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Wound Dressing

The present invention relates to wound dressings having antibacterial, antiviral and/or antifungal activity, to a method of producing such dressings and the use of such dressings in the treatment of wounds. In particular, the invention relates to the dressings for use in the treatment of infected or dehydrated wounds or wounds with scant exudate.

With the rise in antimicrobial resistance and a general call to reduce the use of antibiotics, silver is gaining increasing popularity as an effective antimicrobial agent. The advantage of using silver as an antimicrobial agent is that there is no formation of bacterial tolerance. This is in contrast for instance to many antibiotics. A major drawback when using ionic or metallic silver for antimicrobial purposes is however the lack of control over release of the silver ions within and from the delivery vehicle.

In the past it has been known to deliver silver ions by the use of a simple solution of silver nitrate. It is also known to deliver silver by the use of a complex with sulfadiazine. Silver sulfadiazine is used extensively in the treatment of wounds, and particularly burns, and is incorporated in a cream base and sold under the trademark Flamazine or Silvadene. As the silver is present in such products as a complex, its solubility in wound fluid is low and hence the quantity of active silver present is also low.

It is also known to deliver silver ions from a wound dressing such as those comprising a gelling fibre as found in AQUACEL®Ag. These dressings comprise gel forming fibres which have been ion exchanged with for instance silver nitrate to incorporate silver ions into the fibres. When in contact with an exuding wound, the dressing takes up moisture and releases the silver to the exudate and the wound itself. As it is the presence of moisture (exudate) in the dressing that enables the silver ions to be released, it would be expected that the state of hydration of the dressing would affect the duration for which silver is available and the quantity of silver that is available. It

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could be expected that on application of the dressing to the wound, the release of silver ions from the dressing would be initially high but tail off over time as the dressing dehydrates. This could happen for instance if the amount of exudate produced by the wound is insufficient to maintain hydration in the dressing, or if the rate of evaporation of moisture from the dressing is high or at least exceeds the rate of absorption from the wound.

It is generally recognised that healing is assisted by the maintenance of a moist wound healing environment. A dry dressing therefore not only limits the supply of silver ions to the wound from a silver containing dressing, it also deprives the wound of the benefits of moist wound healing. In addition, a dry dressing may adhere to the wound causing tissue damage on removal.

There thus exists a need for a dressing which sustains the release of silver ions to the wound by reducing the tendency for the dressing to dehydrate during its wear time.

There is also a need for a dressing with a reduced tendency to adhere to the wound either by reducing the tendency for the dressing to dehydrate during its wear time or by a slow rate of hydration from the wound.

There is also a need for a wound dressing with a sustained release of silver ions which maintains an effective concentration of silver ions in the wound over its wear time assisted by providing a sustained hydration in the dressing over that wear time.

A sustained release of silver ions into the wound is assisted by a dressing which does not readily dehydrate and thus maintains moisture in the dressing for a longer time.

We have now found that wound dressings can be prepared which give a controlled, sustained release of silver ions within the dressing and into the adjacent wound fluid to give antimicrobial activity and moist wound healing over the wear time. Surprisingly, the required hydration property is provided by a dressing comprising an open structure of woven or nonwoven gel forming fibres. By open structure is meant a regular or

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irregular, two or three dimensional construct with a large volume for a given mass in which the free internal fabric volume exceeds the solid fibre volume.

It is thought that the open structure allows moisture to be retained between the fibres as well as in the fibres themselves and that this contributes to the maintenance of

5 moisture in the dressing.

In the past, open structures were not thought to be practical for use on wounds because the open structure on its own lacks the integrity when gelled to be removed from the wound in one piece. Collapse or fragmentation of the dressing necessitates flushing of

10 the wound with the risk of possible retention of parts of the used dressing in the wound.

However, the integrity of open structures can be improved with reinforcement from other fibres or threads such as textile fibres or threads or fibres with less ability to absorb and gel.

15 Accordingly, the invention provides for a wound dressing comprising a mat of gel forming fibres comprising silver, the mat having an open structure reinforced with textile fibres or fibres or threads of limited absorbency for use in the treatment of infected wounds.

