel or organogel according to the present invention.

In a further aspect, the present invention also relates to a surgical implant, or stent, the surgical implant or stent comprising a peptide scaffold, wherein the peptide scaffold is formed by a hydrogel or organogel according to the present invention.

15

In a further aspect, the present invention also relates to a pharmaceutical and/or cosmetic composition and/or a biomedical device and/or electronic device and/or a solution comprising the peptide according to the present invention.

20 In one embodiment, the pharmaceutical and/or cosmetic composition and/or the biomedical device, and/or the electronic device and/or the solution according to the present invention further comprises a pharmaceutically active compound.

25 In one embodiment, the pharmaceutical and/or cosmetic composition and/or solution is provided in the form of a topical gel or cream, a spray, a powder, or a sheet, patch or membrane, or wherein the pharmaceutical and/or cosmetic composition and/or solution is provided in the form of an injectable solution.

30 In one embodiment, the pharmaceutical and/or cosmetic composition and/or according to the present invention further comprises a pharmaceutically acceptable carrier.

In a further aspect, the present invention also relates to a kit of parts, the kit comprising a first container with a peptide according to the present invention and a second container with an aqueous or organic solution.

In one embodiment, the aqueous or organic solution of the second container further comprises a pharmaceutically active compound,
and/or wherein the first container with a peptide further comprises a pharmaceutically active
5 compound.

In a further aspect, the present invention also relates to an *in vitro* or *in vivo* method of tissue regeneration comprising the steps:

- (a) providing a hydrogel as defined above,
- 10 (b) exposing said hydrogel or organogel to cells which are to form regenerated tissue,
- (c) allowing said cells to grow on said hydrogel or organogel.

In one embodiment, the method is performed *in vivo*, wherein, in step a), said hydrogel is
15 provided at a place in a body where tissue regeneration is intended,
wherein said step a) is preferably performed by injecting said hydrogel at a place in the body where tissue regeneration is intended.

In a further aspect, the present invention also relates to a method of treatment of a wound and
20 for wound healing, said method comprising the step of
applying an effective amount of a hydrogel or organogel according to the present invention or a pharmaceutical composition according to the present invention to a wound.

In a further aspect, the present invention also relates to a bioimaging device comprising a hydrogel or organogel according to the present invention for *in vitro* and/or *in vivo* use,
25 preferably for oral application, for injection and/or for topical application.

In a further aspect, the present invention also relates to a 2D or 3D cell culture substrate comprising a hydrogel or organogel according to the present invention.

30

The present inventors surprisingly invented minimal sequences of linear peptides that enable the formation of supergelators in solutions, particularly aqueous solutions, which peptides thus are useful particularly for biological and biomedical applications. These are ultrashort peptides with amino acid compositions between 2-4 amino acids which were rationally de-

signed and investigated. Such ultrashort peptides have the additional advantage that they are extremely easy and economic to synthesise.

The present inventors found that specific amphiphilic peptide sequences show true superegelating properties, forming low molecular weight gels (LMWGs) by entrapping a solvent, e.g. water or other aqueous solutions, such as physiological buffers, of over 99% by weight. Interestingly, these amphiphilic peptides have an innate propensity to self-assemble to three dimensional (3D) fibrous networks in form of hydrogels. These gels can also be termed nanogels, because the diameter of the single fibers of the gel's fiber network have nanometer diameters. These peptide compounds are self-driven by non-covalent interactions to form soft solid material. Based on the nature of the peptides involved, generally composed of natural amino acids, these soft materials can easily be used for biomedical applications, in particular for tissue engineering.

Since the nature of the self-assembling process depends solely on the sequence information, the present inventors have observed that amphiphilic peptides, comprising a mixture of aliphatic and aromatic amino acids with at least one aromatic amino acid, show stronger self-assembling propensities, when the non-polar aromatic residue is exchanged by a non-aromatic counter residue, i.e. phenylalanine is exchanged by cyclohexylalanine. Without wishing to be bound by any theory or mechanism, the present inventors explain this effect of improved gelation properties for peptides in which hydrophobic aromatic residues have been exchanged for non-aromatic residues by an improved self-assembly process. Again without wishing to be bound by any mechanism or theory, the assembly mechanism seems to occur in a stepwise process that involves different structural transition steps, starting from a random structure to a helical intermediate, followed by a beta-sheet and then a beta-turn or cross-beta end structure. In such transition, a more rigid aromatic structure provides less flexibility and thus hampers the required change of secondary structures during scaffold formation.

The inventors could show that the topography of the fibers and the assembled networks strongly resemble the extracellular matrix (ECM). Depending on the nature of the polar amino acid moiety which is part of the amphiphilic peptide structure, nanogels can be formed in situ. The in situ formation of gels allows the parenteral application of therapeutic relevant molecules such as therapeutics, cells, nanoparticles, small molecules, nucleic acids, and others. Depending on the nature of the amino acids side chain, side-specific biofunctionalization can

be introduced to the peptide structure, although this must be done under premise that gelation and the formation of supramolecular structures is not enabled.

Thus, functional groups, such as glycans, i.e. by glycosylation, aldehyde or keto groups, phosphorylation, sulfuration, nanoparticle-functionalization, biotin-functionalization for affinity anchors such as streptavidin, besides others, addition of bioactive sequences such as the RGD adherence-promoting motif, cross-linking motifs, etc.

Furthermore, the peptides according to the present invention are also particularly useful for formulating aqueous or other solvent compositions, herein also sometimes referred to as “inks” or “bioinks”, which can be used for printing structures, in particular three-dimensional (“3D”) structures. Such printed structures make use of the gelation properties of the peptides according to the present invention and can themselves act as scaffolds for other entities, such as cells, compounds, particles, in particular nanoparticles etc.

BRIEF DESCRIPTION OF THE DRAWINGS

To further illustrate the technical features of embodiments of the present invention more clearly, the accompanying drawings provided for describing various embodiments are introduced briefly in the following. They are merely exemplary embodiments of the present invention and are not intended to limit it. Modifications on these embodiments are possible without departing from the scope of the present invention as defined in the claims.

Figure 1A shows ultrashort peptides IVZK and IVFK self-assemble into macromolecular nanofibrous hydrogels.

Figure 1B shows the chemical structures of the ultrashort peptides IVZK and IVFK and corresponding hydrogels as well as high resolution transmission electron microscopy (TEM) images.

