Advances in Engineering Research, volume 181
International Conference on Electronical, Mechanical and Materials Engineering (ICE2ME 2019)

Design and Preparation of Novel Cross-linked Polyvinyl Alcohol Extra Permeable Foam Dressings for NPWT *via* a Combined Process of Super Clean Air foaming and Ultra Precision Machining

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***Abstract*—Design and preparation of novel cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings for negative pressure wound therapy(NPWT) was studied. A series of cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with different macroporosities in the range of 700 μm~920 μm were obtained. The dried cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings showed good elongation rate in the range of ca.340%-404% and extra permeability in the range of 88~92%. The extra permeability and good elongation must be contributed from open cell structures. Characteristics of resulting cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could provide a powerful potential in the clinic application of negative pressure wound therapy(NPWT) and could enhance the range of clinic application of negative pressure wound therapy(NPWT).**

Keywords—PVA; Foam; Matrix

I. INTRODUCTION

Negative pressure wound therapy (NPWT) is a medical procedure in which a sealed wound dressing containing a foam matrix structure attached to a pump to create a negative pressure environment in the wound, which promotes wound healing in acute, chronic and burn wounds. In usual, applying continued vacuum helps to increase blood flow to the area and draw out excess fluid from the wound[1-6]. Two sponges are available for negative pressure wound therapy (NPWT) [1]. In usual, a black polyurethane (PU) sponge with a pore size of 400–600 μm intended for deep defects as granulation is strongly promoted and the pore size is suitable for heavy secretions in negative pressure wound therapy (NPWT). With a longer duration of application, it can grow together with the wound's base. This can be prevented by placing gauze under the sponge also facilitating dressing change. The sponge could be employed on the wound for up to almost one week[1]. The design of the medical device could be developed and applied for new microscopic surgical clinical treatments by using new biomaterials. For the design of new medical devices, selections of suitable materials nor resins for biomedical applications such as polyurethane, polymethacrylate, polynorbornene, polyester, and polymeric resins could be substantially considered and employed [7–12]. Also, the modification technology could be considered to change the microenvironment of materials for specific application[13,14]. Furthermore, the biological and clinical evaluations of materials and medical devices by using polyvinyl alcohol(PVA) foam must be considered for the application and design[1-6]. New anti-adhesion novel cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings derived from a super clean air-foaming process were designed for negative pressure wound therapy (NPWT). Characterization of new designed anti-adhesion novel cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could be established by determining water morphology, water permeability, thickness, macroporosity, mechanical property of resulting samples.

II. EXPERIMENTAL

A. Materials

The negative pressure wound therapy (NPWT) utilizes foam dressings to create an optimal wound healing environment. The anti-adhesion material was important for this clinic application. Polyvinyl alcohol (PVA foam dressing could be considered as a good anti-adhesion material. The cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing for NPWT was prepared by using medical grade Cenefom PVA materials. Furthermore, a combination of a super clean air-foaming process and ultra-precision machining process was designed to build up an extra permeable microenvironments and architectures in the PVA materials. A series of cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings were prepared. Mechanical property of the cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing was determined.

B. Mechanical Property

Mechanical property of the cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing was determined.

C. Macroporosities

The resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dtessings with different macroporosities were determined by using optical microscopy(Olympus BX53M).

D. Water Permeability

The water permeability of the resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could be determined by following ASTM D4491(standard test methods for water permeability).

III. Results and Discussion

In this study, a novel anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing for negative pressure wound therapy (NPWT) was obtained by using a designed process, which could build up a high permeable fully open cell structure within the cross-linked PVA foam matrix. Fully open cell structure could be characterized by using optical microscopy(OM)(Figure I). The resulting cross-linked PVA foam matrix with fully open cell structure could provide excellent water permeability. The water permeability of the resulting cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could be observed in the range of 88~92%, which is remarkable higher value among other NPWT dressings with water permeability in the range of 19~60%, by using ASTM D4491(standard test methods for water permeability). The resulting cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with different macroporosities were obtained in the range of 700~920μm diameters. Negative pressure wound therapy is a medical procedure in which foam dressing is used to enhance and promote wound healing in acute, chronic and burn wounds. The resulting cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing could be considered as a kind of vacuum dressing for negative pressure wound therapy (NPWT). The NPWT therapy involves using a sealed wound dressing attached to a pump to create a negative pressure environment in the wound.