20 Such dressings may have the advantage that hydration is maintained over the wear time of the dressing so that a prolonged delivery of silver ions is experienced by the wound. This is thought to be due to the combination of the open structure of the fibrous mat and the non-gel forming fibres providing the necessary integrity to allow the dressing to be removed from the wound in one piece at the end of its wear time.

25 Preferably the open structure of the fibrous mat is provided by a nonwoven fibrous mat that has been entangled by fluid jet entanglement such as hydro entanglement or needle punching. The open structure may be defined by the extent of entanglement in the dressing. The extent of entanglement may be expressed as the number of

30 entanglements per square centimetre or more usually by a punch density. Preferably the nonwoven fibrous mat is needle punched or entangled to a punch density of less

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than 60 per cm², and more preferably from 50 to 10 per cm². Most preferably the punch density is from 40 to 10 per cm²

5 In fluid entanglement the jet pressure, diameter and spacing also give a density of entanglement equivalent to a needle punch density in that they give a number of entanglements per square centimetre.

10 The fibrous mat of gel forming fibres preferably has a basis weight of from 30 to 1000 grams per square meter. More preferably the basis weight is from 100 to 200 grams per square meter and most preferably from 150 to 200 grams per square meter.

15 Preferably the dressing has a rate of moisture loss at least 25% lower than a dressing made from a mat with a needle punch density of 60 per cm² or higher. More preferably the rate of moisture loss is from 30% to 60% lower than that from a dressing with a needle punch density of 60 per cm² or higher.

20 Preferably the dressing maintains the hydration of the wound by having a rate of moisture loss (as measured by the percentage weight loss from the dressing) of less than 75% over the first 48 hours of wear. More preferably the rate of moisture loss is from 70% to 50% over the first 48 hours of wear.

25 Preferably the nonwoven fibrous mat is reinforced with textile fibres blended with the gel-forming fibres during the formation of the mat. Alternatively, the textile fibres are present as a thread or yarn stitch-bonded on the fibrous mat for instance as described in PCT/GB2009/001138.

30 We have found that a desired final concentration of silver in the dry wound dressing is between about 0.1% and 20% by weight, for example. Preferably between 0.1% to 10% by weight and more preferably between 0.5% and 5% by weight of the dressing. Such concentrations can be achieved by the preparation method described in WO02/43743A.

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We have also found that a desired concentration of ionic silver released by the dressing into water is preferably less than 1.5 ppm and, more preferably, between 1.5 ppm and 0.5 ppm. Most preferably the concentration of ionic silver released by the dressing into water is about 1 ppm.

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By gel forming fibres is meant hygroscopic fibres which upon the uptake of wound exudate become moist slippery or gelatinous and thus reduce the tendency for the surrounding fibres to adhere to the wound. The gel forming fibres can be of the type which retain their structural integrity on absorption of exudate or can be of the type which lose their fibrous form and become a structureless gel. The gel forming fibres are preferably spun sodium carboxymethylcellulose fibres, chemically modified cellulosic fibres, cellulose ethyl sulphonate fibres, pectin fibres, alginate fibres, chitosan fibres, hyaluronic acid fibres, or other polysaccharide fibres or fibres derived from gums. The cellulosic fibres preferably have a degree of substitution of at least 0.05 carboxymethyl groups per glucose unit or equivalent ethyl sulphonate. The gel forming fibres preferably have an absorbency of at least 5 grams 0.9% saline solution per gram of fibre (as measured by the free swell absorbency method BS EN 13726-1:2002 Test methods for primary wound dressings – Part 1 : Aspects of absorbency, Method 3.2 free swell absorptive capacity).

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Preferably the gel forming fibres have an absorbency of at least 10 g/g as measured in the free swell absorbency method, more preferably between 15 g/g and 30 g/g.

Preferably the textile fibres have an absorbency of less than 10g/g as measured by the free swell method and more preferably less than 5 g/g. The dressing may for instance comprise non gel forming fibres and in particular textile fibres such as Lyocell (sometimes branded as Tencel®), cotton or viscose and may comprise elastane (sometimes branded as Spandex or Lycra®) or other elastic fibre.

