

## Ambient Temperature Affect the Pore size of PVA Nanofibers Tissues

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### Abstract

Electrospinning has recently emerged as a leading technique for generating biomimetic scaffolds made of synthetic and natural polymers for tissue engineering applications. PVA was dissolved in distilled water at concentration (10% wt). PVA 10% DW solution was prepared as biopolymeric materials for fabricating tissue engineered scaffolds by electrospinning, varying ambient temperature (25, 30, 35, 40, 45 and 50) °C and investigated the ambient temperature effect on tissue nanofibers pore size. Scanning electron microscopy was utilized to profile the topography of individual electrospun fibers. Statistical measurements for each SEM images lead to measure the mean pore size of tissue obtained. Our results indicate that the average pore size of PVA fiber tissues could be scaled down to mean values (132-300)nm smooth nanofibers without any beads, pore size decreased as ambient temperature increase to certain temperature at (40 °C) and retrain increasing at (45 and 50) °C temperature.

**Key words:** Ambient temperature, electrospinning, Tissue, Nanofibers.

### تأثير درجة حرارة المحيط على الحجم المسامي لانسجة اليااف بولي فينال الكحول النانويه

#### الخلاصه:

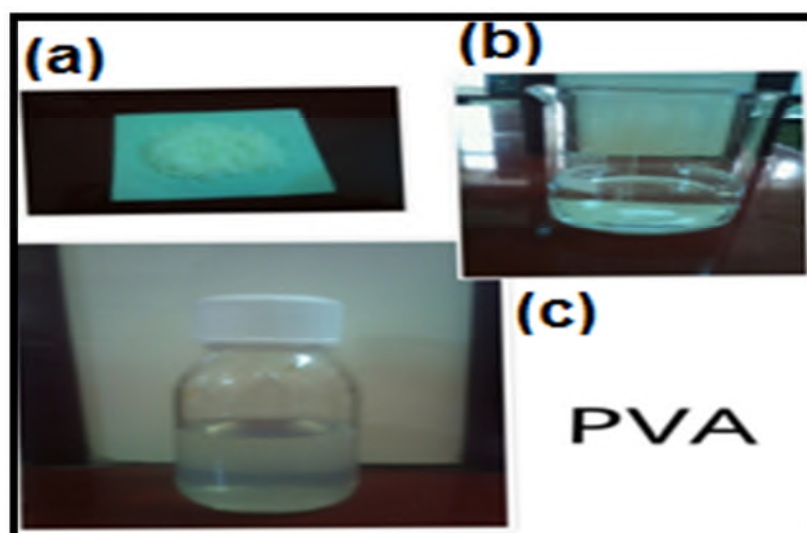
برز البرم الالكتروني حديثا كتنقيه رائده لتخليق سقالات محاكاة بايولوجيا مصنعه من بوليمرات صناعيه او طبيعيه لاستخدامات الهندسة النسيجييه . أذيب بولي فينال الكحول في ماء مقطر بتركيز 10% وزنيا . حضر بولي فينال الكحول 10% من الماء المقطر كماده سائل بوليمر احيائي لتصنيع سقالات هنسة نسيجييه بالبرم الالكتروني ، وبتغيير درجات حرارة المحيط ( 25, 30, 35, 40, 45, 50 ) °م ودراسة تأثير تغيير درجة حرارة المحيط على حجم المسامي لانسجه الليفيه النانويه .أستخدم فحص المجهر الالكتروني الماسح لتحديد شكل وطوبوغرافية الاليااف المبرمه الكترونيا . واجريت حسابات احصائيه من كل صور من صور المجهر الالكتروني الماسح المأخوذه للاليااف لتحديد معدل حجم المسامات للنسيج المحضر والمفحوص . النتائج التي تم الحصول عليها تدل على أن معدل حجم المسامات للاليااف أنسجه بولي فينال الكحول يمكن أن تتدرج الى قيمه ممتده بين ( 132-300 ) نانومتر للاليااف ملساء دون حصول اي عقد ، والحجم المسامي يتناقص بزيادة درجة حرارة المحيطه الى درجه حراره معينه هي 40 م ° والتي بعدها يعود للتزايد عند درجات حراره ( 45, 50 ) م ° .