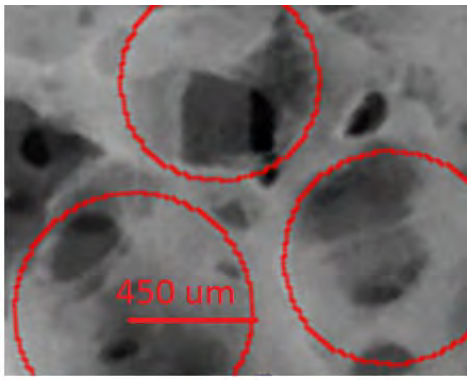

FIGURE I. PHOTOS OF THE CROSS-LINKED POLYVINYL ALCOHOL EXTRA PERMEABLE FOAM (CPVAEPF) DRESSING FOR NPWT

A. Macroporosities

The cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with different macroporosities in the range of 700 μm~920 μm were obtained as showed in Figure I.

B. Elongation Property

The resulting cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings showed good elongation property such as cPVAEPF with 360% of elongation rate(Table I).

TABLE I. MECHANICAL PROPERTY OF ANTI-ADHESION CROSS-LINKED POLYVINYL ALCOHOL EXTRA PERMEABLE FOAM (CPVAEPF) DRESSINGS

	Elongation at Break (%)	Tensile Strength (kPa)
cPVAEPF	360.8	204.3

C. Mold-inhibiting Property

Mold-inhibiting property of the resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressing was determined by using mould test. At the same time, the other PVA dressings(such as S1, S2, and S3) *via* a starch-foaming process were determined for comparison. After 4 days, the resulting PVAF nasal matrix was still clear and the other medical devices were covered with mold as showed in Figure II.

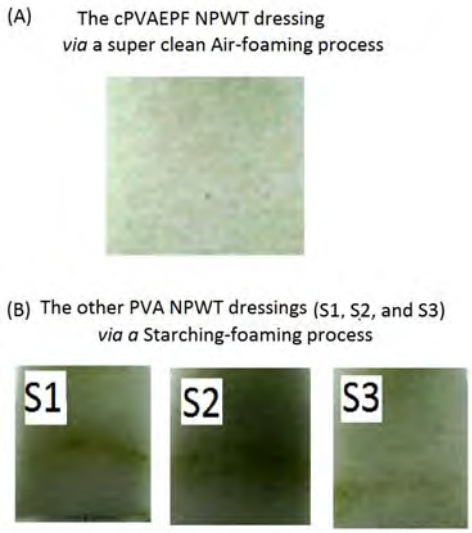

FIGURE II. MOULD TEST OF (A) THE RESULTING CPVAEPF NPWT DRESSINGS VIA A SUPER CLEAN AIR-FOAMING PROCESS AND (B) THE OTHER PVA DRESSINGS(S1, S2, S3) VIA A STARCH-FOAMING PROCESS

D. Clinic Application for NPWT

The resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with good anti-adhesion property could be employed to solve the anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with fully open cell microstructure solving the low permeability problems of traditional PVA foam dressing for NPWT applicationas showed in Figure III[2]. The anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could be a kind of contact dressings to provide good anti-adhesion property, water permeability, and mechanical property. Furthermore,

most PVA NPWT dressings have low pH values (pH<4). The pH value of cPVAEPF dressing is ca. 6.8. It could be a powerful medical device for NPWT. Of course, the other clinic application also could be considered because of their excellent properties.

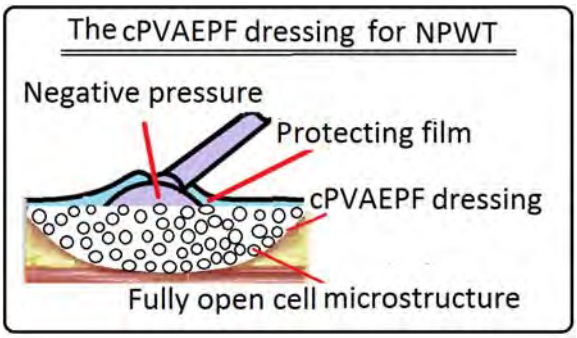

FIGURE III. (A)PHOTO OF ANTI-ADHESION CROSS-LINKED POLYVINYL ALCOHOL EXTRA PERMEABLE FOAM (CPVAEPF) DRESSINGS WITH FULLY OPEN CELL MICROSTRUCTURE SOLVING THE LOW PERMEABILITY PROBLEMS OF TRADITIONAL PVA FOAM DRESSING FOR NPWT APPLICATION[2]

IV. CONCLUSIONS

In this study, a series of new anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings with macroporosities in the range of 700 µm~920 µm were obtained. The resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings showed good elongation property such as cPVAEPF with 360% of elongation rate. The resulting anti-adhesion cross-linked polyvinyl alcohol extra permeable foam (cPVAEPF) dressings could provide a powerful potential in the clinic application of NPWT and enhance the range of clinic application of NPWT.

ACKNOWLEDGMENT

Authors would like to acknowledge Taiwan PARSD Pharmaceutical Consulting Ltd Co. for financial and technical supports. The authors also thank for technical assistances of Chien-Ho Shen.

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