The average fiber diameter of IVFK peptide was calculated by plotting the distribution curve using the data collected from 13 TEM images. The average diameter is 10.3 nm (left low panel).

The IVZK TEM shows three different types of average diameters (4.0 nm, 8.6 nm and 15.5 nm) (right low panel). The number of images used to calculate the average diameter were 10.

The fibers diameter with 8.6nm were the most abundant ones as compared to other fiber diameters. The single monomer fiber has an average diameter of 4.0 nm.

Figure 2 shows morphological characterization of the self-assembling peptide IVFK and IVZK hydrogels by FESEM showing different magnifications.

Figure 3 shows high mechanical strength was demonstrated for the peptide hydrogels. Storage moduli (G') of different hydrogels (20 mg/mL) as a function of angular frequency under 0.1% strain, at 25°C. Frequency sweep was performed at 0.1% strain.

Figure 4 shows cell morphology of HeLa cells, HEK 293T cells, and human dermal fibroblasts used for 3D cell culturing on peptide hydrogels.

Figure 5 shows graphical presentation of the MTT biocompatibility assay of HeLa with IVFK peptide.

Figure 6 shows Live/Dead staining of HeLa cells treated with IVFK peptide.

Figure 7 shows graphical presentation of the MTT biocompatibility assay of HeLa with IVZK peptide.

Figure 8 shows Live/dead images of HeLa cells treated with IVZK peptide.

Figure 9 shows graphical presentation of the MTT biocompatibility assay of HEK 293 T with IVFK peptide.

Figure 10 shows 3D Cell Viability Assay of Bioprinted Constructs. Live/Dead Staining of HEK 293 T cells treated with IVFK peptide

Figure 11 shows 3D Cell Viability Assay of Bioprinted Constructs. Live/Dead staining of HEK 293 T cells treated with IVFK peptide.

Figure 12 shows graphical presentation of the MTT biocompatibility assay of HEK 293 T with IVZK peptide.

Figure 13 shows 3D cell viability assay of bioprinted constructs. Live/Dead staining of HEK 293 T cells treated with IVZK peptide.

5 Figure 14 shows 3D cell viability assay of bioprinted constructs. Live/Dead staining of HEK 293 T cells treated with IVZK peptide.

Figure 15 shows peptide hydrogels cultured with human myoblast cells for one week.

10 Figure 16 shows 3D bioprinting of human dermal fibroblast cells using IVZK peptide solution as bioink (human dermal fibroblast cells – 4 million/ml; peptide – 10 mg/ml).

Figure 17 shows fluorescent images of human dermal fibroblasts embedded IVZK peptide hydrogels (human dermal fibroblast cells – 4 million/ml; peptide – 10 mg/ml). Actin
15 cytoskeletal staining in green using phalloidin, nucleus staining in blue using DAPI.

Figure 18 shows fluorescent images of 3D human dermal fibroblasts embedded IVZK peptide hydrogels (human dermal fibroblast cells – 4 million/ml; peptide – 10 mg/ml). Actin
20 cytoskeletal staining in green using phalloidin, nucleus staining in blue using DAPI.

Figure 19 shows fluorescence confocal microscopy images of 3D bioprinted human bone marrow-derived mesenchymal stem cells (BM-MSCs) cells using IVZK bioink at different days of cell culturing (nucleus is shown in blue, F-actin is shown in red and vinculin is shown in green).

25 Furthermore, embodiments of the invention are now further described by reference to the following examples which are given to illustrate, not to limit the present invention.

30 EXAMPLES

Peptide Synthesis

Peptides were manually synthesized using solid phase peptide synthesis and purified to above 95% via HPLC. Amino acid and peptide content analysis were performed. Peptide molecules were synthesized manually using standard solid peptide synthesis on MBHA Rink Amide resin. DCM was used to swell the resin inside the reaction vessel for 30 min. Then, the solvent was removed by applying vacuum to the vessel. The Fmoc-protected group on the resin was removed by treating the resin with 10 mL of 20% (v/v) piperidine/DMF solution for 20 min. DMF and DCM were subsequently used to rinse the resin after each reaction to remove the excess materials from the vessel. Then, amino acid residue solution containing of 3 equivalents of N-protected amino acid, 2.9 equivalents of TBTU and 6 equivalents of DIPEA for each 1 equivalent mol of resin was poured and agitated for at least 2 h. Kaiser Test was performed after each coupling to examine the success of peptide coupling. The Fmoc protected group of the N-terminal peptide sequence was removed by adding 10 mL of 20% (v/v) piperidine/DMF and agitating for 20 min. These sequential steps that were amino acid coupling, washing, Kaiser Test, and Fmoc cleavage were repeated until the last sequence of amino acids. Acetylation was performed by pouring a mixed solution of acetic anhydride, DIPEA, and DMF to the vessel in order to cap the peptide sequence. The peptide sequence was then cleaved from the resin by mixing with acid solution that contained of 95% TFA, 2.5% water, and 2.5% triisopropylsilane for 2 h. The resin then was rinsed only with DCM and collected into the round bottom flask. The removal of excess TFA and DCM from the collected peptide solution was carried out by using rotary evaporation. Diethyl ether was added into the flask to disperse the peptide and kept for overnight. This solution then was centrifuged to separate the solid form of peptide from diethyl ether. The collected white solid was subsequently dissolved in water and freeze-dried to get the fluffy form of peptide. Finally, the peptide was purified by using prep-HPLC before being used.

9-Fluorenylmethoxycarbonyl (Fmoc) protected amino acids, Rink Amide MBHA resin, 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium tetrafluoroborate (TBTU) and 1-hydroxy-7-azabenzotriazole (HOAt) were purchased from GL Biochem. N,N-dimethylformamide (DMF), dichloromethane (DCM), diethyl ether, N,N-diisopropylethylamine (DIPEA), piperidine, and triisopropylsilane were purchased from Sigma-Aldrich. Acetic anhydride, dimethyl sulfoxide (DMSO), acetonitrile were purchased from Fisher Scientific. Trifluoroacetic acid (TFA) were purchased from Acros. The chemicals were used as received, without any purification.

Peptide Hydrogel Preparation

Lyophilized peptides were dissolved in milliQ water and vortexed to get a homogenous solution. Subsequently, 10X phosphate buffered saline at the final concentration of 1X was added to the peptide solution and vortexed shortly. Gelation occurred within few seconds to minutes or hours depending on the peptide sequence.