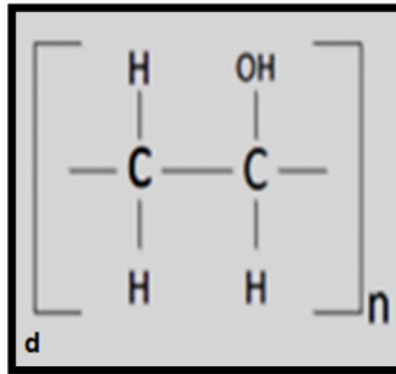
## INTRODUCTION

Electrospinning traces its roots to electrostatic spraying. Electrospinning represents an attractive approach for polymer biomaterials processing, with the opportunity for control over morphology, porosity and composition using simple equipment [1]. Electrospinning process can produce the diameter of polymeric fibers from micrometer (10-100  $\mu\text{m}$ ) to sub-microns or nanometer (0.01 - 0.1  $\mu\text{m}$ ), that leads to create some special characteristics such as high surface area to volume ratio (as large as  $10^3$  times of microfiber), high porosity and pore size in nano range[3]. Materials in nanofiber form have an exceptionally high specific surface area, which enables a high proportion of atoms to be on the fiber surface. This will result in quantum efficiency, nanoscale effect of unusually high surface energy, surface reactivity, high thermal conductivity and high strength [2]. The unique characteristic of electrospinning is, it can provide an easy and controlled method to produce nanofibers. Nanofibers are desired because they have a large surface area to volume ratio. High surface area provides more area to bind virus and can achieve higher virus removal and larger membrane capacities [4]. Materials in nanofiber form have an exceptionally high specific surface area, which enables a high proportion of atoms to be on the fiber surface. This will result in quantum efficiency, nanoscale effect of unusually high surface energy, surface reactivity, high thermal conductivity and high strength [5]. The aim of the work was to study the effect of ambient temperatures on the porosity and in turn on the tensile strength of prepared members and study the variation of porosity by SEM images and analysis.

## Materials and Methods

Polyvinyl alcohol (PVA) which represent by  $(\text{C}_2\text{H}_4\text{O})_n$  is the world's largest volume, synthetic, water soluble polymer. PVA is nonhazardous and is used in many adhesives, a polymer with a repeating vinyl alcohol unit and its molecular weight (80,000), Preparation of Polyvinyl Alcohol Density (1.31  $\text{g}/\text{cm}^3$ ) from (Sinopharm chemical Reagent Co.) (100 ml of PVA [10%] water solution] (10 gm of PVA – 90ml of distilled water) chemical structure of PVA as shown in fig (1) [6-8].





**Figure (1): (a,b and c) PVA preparation: (a) powder, (b) distilled water, (c)PVA solution .respectively,(d) Chemical Structure of PVA which is represented by  $(C_2H_4O)_n$  formula.**

Important test for prepared PVA polymer solution before spinning process, carried with Electrical conductivity (Used Cand 7110 inolab), Viscosity (using Viscometer (DV-II+Pro ) Brook field) and Surface Tensiometer Model (JYW -200A LARYEE TECHNOLOGY CO.).

An experimental laboratory stand for manufacturing nonwoven materials by means of the electrospinning technique was designed and constructed. a photograph of its main parts and a photograph of the electrically driven bending instability of the jet, are presented in Figure(2).