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The wound dressing may comprise a fibrous mat in the form of a strip or a roll with an open structure and comprising gel forming fibres, the strip having longitudinal lines of stitches formed from a thread and optionally transverse lines of stitches formed from a

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thread. The longitudinal stitching is longitudinal in that it is generally parallel to the long dimension of the strip.

5 The transverse stitching is transverse in that it joins the longitudinal lines of stitches together and in some embodiments is generally perpendicular to the long dimension of the strip.

The thread may be a single filament or multiple filament yarn or a staple fibre yarn. The thread can be cellulosic, elastane, nylon, polyester or polyurethane. The thread can
10 be impregnated with an active agent for example with an antimicrobial agent or confer other properties such as radio-opaque qualities.

The dressing may be stitched with lines of longitudinal stitching from 1mm to 10mm apart and preferably from 2 mm to 5 mm apart. The lines of longitudinal stitching may be a lock stitch and may typically be crochet or chain stitch but other stitch patterns
15 may also be used. The dressing may also comprise rows of transverse stitches; the rows of transverse stitching may be from 1 to 10mm apart and preferably from 2 to 5 mm apart. The transverse lines of stitches may be a pattern stitch and may be crocheted or may be a basting stitch between two layers of superposed gel forming fibres. Preferably, the lines of stitching are made in a thread such as lyocell. The transverse stitches serve
20 to link adjacent longitudinal lines of stitches together to add strength to the dressing in a transverse direction.

Modification of cellulose fibres can be achieved, for example, by sequential or simultaneous treatment of the cellulosic material with a strong alkali, such as aqueous
25 sodium hydroxide, and monochloroacetic acid or a salt thereof. The appropriate reaction conditions will depend upon the composition of the fabric and the degree of carboxymethylation or ethyl sulphonation required and will be readily apparent to the person skilled in the art. They may be identical or similar to those described in WO 93/12275, WO 94/16746 or WO 00/01425 to which the reader is directed for further
30 detail.

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Desirably the chemical modification is carried out in the presence of industrial methylated spirits (IMS), and IMS is preferably also used in a subsequent washing step, suitably along with water, as a cleaner and steriliser. The degree of substitution is desirably such that upon absorption of exudate the fibres at the skin-contacting surface of the dressing form a gel.

The open structure of the fibrous mat may be provided by a nonwoven mat of gel-forming fibres made by a needle felting/ carding technique to form a web. The mat may have an antimicrobial material incorporated into it and in particular silver by the method described in WO 02/43743. The roll may be stitched in the longitudinal direction with lines of stitching in lyocell yarn. The longitudinal lines of stitches may be supplemented by transverse lines of stitching in the form of continuous, angular zigzags which extend between adjacent longitudinal lines of stitches. In this way stitch free gaps are left between columns of longitudinal stitching. The roll may be slit in the longitudinal direction in the stitch free gaps to form dressings of various sizes. For instance strips of 1 cm x 45 cm, squares of 5 cm x 5 cm or rectangles of 20 cm x 30 cm.

The invention is illustrated by the following figures in which:

Figure 1 is a table showing results from Example 1 below.

The invention is illustrated by the following examples.

Example 1.

The dehydration properties of various fibrous mats for use in wound dressings according to the invention were compared.

The fibrous mat samples used are detailed below in Table 1:

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Prototype	Description	
	Basis weight (g per m ² or gsm)	Needle Punch Density (punches per cm ²)
Dehydration Test		
HF-2010/200	88	60
HF-2010/209	171	30
HF-2010/211	181	30
HF-2010/214	218	30
HF-2010/216	104	15
HF-2010/218	163	75
HF-2010/219	163	100
HF-2010/223	183	30
HF-2010/225	184	50
HF-2010/226	183	100

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In the test, 5 cm x 5 cm samples of the prototypes were immersed in an isotonic solution until fully hydrated and then placed on a petri dish. The dehydration rates of the prototypes were assessed gravimetrically as shown in Figure 1.

10 Figure 1 shows how the different degrees of needle punch density affected the hydration performance of the mats. Among the prototype mats that managed to retain the fluid for longer are:

HF-2010/223, HF-2010/209, HF-2010/211, HF-2010/214 and HF-2010/216.