Rheology Analysis

The mechanical strength of the peptide hydrogels was measured using ARES-G2 rheometer (TA instruments) with an 8 mm parallel plate geometry at 22°C. 150 μ L hydrogels were prepared inside a 9.6 mm diameter of polypropylene ring in which the top and bottom of each ring cast was covered with parafilm and kept inside a sealed tissue culture dish for overnight. After loading the hydrogel on peltier plate of the rheometer, water was dropped on the surrounded area to suppress the evaporation of the hydrogel. The gap measurement was adjusted between 1.6 and 1.9 mm. Time sweep measurement was performed prior to frequency sweep and amplitude sweep for 900 s duration with constant strain and angular frequency of 0.1% and 1 rad/s, respectively. The modulus values at the end of time sweep analysis were used as the standard equilibrium modulus for each hydrogel. Oscillatory frequency-sweep analysis were performed with 1% strain for a range of 0.1–100 rad/s. Oscillatory amplitude-sweep measurements were done with the constant angular frequency of 1 rad/s from 0.1 to 100% strain.

Transmission Electron Microscopy (TEM) Studies

The TEM studies were carried out on two different instruments; Tecnai G2 Spirit Twin with accelerating voltage of 120 kV and FEI Titan G2 80-300 CT with 300kV emission gun. The Cryo TEM imaging was performed in low dose mode by using FEI's Titan Krios operating at 300 kV. The TEM samples for peptide nanofiber were prepared from diluted peptide hydrogel in water. One drop of this solution was then introduced on a carbon coated copper grid that has been treated with glow discharge plasma before being used. The drop was then kept for 10 minutes before being blotted using filter paper. To get a better contrast, the grid was stained using 2% uranyl acetate for 1 minute and then was dried for at least one day before imaging. The diameter of IVFK and IVZK peptide nanofibers were measured using an image-analysis software ImageJ from 13 and 10 TEM images, respectively. A size distribution his-

togram for each peptide nanofiber was created in Origin to calculate the average diameter of both peptides. See e.g. Figure 1B.

FESEM Analysis

5 Peptide hydrogels were shock frozen in liquid nitrogen and immediately stored at -80°C overnight. The samples were then vacuum dried in a freeze dryer (Labconco, USA) for 2-3 days. Subsequently, the lyophilized hydrogel samples were fixed onto an aluminium sample holder using conductive carbon tape and sputtered with platinum in a sputter coater. Three rounds of coating were performed at different angles to ensure complete coating. The surface
10 of interest was then examined with a field-emission scanning electron microscope (FEI Nova Nano630 SEM, Oregon, USA) using an accelerating voltage of 5–10 kV or was visualized using FEI Quanta 200 FEG SEM with an accelerating voltage of 2-3 kV. The freeze-dried samples were adhered to carbon conductive tape on SEM stub and sputter coated with 3 nm of Platinum.

15

Cell Culture

Cells were cultured in medium 106 (Thermo Fisher Scientific, USA) supplemented with 10% fetal bovine serum and 1% penicillin/streptomycin. The cells were maintained either in a T175 or T75 cell culture flask (Corning, USA) at 37°C in a humidified incubator with 95% air
20 and 5% CO_2 . The cells were subcultured by trypsinization at approximately 80% confluence. The culture media was replenished every 48 hours.

MTT Assay

Biocompatibility studies were carried out in 96-well plates (Corning, USA). HDFn cells
25 (10,000 cells/well) were seeded into a 96-well plate and incubated overnight in 200 μL complete growth medium. After incubation, media in the wells were changed. Peptides were weighed out and dissolved in milliQ water. To test the compatibility, peptides at different concentrations viz 5 mg/mL, 4 mg/mL, 2 mg/mL, 1 mg/mL and 0.5 mg/mL were added to the wells. Untreated wells were used as positive controls. The plates were incubated for 24 hours.
30 Cell viability was determined by means of a colorimetric microculture assay (Vybrant® MTT Cell Proliferation Assay Kit, Thermo Fisher Scientific, USA) according to the manufacturer's protocol. Briefly, the plates were taken, the medium was carefully removed and fresh serum

free medium containing 10% MTT reagent was added. After 2 h of incubation at 37°C, the supernatant media was removed and 200 µL of DMSO was added to each wells to dissolve the formazan crystals. Finally, the absorption of individual wells was read at 540 nm using a plate reader (PHERAstar FS, Germany).

5

Live/Dead Staining

Cells were seeded and treated with peptides according to the protocol described above. After 24 h of incubation, the spent media were removed and replaced with DPBS solution containing approximately 2 mM calcein AM and 4 mM ethidium homodimer-1 (LIVE/DEAD® Viability/Cytotoxicity Kit, Life Technologies™) and incubated for 40 min in dark. Before imaging, the staining solution was removed and fresh DPBS was added. Stained cells were imaged under an inverted confocal microscope (Zeiss LSM 710 Inverted Confocal Microscope, Germany).

10

15

Cells (25,000 cells/plate) were embedded in 3D culture with hydrogel in a glass based confocal dish and incubated for 24 h using untreated cells as controls. After 24 h, the medium replaced with PBS(1X) solution containing approximately 2 µM calcein and 4 µM ethidium homodimer-1 (LIVE/DEAD Viability/Cytotoxicity Kit, Molecular Probe, L3224) and incubated for 30 min. Live cells were imaged in the green channel and dead cells in the red channel using ZEISS fluorescence microscope. The obtained pictures were superimposed using ImageJ as shown in figure 8.

20

Cytoskeletal staining

Immunostaining was performed after 24 h of culture. In brief, the cells were fixed with 3.7% paraformaldehyde solution for 30 minutes and incubated in a cold cytoskeleton buffer (3 mM MgCl₂, 300 mM sucrose and 0.5% Triton X-100 in PBS solution) for 10 minutes to permeabilise the cell membranes. The permeabilised cells were incubated in blocking buffer solution (5% FBS, 0.1% Tween-20, and 0.02% sodium azide in PBS) for 30 minutes at 37°C, followed by incubation in antivinculin (1:100) for 1 hour at 37°C and subsequently with anti-mouse IgG (whole molecule)-FITC and rhodamine-phalloidin (1:200) for 1 hour at 37°C. Further, the cells were incubated in DAPI for 1 hour at 37°C to counterstain the nucleus. These fluorescent dye treated cells were observed and imaged using laser scanning confocal microscope (Zeiss LSM 710 Inverted Confocal Microscope, Germany).

