# Application of Zinc Ion Embedded Nylon Antimicrobial Technology for Design Flexibility of Wound Dressings

Acteev MED

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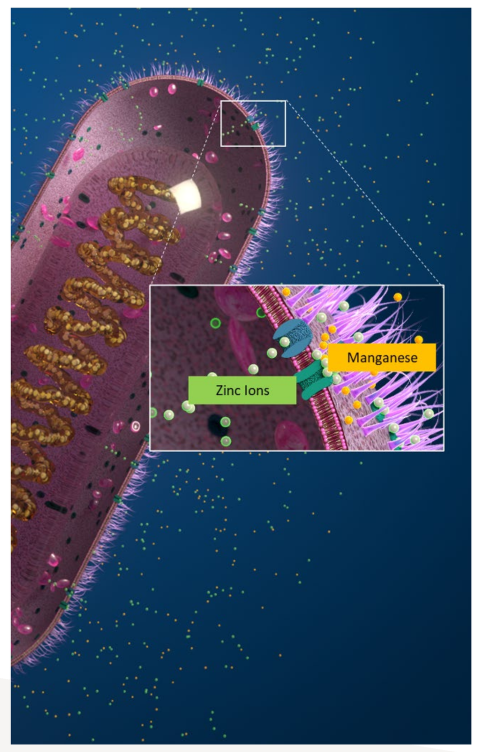
## Introduction

Wound healing is a dynamic and complex process that follows several phases of healing.1 Advanced wound dressings are specifically designed to promote these phases and/or a particular pathological condition. Most wound dressings are composite products with a combination of materials to incorporate various features, including antimicrobial properties. Incorporating the antimicrobial technology in the dressing typically involves additional manufacturing steps and is sometimes not feasible for certain components due to material processing limitations. A novel polymer based on high performance nylon which incorporates and maintains zinc in its ionic form was developed. It was converted into multiple forms with different features without any additional coating, chemicals, or textile processing to offer design flexibility of modern wound dressings.

## Zinc–Effective, Yet Safe and All-natural Antimicrobial Option

- Zinc has proven therapeutic benefits and is commonly applied to soothe the skin.
- $Zn^{2}$+ induces $Mn^{2}$+ starvation, resulting in bactericidal behavior[2]
- Active Zinc ingredient is labeled GRAS, or Generally Regarded as Safe, by the U.S. Food and Drug Administration
- Various end-forms demonstrated effective antibacterial and antifungal properties while tested to be non-cytotoxic while exposed to exposing the extract fluid to mouse fibroblast cells.




### Independent laboratories have tested various end forms for efficacy against common bacterial and fungal strains

| Microbe | Efficacy | Test Method |
|---|---|---|
| *Staphylococcus aureus* | >99.99%[i] | ISO 20743 |
| *Klebsiella pneumoniae* | >99.99%[i] | ISO 20743 |
| *Escherichia coli* | >99.99%[i] | ASTM E3160 |
| *Candida albicans* | 99.3%[ii] | ASTM E3160 |
| *Candida auris* | 99.3%[ii] | ASTM E3160 |
| *Aspergillus brasiliensis*<br>*Penicillium funiculosum*<br>*Chaetomium globosum*<br>*Trichoderma virens*<br>*Aureobasidium pullulans* | No Growth | ASTM G21 |

*[i]Testing conducted on Acteev Protect fabric made with 70 denier/68 filament yarn and filaments. ii Testing conducted on Acteev Protect 34 gsm spunbond material.*

## Design Flexibility of Wound Dressings

- Wound dressings are composed of various layers of materials, having different moisture and pressure management properties.
- Desired antimicrobial properties in these layers are typically imparted by topical treatment or by using electroplated fibers/textiles

| | |
|---|---|
| **Electroplated Fibers and Textiles** | Limits dyeability and physical properties: Wicking, absorption, abrasion. |
| **Topical Treatment** | Applied after dyeing through dye bath, pad, plasma treatment, foams, and spray coating. Limited to some end-forms. |
| **Novel Zinc Embedded Polymer** | Zinc added during the polymerization process, leaving Zinc ions dispersed at the molecular level. Maintains nylon properties: dyeability, wicking, absorption, conformability. |