**Figure(2): a-Nanobond Electrospinning system with rotation collector, b- with flat plate collector, c- needle connected to high voltage by upper electrode ,and d- flat aluminum plate collector connected to earthing lower electrode, with Taylor cone and spun image.**

After fixing the plastic syringe (10ml) on to the pump, the pump was turned on. (0.2ml/h) value of the flow, the polymer solution started flowing out of the needle(with orifice size 0.6mm), the voltage was turned on. The voltage was increased until a jet of polymer solution ejected from the tip of needle.The stand is composed of three basic elements: a high voltage generator, an upper and a lower

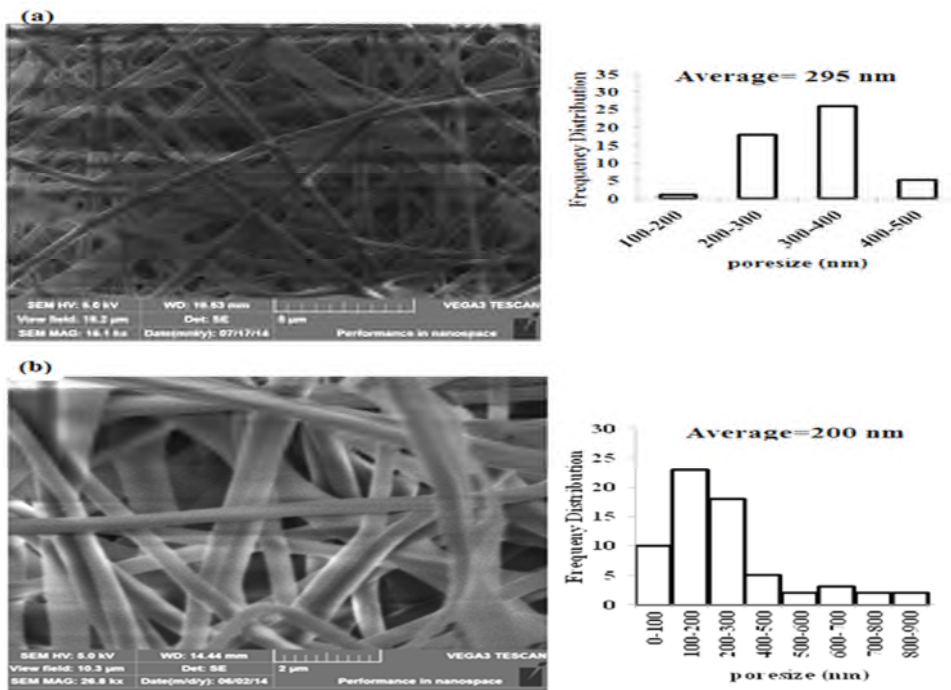
electrode. The upper electrode serves for extruding the polymer and enables the polymer drops to achieve a suitable electric potential. The second (lower) electrode is the take-up electrode, in relation to which the electric potential of the polymer is applied, and on which the fibers are deposited during the process of manufacturing the non-woven. The voltage was further adjusted to stabilize the (Taylor cone) and the jet at (15KV), needle tip to collector distance at 20 cm, varying the ambient temperature (25,30,35,40,45 and 50) °C, After finished experiments the samples prepared were removed from collector and kept at ambient temperature for (24 hours) to ensure elimination of solvents.

For analysis of the morphology of the electrospun fibers, the samples were sputter-coated with Au and examined with a scanning electron microscope (SEM, VEGA). Each micrograph from an SEM scan was statically analyzed. The average pore size and the periodicity of fibers were calculated and drawn as histogram to obtain the porosity distribution and the average fiber diameter.

**Results and Dissuasions**

Testing the PVA water solution properties, Electrical conductivity (Used Cand 7110 inolab) obtained 1222 (μS/cm) and Viscosity (using Viscometer (DV-II+Pro) Brook field) obtained 2014 (Cp) at 19 °C temperature and surface tension (44 mN/m<sup>2</sup>).

From SEM images of samples and their histogram, observed that increase in temperature leads to decreasing pore size for temperature (25,30,35,40) °C as shown in figures (3-a), (3-b), (3-c), (3-d), after (40C) at (45°C) and (50°C), pore size returns slight increase as shown in figures (3-e), (3-d).