25

30

3D Culture of Cells in Peptide Hydrogels

Cells were encapsulated in peptide hydrogels in 24 well tissue culture plates. Peptide solutions were added to the plate at 200 μ L per well. Cells were resuspended in 3X PBS were added to each well at 100,000 cells/well and gently mixed. The final concentration of the peptide hydrogel was 1X after the addition of 3X PBS containing cells. Gelation occurred within 3-5 minutes and subsequently, culture medium was added to the wells. At pre-determined time points, the 3D cell viability assay, live/dead assay and cytoskeletal staining were performed.

3D cell culture was performed by making base on the bottom of plate to make sure that the cells grow in 3D construct, the base was made by pipetting peptide solution (peptide with water) into confocal plate and mixed with (PBS). After gel formation, peptide solution was added on top of this base. Cultured human dermal fibroblasts was trypsinized, centrifuged and resuspended with PBS (2X) and mixed with peptide solution placed on top of the base. Once the gel form, DMEM was added on top as shown in figure 5 and incubate at 37 °C incubator and 5% CO₂ for 48 hours and then different biocompatibility assays were applied on this construct.

3D Cell Proliferation Assay

The CellTiter-Glo® luminescent 3D cell viability assay is a method to determine the number of viable cells in 3D hydrogels based on quantification of the ATP present, which signals the presence of metabolically active cells. After each time point, the hydrogels cultured with cells were washed twice with DPBS. Fresh medium was added to each well and equal amount of CellTiter-Glo® luminescent reagent was also added to the gels. The contents were mixed for 2 minutes to digest the hydrogels and then incubated for 10 minutes. After incubation, the luminescence was recorded using a plate reader (PHERAstar FS, Germany).

3D Bioprinting

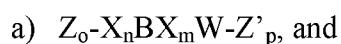
A 3D bioprinter was used to print constructs using peptide bioinks. To print peptide bioinks, the inventors designed a co-axial needle with three inlets. The top inlet was connected to 10X PBS solution, the right inlet was connected to cells suspended in serum free media and the left

inlet was connected to peptide dissolved in milliQ water (15 mg/mL). The tubes, connectors and the co-axial nozzle were autoclaved before printing. While printing, three solutions were pumped into the nozzle with the aid of syringe pumps. The flow rate of peptide solution and cells solution were 25 μ L/min while the flow rate of 10X PBS was maintained at 20 μ L/min.

- 5 Peptide solution mix with the cells and 10X PBS at the junction inside the co-axial nozzle just before the exit. Gelation occurs instantaneously and the peptide bioinks were printed. A simple ring structure was bioprinted in a layer-by-layer fashion with a diameter of about 8 mm and thickness about 2 mm. The constructs were printed onto 35-mm tissue culture petri dish. After bioprinting, the constructs were placed in biosafety cabinet for 3 min to further facilitate
- 10 self-assembly of peptide bioinks. Then, the constructs were gently washed 2 or 3 times with culture medium. To each dish, 3 mL of culture medium was added and cultured in a humidified incubator at 37 °C and 5% CO₂. At pre-determined time points, the constructs were taken out to perform 3D assay and cytoskeletal staining of cells as described above.
- 15 The peptides according to the present invention are excellent gelators, and the gels formed can be used for many different purposes and applications. The features disclosed in the foregoing description, in the claims or in the accompanying drawings may, both separately and in any combination thereof, be material for realizing the invention in diverse forms thereof.
- 20 Further modifications of the preferred embodiments are possible without leaving the scope of the invention which is solely defined by the claims.

Claims

1. A peptide capable of forming a gel by self-assembly, said peptide having a general formula selected from:



wherein Z is an N-terminal protecting group and Z' is a C-terminal protecting group, with o and p being independently selected from 0 and 1;

wherein X is, independently at each occurrence, an aliphatic amino acid selected from isoleucine, norleucine, leucine, valine, alanine, glycine, homoallylglycine and homopropargylglycine with n and m being integers being independently selected from 0, 1 and 2, with the proviso that $m+n \leq 2$,

wherein B is an aromatic amino acid selected from phenylalanine and tryptophan, or is an aliphatic counterpart of said aromatic amino acid, said aliphatic counterpart being selected from cyclohexylalanine, 4-hydroxy-cyclohexylalanine, 3,4-dihydroxycyclohexylalanine.

Wherein W is a polar amino acid selected from aspartic acid, glutamic acid, asparagine, glutamine, lysine, 5-N-ethyl-glutamine (thearnine), citrulline, thio-citrulline, cysteine, homocysteine, methionine, ethionine, selenomethionine, telluromethionine, threonine, allothreonine, serine, homoserine, tyrosine, histidine, arginine, homoarginine, ornithine, lysine, N(6)-carboxymethyllysine, histidine, 2,4-diaminobutyric acid (Dab), 2,3-diaminopropionic acid (Dap), and N(6)-carboxymethyllysine,

wherein said polar amino acid is preferably selected from the group consisting of aspartic acid, asparagine, glutamic acid, glutamine, serine, threonine, methionine, arginine, histidine, lysine, ornithine (Orn), 2,4-diaminobutyric acid (Dab), and 2,3-diaminopropionic acid (Dap).

2. The peptide according to claim 1, wherein o and p are each 1.

3. The peptide according to any of claims 1-2, wherein Z has the general formula $-C(O)-R$, wherein R is selected from the group consisting of H, unsubstituted or substituted alkyls, and unsubstituted or substituted aryls, wherein R is preferably selected from the group consisting of methyl, ethyl, propyl, isopropyl, butyl and isobutyl, and wherein Z' is $-NR_1R_2$, R_1 and R_2 being independently selected from H and C_1-C_{10} alkyl, said- NR_1R_2 thus forming an amide group at the C-terminus of said peptide, wherein preferably Z is an acetyl group, and wherein preferably Z' is NH_2 .
4. The peptide according to any of the foregoing claims, wherein said amino acids in said peptide are either L-amino acids or D-amino acids.
5. The peptide according to any of the foregoing claims, wherein each of the hydrophilic amino acids has a polar group which is independently selected from a hydroxyl, an ether, a carboxyl, an imido, an amido, an ester, an amino, a guanidine, a thio, a thioether, a seleno and a telluro group.
6. The peptide according to any of the foregoing claims, wherein said gel is a hydrogel or is an organogel.
7. The peptide according to any of the foregoing claims, wherein the peptide consists of a sequence selected from