15 Despite the basis weight differences of the prototypes tested, the best performing prototypes have all been textiled with a low needle punch density, for instance less than 60.

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Table 2 shows the needle punch density against the % weight loss on drying for the samples in Table 1.

gsm	p/cm ²	batch	24 hrs		48 hrs	
			%loss	Rank	%loss	Rank
171	30	HF-2010/209	36	1	60	2
183	30	HF-2010/223	38	2	59	1
218	30	HF-2010/214	39	3	65	4
104	15	HF-2010/216	41	4	68	6
181	30	HF-2010/211	42	5	64	3
184	50	HF-2010/225	42	6	71	7
104	15	HF-2010/216	43	7	68	5
183	100	HF-2010/226	47	8	75	8
163	100	HF-2010/219	57	9	87	9
88	60	HF-2010/200	62	10	94	11
163	75	HF-2010/218	65	11	90	10

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The mats to be used in dressings according to the invention demonstrated that they can maintain a moist wound environment for a sustained period of time. It can be concluded, that a low needle punch density, provides a “loftier” structure which allows more space between the fibres to expand and gel, thus, increasing the absorption capacity. This structure also contributes to retaining the fluid for a longer time, therefore, drying out at a slower rate.

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These results show that a dressing according to the invention maintains a moist wound environment for the wear time of a dressing.

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Example 2

A wound dressing according to the invention was made by preparing two mats of gel-forming fibres (carboxymethylcellulose) by carding, cross-lapping and needle punching

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to a needle punch density of 22 to make a mat of 70 gsm. The mats were impregnated with silver ions by the method described in WO/02 43743A to give a total silver content of around 1.18% based on the anhydrous dressing. The mats were placed one on top of the other and stitch-bonded by the method described in PCT/GB2009/001138 so that
5 the weft stitches were in between the mats.

The release of silver from such a wound dressing was measured by silver assay using atomic absorption spectrophotometer (AAS) equipped with a silver hollow cathode lamp. In that method a dialysis membrane was pre-soaked in water for a minimum of
10 16 hours. Samples of the dressing are cut into 5 cm x 5 cm squares and weighed. Each sample is placed into a pouch created from the prehydrated dialysis membrane and placed into 200 ml of isotonic saline at 37 °C contained within a suitable screw topped glass vessel and stirred by magnetic stirrer. A 10.0 ml aliquot from each vessel was taken at the following time-points: 3 h, 6 h, 24 h, 48 h, 72 h and 96 h and replaced with
15 10.0 ml of fresh saline in order to maintain the dissolution volume of 200 ml. The liquid samples were then assayed by AAS comparing to standard silver solutions of known concentration.

The results were as follows:

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Time point (hours)	Silver Released ppm (µg/ml)	Std Dev
3	0.36	0.01
6	0.37	0.02
24	0.37	0.00
48	0.37	0.01
72	0.40	0.01
96	0.41	0.01

These results show that dressings according to the invention give a steady release of silver from the dressing.

Example 3

This example shows the relationship between the hydration state of the optimized open structure fibrous mat and antimicrobial effectiveness.

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An optimized open structure fibrous mat according to the invention consists of two gel forming 77 gsm mats stitch-bonded together following the method described in PCT/GB2009/001138. Each mat being comprised of carded, cross-lapped and needled punched sodium carboxymethylcellulose fibres (at a needle punch density of 22 per

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cm²) which have been previously impregnated with silver ions as described in WO02/43743A.

140mm diameter pre-dried Tryptone Soy Agar (TSA) test plates were surface-inoculated with *Staphylococcus aureus* (NCIMB 9518) to create a confluent lawn and incubated for 4 hours at 35°C to initiate growth. The surface of each plate was then

15 totally covered with sterile prehydrated dialysis membrane. Dry 35 mm diameter optimized open structure fibrous mats, were placed on top of the dialysis membrane at the centre of each plate. In half the tests (n=3) the optimized open structure fibrous mat was saturated with isotonic saline (2ml), for the other half of the tests the mat was left dry. Plates were incubated at 35°C for 48 hours. The open structure fibrous mats

20 were then removed and the plates re-incubated for a further 24 hours.