## Example of Simplified Antimicrobial Wound Pad Manufacturing Process

**Zinc ion embedded Nylon 66** → **Staple Fiber** (1.7 dpf, 38 mm) → **Needle Punch Nonwoven** Soft, moisture wicking, highly absorptive, anti-odor, anti-microbial

## Variable physical properties of different end-forms made with Zinc Ion Embedded Nylon

| Form Factor | Basis Weight | Thickness | Apparent Density | Air Permeability | Wicking | Bulk Absorption |
|---|---|---|---|---|---|---|
| | gsm | mm | g/cc | cfm | mm | g/g (%) |
| | ASTM D3776 | Min press. 0.1 kPa | | ASTM D737 | Ref. # 3 | Ref. # 3 |
| Circular Knit | 125 | 0.51 | 0.245 | 276 | 83 | 278% |
| Warp Knit | 285 | 0.65 | 0.439 | 39 | 3 | 145% |
| Spunbond-1 | 10 | 0.11 | 0.091 | >1500 | 1 | 916% |
| Spunbond-2 | 34 | 0.26 | 0.131 | 1065 | 2 | 462% |
| Spunlace-1 | 60 | 0.76 | 0.079 | 529 | 42 | 770% |
| Spunlace-2 | 110 | 0.74 | 0.149 | 258 | 67 | 487% |
| Needlepunch-1 | 120 | 2.19 | 0.055 | 445 | 18 | 1543% |
| Needlepunch-2 | 300 | 3.51 | 0.085 | 180 | 38 | 1100% |
| Needlepunch-3 | 650 | 5.57 | 0.117 | 40 | 70 | 800% |

## Methods

1. During polymerization of nylon 66, active Zinc was introduced.
2. Zinc polymer was utilized to create various forms, such as spunbond, spunlace (hydroentanglement), needle-punch non-woven, warp-knit, and circular knit textiles.
3. Basis weight, air permeability, moisture wicking, bulk absorption were measured as per ASTM methods. Dyeability, cytotoxicity were tested.
4. Retention of Zinc was determined by before and after laundering analysis after 100 washes as per AATCC protocol.
5. Antimicrobial efficacy against gram-positive and gram-negative bacterial strains using industry standard ISO20743 as a testing framework was conducted.

## Results and Discussion

Simplified and streamlined manufacturing process commonly used for fibers, was adopted without any manufacturing challenges to produce various antimicrobial substrates with zinc embedded nylon technology. The versatility in performances was demonstrated. Apparent densities of 0.1 g/cc to 0.2 g/cc were achieved. Vertical wicking was tuned from 0 mm to 100 mm. Bulk absorptions of these forms were also varied from 2 to 15 times of its initial weight. Laundering 100 times does not impact the concentration of the active ingredient in the polymer with zinc retention over 90%. All these forms showed very good antibacterial properties, up to 5-7 log reduction, while tested against S. aureus and K. pneumonia.

## Conclusion

Modern wound dressing are composite products with various layers providing specific moisture and pressure management characteristics along with antimicrobial properties. This novel polymer technology demonstrated the capability of achieving variable properties, while maintaining good antibacterial efficacy. A simplified manufacturing process is now possible that can be incorporated to design modern antimicrobial wound dressings. Performance against skin and wounds would need to be studied.

## References:

1. Wallace HA, Basehore BM, Zito PM. Wound Healing Phases. [Updated 2022 Aug 25]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470443/
2. McDevitt CA, Ogunniyi AD, Valkov E, Lawrence MC, Kobe B, McEwan AG, Paton JC. A molecular mechanism for bacterial susceptibility to zinc. PLoS Pathog. 2011 Nov;7(11):e1002357.
3. Cruz J, Leitão A, Silveira D, Pichandi S, Pinto M, Fangueiro R. Study of moisture absorption characteristics of cotton terry towel fabrics. Procedia Engineering, 2017, vol. 200, p389-398.

**CIRCULAR KNIT**

**WARP KNIT**

**SPUNBOND**

**SPUNLACE**

**NEEDLEPUNCH**

**OTHER**