IVFK	(SEQ ID NO:1)
IVOK	(SEQ ID NO:2)
IFVK	(SEQ ID NO:3)
IOVK	(SEQ ID NO:4)
FIVK	(SEQ ID NO:5)
OIVK	(SEQ ID NO:6)
FVIK	(SEQ ID NO:7)
OVIK	(SEQ ID NO:8)
IVFD	(SEQ ID NO:9)

IVOD	(SEQ ID NO:10)
IFVD	(SEQ ID NO:11)
IOVD	(SEQ ID NO:12)
FIVD	(SEQ ID NO:13)
OIVD	(SEQ ID NO:14)
FVID	(SEQ ID NO:15)
OVID	(SEQ ID NO:16)

IVFE	(SEQ ID NO:17)
IVOE	(SEQ ID NO:18)
IFVE	(SEQ ID NO:19)
IOVE	(SEQ ID NO:20)
FIVE	(SEQ ID NO:21)
OIVE	(SEQ ID NO:22)
FVIE	(SEQ ID NO:23)
OVIE	(SEQ ID NO:24)

IVFS	(SEQ ID NO:25)
IVOS	(SEQ ID NO:26)
IFVS	(SEQ ID NO:27)
IOVS	(SEQ ID NO:28)
FIVS	(SEQ ID NO:29)
OIVS	(SEQ ID NO:30)
FVIS	(SEQ ID NO:31)
OVIS	(SEQ ID NO:32)

IVFR	(SEQ ID NO:33)
IVOR	(SEQ ID NO:34)
IFVR	(SEQ ID NO:35)
IOVR	(SEQ ID NO:36)
FIVR	(SEQ ID NO:37)
OIVR	(SEQ ID NO:38)
FVIR	(SEQ ID NO:39)
OVIR	(SEQ ID NO:40)

IVF(Dab)	(SEQ ID NO:41)
IVO(Dab)	(SEQ ID NO:42)
IFV(Dab)	(SEQ ID NO:43)
IOV(Dab)	(SEQ ID NO:44)
FIV(Dab)	(SEQ ID NO:45)
OIV(Dab)	(SEQ ID NO:46)
FVI(Dab)	(SEQ ID NO:47)
OVI(Dab)	(SEQ ID NO:48)

IVF(Dap)	(SEQ ID NO:49)
IVO(Dap)	(SEQ ID NO:50)
IFV(Dap)	(SEQ ID NO:51)
IOV(Dap)	(SEQ ID NO:52)
FIV(Dap)	(SEQ ID NO:53)
OIV(Dap)	(SEQ ID NO:54)
FVI(Dap)	(SEQ ID NO:55)
OVI(Dap)	(SEQ ID NO:56)

IVF(Orn)	(SEQ ID NO:57)
IVO(Orn)	(SEQ ID NO:58)
IFV(Orn)	(SEQ ID NO:59)
IOV(Orn)	(SEQ ID NO:60)
FIV(Orn)	(SEQ ID NO:61)
OIV(Orn)	(SEQ ID NO:62)
FVI(Orn)	(SEQ ID NO:63)
OVI(Orn)	(SEQ ID NO:64)

KFVI	(SEQ ID NO:65)
KOVI	(SEQ ID NO:66)
KVFI	(SEQ ID NO:67)
KVOI	(SEQ ID NO:68)
KVIF	(SEQ ID NO:69)
KVIO	(SEQ ID NO:70)

KIVF (SEQ ID NO:71)
KIVO (SEQ ID NO:72)

DFVI (SEQ ID NO:73)
DOVI (SEQ ID NO:74)
DVFI (SEQ ID NO:75)
DVOI (SEQ ID NO:76)
DVIF (SEQ ID NO:77)
DVIO (SEQ ID NO:78)
DIVF (SEQ ID NO:79)
DIVO (SEQ ID NO:80)

EFVI (SEQ ID NO:81)
EOVI (SEQ ID NO:82)
EVFI (SEQ ID NO:83)
EVOI (SEQ ID NO:84)
EVIF (SEQ ID NO:85)
EVIO (SEQ ID NO:86)
EIVF (SEQ ID NO:87)
EIVO (SEQ ID NO:88)

SFVI (SEQ ID NO:89)
SOVI (SEQ ID NO:90)
SVFI (SEQ ID NO:91)
SVOI (SEQ ID NO:92)
SVIF (SEQ ID NO:93)
SVIO (SEQ ID NO:94)
SIVF (SEQ ID NO:95)
SIVO (SEQ ID NO:96)

RFVI (SEQ ID NO:97)
ROVI (SEQ ID NO:98)
RVFI (SEQ ID NO:99)
RVOI (SEQ ID NO:100)

RVIF	(SEQ ID NO:101)
RVIO	(SEQ ID NO:102)
RIVF	(SEQ ID NO:103)
RIVO	(SEQ ID NO:104)

(Dab)FVI	(SEQ ID NO:105)
(Dab)OVI	(SEQ ID NO:106)
(Dab)VFI	(SEQ ID NO:107)
(Dab)VOI	(SEQ ID NO:108)
(Dab)VIF	(SEQ ID NO:109)
(Dab)VIO	(SEQ ID NO:110)
(Dab)IVF	(SEQ ID NO:111)
(Dab)IVO	(SEQ ID NO:112)

(Dap)FVI	(SEQ ID NO:113)
(Dap)OVI	(SEQ ID NO:114)
(Dap)VFI	(SEQ ID NO:115)
(Dap)VOI	(SEQ ID NO:116)
(Dap)VIF	(SEQ ID NO:117)
(Dap)VIO	(SEQ ID NO:118)
(Dap)IVF	(SEQ ID NO:119)
(Dap)IVO	(SEQ ID NO:120)

(Orn)FVI	(SEQ ID NO:121)
(Orn)OVI	(SEQ ID NO:122)
(Orn)VFI	(SEQ ID NO:123)
(Orn)VOI	(SEQ ID NO:124)
(Orn)VIF	(SEQ ID NO:125)
(Orn)VIO	(SEQ ID NO:126)
(Orn)IVF	(SEQ ID NO:127)
(Orn)IVO	(SEQ ID NO:128)

wherein I = isoleucine, L = leucine, V = valine, F = phenylalanine, K = lysine, D = aspartic acid, O = cyclohexylalanine, (Dab) = 2,4-diaminobutyric acid, (Dap) = 2,3-diaminopropionic acid, and (Orn) = ornithine;

wherein each of the sequences may be protected or unprotected at the N-terminus, preferably acetylated or non—acetylated, and may be amidated or non-amidated at the C-terminus, wherein, preferably, said sequence is selected from