Results were as follows:-

Condition	Visual Observation of Agar Plate
Dry	Growth beneath dressing (n=3)
Hydrated	No Growth beneath dressing (n=3)

25

These results confirm that hydration is required for an antimicrobial effect to be exerted by the optimized open structure fibrous mat described. It is therefore possible to conclude that maintaining hydration for a longer period of time will extend the effective period of antimicrobial protection and will improve the overall antimicrobial effect.

Example 4

This example shows the relationship between the rate of dehydration of optimized open structure fibrous mats and the ease of their removal from a fragile surface.

Fibrous mat 5cm x 5cm samples of conventional 100gsm fibre mats with a needle punch density of 60 per cm² and optimized open structure mats according to the invention as described in example 3 were fully hydrated by immersion in isotonic saline. Drained samples were placed on agar plates (tryptone 15 g/l, soy peptone 5 g/l, sodium chloride 5 g/l & Agar No.2 12 g/l). Mats were then left to dehydrate in a forced-air cabinet for 24 hours at ambient room temperature (~22°C). At this point, sample mats had become adhered to the agar surface and could not be removed without disrupting the agar. 10 ml of isotonic saline was then applied to each fibrous mat to start a rehydration process. Taking hold of the edge of the mat with tweezers, a constant gentle lifting force was applied. The time between application of the rehydrating solution and the successful non-disruptive removal of the mat from the agar surface was recorded.

The following results were obtained (results are expressed in seconds):-

Sample replicate	Conventional fibre mat	Open structure mat according to the invention
1	290	40
2	255	60
3	347	23
4	241	48
5	331	49
6	280	40
7	(no result - test error)	50
8	274	36

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Average	288	43
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The conventional fibre mats had a drier appearance after 24 hrs on the agar surface and rehydration was visibly slower when compared to the optimized open structured mats.

In clinical practice, dressings are likely to be changed at fixed intervals rather than

5 when absorption capacity is reached or the dressing begins to adhere due to a reduction in the rate of exudation. There may also be limited time available to make dressing changes. Waiting for rehydration may not therefore be an option. Given these circumstances, the invention offers a distinct advantage in that tissue damage caused by dressing change is less likely to occur with the optimized open structure mat
10 according to the invention.

Claims

1. A wound dressing comprising a mat of gel forming fibres comprising silver, the mat having an open structure reinforced with textile fibres or threads, or fibres or threads of limited absorbency for use in the treatment of wounds.
2. A wound dressing as claimed in claim 1 wherein the mat is a mat of fluid jet entangled or needle punched nonwoven gel forming fibres.
3. A wound dressing as claimed in any preceding claim wherein the mat has a basis weight of from 50 to 200 grams per square meter.
4. A wound dressing as claimed in any preceding claim wherein the open structure is defined by a regular or irregular, two or three dimensional arrangement of fibres with a large volume for a given mass in which the free internal volume exceeds the solid fibre volume.
5. A wound dressing as claimed in any preceding claim wherein the mat has a needle punch density of less than 60 per cm^2 .
6. A wound dressing as claimed in any preceding claim wherein the mat is reinforced with textile fibres blended with the gel-forming fibres in the mat.
7. A wound dressing as claimed in any preceding claim wherein the mat is reinforced with stitch-bonding in a thread of textile fibre.
8. A wound dressing as claimed in any preceding claim wherein the mat is reinforced with stitch-bonding in a line of longitudinal stitches.
9. A wound dressing as claimed in any preceding claim wherein the gel forming fibres are modified cellulose gel forming fibres.

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10. A wound dressing as claimed in any preceding claim wherein the dressing has a rate of moisture loss at least 25% lower than a dressing made from a mat with a needle punch density of 60 per cm² or higher.
- 5 11. A wound dressing as claimed in any preceding claim wherein the dressing maintains the hydration of the wound by having a rate of moisture loss (as measured by the percentage weight loss from the dressing) of less than 75% over the first 48 hours of wear.