Ac-IVFK-NH₂ (SEQ ID NO:1)

Ac-IVOK-NH₂ (SEQ ID NO:2)

Ac-IFVK-NH₂ (SEQ ID NO:3)

Ac-IOVK-NH₂ (SEQ ID NO:4)

Ac-FIVK-NH₂ (SEQ ID NO:5)

Ac-OIVK-NH₂ (SEQ ID NO:6)

Ac-FVIK-NH₂ (SEQ ID NO:7)

Ac-OVIK-NH₂ (SEQ ID NO:8)

Ac-IVFD-COOH (SEQ ID NO:9)

Ac-IVOD-COOH (SEQ ID NO:10)

Ac-IFVD-COOH (SEQ ID NO:11)

Ac-IOVD-COOH (SEQ ID NO:12)

Ac-FIVD-COOH (SEQ ID NO:13)

Ac-OIVD-COOH (SEQ ID NO:14)

Ac-FVID-COOH (SEQ ID NO:15)

Ac-OVID-COOH (SEQ ID NO:16)

Ac-IVFE-COOH (SEQ ID NO:17)

Ac-IVOE-COOH (SEQ ID NO:18)

Ac-IFVE-COOH (SEQ ID NO:19)

Ac-IOVE-COOH (SEQ ID NO:20)

Ac-FIVE-COOH (SEQ ID NO:21)

Ac-OIVE-COOH (SEQ ID NO:22)

Ac-FVIE-COOH (SEQ ID NO:23)

Ac-OVIE-COOH (SEQ ID NO:24)

Ac-IVFS- -NH ₂	(SEQ ID NO:25)
Ac-IVOS- -NH ₂	(SEQ ID NO:26)
Ac-IFVS- -NH ₂	(SEQ ID NO:27)
Ac-IOVS- -NH ₂	(SEQ ID NO:28)
Ac-FIVS- -NH ₂	(SEQ ID NO:29)
Ac-OIVS- -NH ₂	(SEQ ID NO:30)
Ac-FVIS- -NH ₂	(SEQ ID NO:31)
Ac-OVIS- -NH ₂	(SEQ ID NO:32)

Ac-IVFR-NH ₂	(SEQ ID NO:33)
Ac-IVOR-NH ₂	(SEQ ID NO:34)
Ac-IFVR-NH ₂	(SEQ ID NO:35)
Ac-IOVR-NH ₂	(SEQ ID NO:36)
Ac-FIVR-NH ₂	(SEQ ID NO:37)
Ac-OIVR-NH ₂	(SEQ ID NO:38)
Ac-FVIR-NH ₂	(SEQ ID NO:39)
Ac-OVIR-NH ₂	(SEQ ID NO:40)

Ac-IVF(Dab)-NH ₂	(SEQ ID NO:41)
Ac-IVO(Dab) -NH ₂	(SEQ ID NO:42)
Ac-IFV(Dab)-NH ₂	(SEQ ID NO:43)
Ac-IOV(Dab) -NH ₂	(SEQ ID NO:44)
Ac-FIV(Dab) -NH ₂	(SEQ ID NO:45)
Ac-OIV(Dab) -NH ₂	(SEQ ID NO:46)
Ac-FVI(Dab) -NH ₂	(SEQ ID NO:47)
Ac-OVI(Dab) -NH ₂	(SEQ ID NO:48)

Ac-IVF(Dap) -NH ₂	(SEQ ID NO:49)
Ac-IVO(Dap) -NH ₂	(SEQ ID NO:50)
Ac-IFV(Dap) -NH ₂	(SEQ ID NO:51)
Ac-IOV(Dap) -NH ₂	(SEQ ID NO:52)
Ac-FIV(Dap) -NH ₂	(SEQ ID NO:53)
Ac-OIV(Dap) -NH ₂	(SEQ ID NO:54)
Ac-FVI(Dap) -NH ₂	(SEQ ID NO:55)

Ac-OVI(Dap) -NH₂ (SEQ ID NO:56)

Ac-IVF(Orn) -NH₂ (SEQ ID NO:57)

Ac-IVO(Orn) -NH₂ (SEQ ID NO:58)

Ac-IFV(Orn) -NH₂ (SEQ ID NO:59)

Ac-IOV(Orn) -NH₂ (SEQ ID NO:60)

Ac-FIV(Orn) -NH₂ (SEQ ID NO:61)

Ac-OIV(Orn) -NH₂ (SEQ ID NO:62)

Ac-FVI(Orn) -NH₂ (SEQ ID NO:63)

Ac-OVI(Orn) -NH₂ (SEQ ID NO:64)

Ac-KFVI-NH₂ (SEQ ID NO:65)

Ac-KOVI-NH₂ (SEQ ID NO:66)

Ac-KVFI-NH₂ (SEQ ID NO:67)

Ac-KVOI-NH₂ (SEQ ID NO:68)

Ac-KVIF-NH₂ (SEQ ID NO:69)

Ac-KVIO-NH₂ (SEQ ID NO:70)

Ac-KIVF-NH₂ (SEQ ID NO:71)

Ac-KIVO-NH₂ (SEQ ID NO:72)

Ac-DFVI-NH₂ (SEQ ID NO:73)

Ac-DOVI-NH₂ (SEQ ID NO:74)

Ac-DVFI-NH₂ (SEQ ID NO:75)

Ac-DVOI-NH₂ (SEQ ID NO:76)

Ac-DVIF-NH₂ (SEQ ID NO:77)

Ac-DVIO-NH₂ (SEQ ID NO:78)

Ac-DIVF-NH₂ (SEQ ID NO:79)

Ac-DIVO-NH₂ (SEQ ID NO:80)

Ac-EFVI-NH₂ (SEQ ID NO:81)

Ac-EOVI-NH₂ (SEQ ID NO:82)

Ac-EVFI-NH₂ (SEQ ID NO:83)

Ac-EVOI-NH₂ (SEQ ID NO:84)

Ac-EVIF-NH₂ (SEQ ID NO:85)

Ac-EVIO-NH ₂	(SEQ ID NO:86)
Ac-EIVF-NH ₂	(SEQ ID NO:87)
Ac-EIVO-NH ₂	(SEQ ID NO:88)
Ac-SFVI-NH ₂	(SEQ ID NO:89)
Ac-SOVI-NH ₂	(SEQ ID NO:90)
Ac-SVFI-NH ₂	(SEQ ID NO:91)
Ac-SVOI-NH ₂	(SEQ ID NO:92)
Ac-SVIF-NH ₂	(SEQ ID NO:93)
Ac-SVIO-NH ₂	(SEQ ID NO:94)
Ac-SIVF-NH ₂	(SEQ ID NO:95)
Ac-SIVO-NH ₂	(SEQ ID NO:96)
Ac-RFVI-NH ₂	(SEQ ID NO:97)
Ac-ROVI-NH ₂	(SEQ ID NO:98)
Ac-RVFI-NH ₂	(SEQ ID NO:99)
Ac-RVOI-NH ₂	(SEQ ID NO:100)
Ac-RVIF-NH ₂	(SEQ ID NO:101)
Ac-RVIO-NH ₂	(SEQ ID NO:102)
Ac-RIVF-NH ₂	(SEQ ID NO:103)
Ac-RIVO-NH ₂	(SEQ ID NO:104)
Ac-(Dab)FVI –NH ₂	(SEQ ID NO:105)
Ac- (Dab)OVI -NH ₂	(SEQ ID NO:106)
Ac- (Dab)VFI –NH ₂	(SEQ ID NO:107)
Ac- (Dab)VOI –NH ₂	(SEQ ID NO:108)
Ac- (Dab)VIF -NH ₂	(SEQ ID NO:109)
Ac- (Dab)VIO -NH ₂	(SEQ ID NO:110)
Ac- (Dab)IVF –NH ₂	(SEQ ID NO:111)
Ac- (Dab)IVO –NH ₂	(SEQ ID NO:112)
Ac-(Dap)FVI –NH ₂	(SEQ ID NO:113)
Ac-(Dap)OVI -NH ₂	(SEQ ID NO:114)
Ac-(Dap)VFI -NH ₂	(SEQ ID NO:115)

Ac-(Dap)VOI -NH ₂	(SEQ ID NO:116)
Ac-(Dap)VIF -NH ₂	(SEQ ID NO:117)
Ac-(Dap)VIO -NH ₂	(SEQ ID NO:118)
Ac-(Dap)IVF -NH ₂	(SEQ ID NO:119)
Ac-(Dap)IVO -NH ₂	(SEQ ID NO:120)
Ac-(Orn)FVI -NH ₂	(SEQ ID NO:121)
Ac-(Orn)OVI -NH ₂	(SEQ ID NO:122)
Ac-(Orn)VFI -NH ₂	(SEQ ID NO:123)
Ac-(Orn)VOI -NH ₂	(SEQ ID NO:124)
Ac-(Orn)VIF -NH ₂	(SEQ ID NO:125)
Ac-(Orn)VIO -NH ₂	(SEQ ID NO:126)
Ac-(Orn)IVF -NH ₂	(SEQ ID NO:127)
Ac-(Orn)IVO -NH ₂	(SEQ ID NO:128)

wherein Ac = acetyl acetylates the N-terminus, NH₂ = amine, thus amidates the C-terminus, and -COOH = unprotected C-terminus.

8. The peptide according to any of the foregoing claims, wherein said N-terminal protecting group Z is a peptidomimetic molecule, including natural and synthetic amino acid derivatives, wherein the N-terminus of said peptidomimetic molecule may be modified with a functional group selected from the group consisting of carboxylic acid, amide, alcohol, aldehyde, amine, imine, nitrile, an urea analog, phosphate, carbonate, sulfate, nitrate, maleimide, vinyl sulfone, azide, alkyne, alkene, carbohydrate, imide, peroxide, ester, aryl, ketone, sulphite, nitrite, phosphonate, and silane.

9. The peptide according to any of the foregoing claims, wherein said C-terminal group Z' is selected from the group of small molecules, functional groups and linkers.

10. The peptide according to claim 9, wherein said C-terminal group Z' is selected from
- functional groups, such as polar or non-polar functional groups,
such as (but not limited to)

-COOH, -COOR, -COR, -CONHR or -CONRR' with R and R' being selected from the group consisting of H, unsubstituted or substituted alkyls, and unsubstituted or substituted aryls,

-NH₂, -OH, -SH, -CHO, maleimide, imidoester, carbodiimide ester, isocyanate;

- small molecules,

such as (but not limited to) sugars, alcohols, hydroxy acids, amino acids, vitamins, biotin;

- linkers terminating in a polar functional group,

such as (but not limited to) ethylenediamine, PEG, carbodiimide ester, imidoester;

- linkers coupled to small molecules or vitamins,

such as biotin, sugars, hydroxy acids.

11. The peptide according to claim 9 or 10, wherein said C-terminal group Z' is suitable to be used for chemical conjugation or coupling of at least one compound selected from

bioactive molecules or moieties,

such as growth factors, cytokines, lipids, cell receptor ligands, hormones, prodrugs, drugs, vitamins, antigens, antibodies, antibody fragments, oligonucleotides (including but not limited to DNA, messenger RNA, short hairpin RNA, small interfering RNA, microRNA, peptide nucleic acids, aptamers), saccharides;

label(s), dye(s),

such as fluorescent or radioactive label(s), imaging contrast agents;

pathogens,

such as viruses, bacteria and parasites;

micro- and nanoparticles

or combinations thereof

wherein said chemical conjugation can be carried out before or after self-assembly of the peptide.

12. The peptide according to any of the foregoing claims, wherein the C-terminus of the peptide is functionalized, such as by chemical conjugation or coupling of at least one compound selected from

bioactive molecules or moieties,

such as growth factors, cytokines, lipids, cell receptor ligands, hormones, prodrugs, drugs, vitamins, antigens, antibodies, antibody fragments, oligonucleotides (including but not limited to DNA, messenger RNA, short hairpin RNA, small interfering RNA, microRNA, peptide nucleic acids, aptamers), saccharides;

label(s), dye(s),

such as fluorescent or radioactive label(s), imaging contrast agents;

pathogens,

such as viruses, bacteria and parasites;

micro- and nanoparticles

or combinations thereof

wherein said chemical conjugation can be carried out before or after self-assembly of the peptide and/or peptidomimetic.

13. The peptide according to any of the foregoing claims, wherein said C-terminal group Z' is a peptidomimetic molecule, including natural and synthetic amino acid derivatives, wherein the C-terminus of said peptidomimetic molecule may be modified with a functional group selected from the group consisting of carboxylic acid, amide, alcohol, aldehyde, amine, imine, nitrile, an urea analog, phosphate, carbonate, sulfate, nitrate, maleimide, vinyl sulfone, azide, alkyne, alkene, carbohydrate, imide, peroxide, ester, aryl, ketone, sulphite, nitrite, phosphonate, and silane.

14. The peptide according to any of the foregoing claims, being stable in aqueous solution at physiological conditions at ambient temperature for a period of time in the range from 1 day to at least 6 months, preferably to at least 8 months more preferably to at least 12 months.

15. The peptide according to any of the foregoing claims, being stable in aqueous solution at physiological conditions, at a temperature up to 90 °C, for at least 1 hour.

16. A hydrogel or organogel comprising the peptide of any one of claims 1 to 15.

17. The hydrogel or organogel according to claim 16, wherein the hydrogel is stable in aqueous solution at ambient temperature for a period of at least 1 month, preferably at least 2 to 4 months, more preferably at least 6 to 12 months.
18. The hydrogel or organogel according to claim 16 or 17, wherein the hydrogel is characterized by a storage modulus G' to loss modulus G'' ratio that is greater than 2 to 5.
19. The hydrogel or organogel according to any one of claims 16 to 18, wherein the hydrogel or organogel is characterized by a storage modulus G' from 500Pa to 200,000 Pa at a frequency in the range of from 0.1 Hz to 100 Hz.
20. The hydrogel or organogel according to any one of claims 16 to 19, wherein the hydrogel or organogel has a higher mechanical strength than collagen or its hydrolyzed form (gelatin).
21. The hydrogel or organogel according to any one of claims 16 to 20, comprising fibers of the peptide of any one of claims 1 to 15, said fibers defining a network that is capable of entrapping at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a micro-or nanoparticle, a small organic molecule or a pharmaceutically active compound.
22. The hydrogel or organogel according to claim 21, wherein the hydrogel comprises at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a small organic molecule, a micro-or nanoparticle, or a pharmaceutically active compound entrapped by the network of fibers.
23. The hydrogel or organogel according to claim 22, wherein the fibers are coupled to the at least one of a microorganism, a virus particle, a peptide, a peptoid, a protein, a nucleic acid, an oligosaccharide, a polysaccharide, a vitamin, an inorganic molecule, a synthetic polymer, a small organic molecule, a micro-or nanoparticle, or a pharmaceutically active compound entrapped by the network of fibers.

24. The hydrogel or organogel according to any one of claims 17 to 23, wherein the hydrogel or organogel is comprised in at least one of a fuel cell, a solar cell, an electronic cell, a biosensing device, a medical device, an implant, a pharmaceutical composition and a cosmetic composition.
25. The hydrogel or organogel according to any of claims 16 to 24, which is injectable.
26. Use of the peptide according to any of claims 1 – 15 or of the hydrogel or organogel according to any one of claims 16 to 25 in at least one of the following:
medical tool kit,
a fuel cell,
a solar cell,
an electronic cell,
regenerative medicine and tissue regeneration,
implantable scaffold
disease model
wound healing,
2D and 3D synthetic cell culture substrate,
stem cell therapy,
injectable therapies,
biosensor development,
high-throughput screening,
biofunctionalized surfaces,
printing
biofabrication, such as bio-printing, and
gene therapy.
27. A method of preparing a hydrogel or organogel, the method comprising dissolving a peptide according to any one of claims 1 to 15 in an aqueous solution or an organic solution, respectively.
28. The method of claim 27, wherein the dissolved peptide in aqueous or organic solution is further exposed to temperature, wherein the temperature is in the range from 20 °C to 90 °C, preferably from 20 °C to 70 °C.

29. The method of claim 27 or 28, wherein the peptide is dissolved at a concentration from 0.01 µg/ml to 100 mg/ml, preferably at a concentration from 1 mg/ml to 50 mg/ml, more preferably at a concentration from about 1 mg/ml to about 20 mg/ml.

30. A cell or tissue graft or device comprising a hydrogel or organogel of any of claims of 16 to 25.

31. A wound dressing or wound healing agent comprising a hydrogel or organogel of any one of claims 16 to 25.

32. A surgical implant, or stent, the surgical implant or stent comprising a peptide scaffold, wherein the peptide scaffold is formed by a hydrogel or organogel according to any one of claims 16 to 25.

33. A pharmaceutical and/or cosmetic composition and/or a biomedical device and/or electronic device and/or a solution comprising the peptide of any one of claims 1 to 15.

34. The pharmaceutical and/or cosmetic composition and/or the biomedical device, and/or the electronic device and/or the solution of claim 33, further comprising a pharmaceutically active compound.

35. The pharmaceutical or cosmetic composition or solution of any of claims 33 to 34, wherein the pharmaceutical and/or cosmetic composition and/or solution is provided in the form of a topical gel or cream, a spray, a powder, or a sheet, patch or membrane, or wherein the pharmaceutical and/or cosmetic composition and/or solution is provided in the form of an injectable solution.

36. The pharmaceutical and/or cosmetic composition and/or solution of any one of claims 33 to 35, further comprising a pharmaceutically acceptable carrier.

37. A kit of parts, the kit comprising a first container with a peptide according to any one of claims 1 to 15 and a second container with an aqueous or organic solution.

38. The kit of parts of claim 37, wherein the aqueous or organic solution of the second container further comprises a pharmaceutically active compound.

and/or wherein the first container with a peptide further comprises a pharmaceutically active compound.

39. An *in vitro* or *in vivo* method of tissue regeneration comprising the steps:

- (a) providing a hydrogel as defined in any of claims 16 to 25,
- (b) exposing said hydrogel or organogel to cells which are to form regenerated tissue,
- (c) allowing said cells to grow on said hydrogel or organogel.

40. The method of claim 39, which is performed *in vivo*, wherein, in step a), said hydrogel is provided at a place in a body where tissue regeneration is intended, wherein said step a) is preferably performed by injecting said hydrogel at a place in the body where tissue regeneration is intended.

41. A method of treatment of a wound and for wound healing, said method comprising the step of

applying an effective amount of a hydrogel or organogel of any one of claims 16 to 25 or a pharmaceutical composition of any one of claims 33 to 36 to a wound.

42. A bioimaging device comprising a hydrogel or organogel of any one of claims 16 to 25 for *in vitro* and/or *in vivo* use, preferably for oral application, for injection and/or for topical application.

43. A 2D or 3D cell culture substrate comprising a hydrogel or organogel of any one of claims 16 to 25.