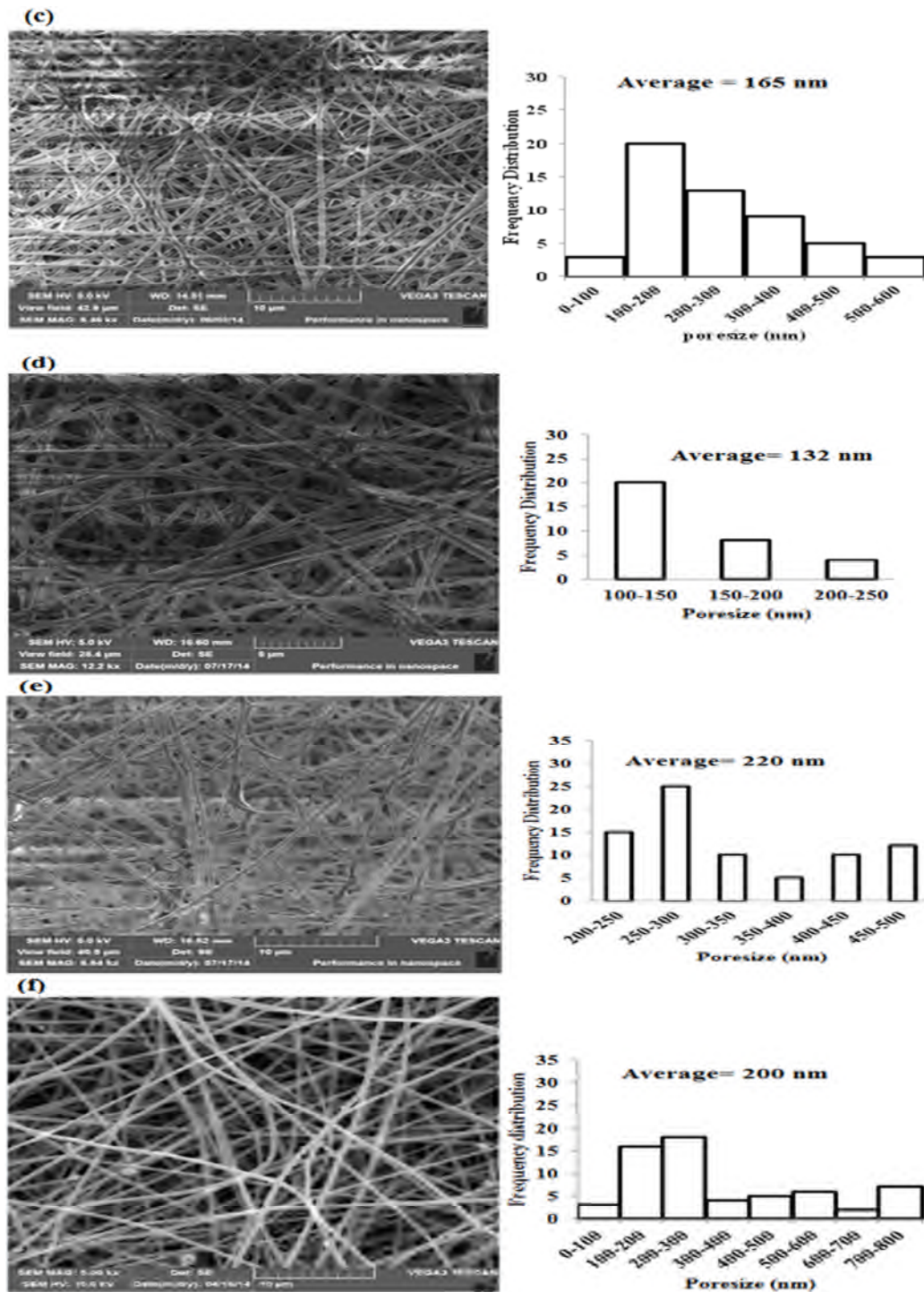


Figure (3): SEM images of (PVA) electrospun pore size with their histogram, (a) at temperature 25 °C, (b) 30°C, (c) 35°C, (d) 40°C, (e) 45°C and (f) 50°C.



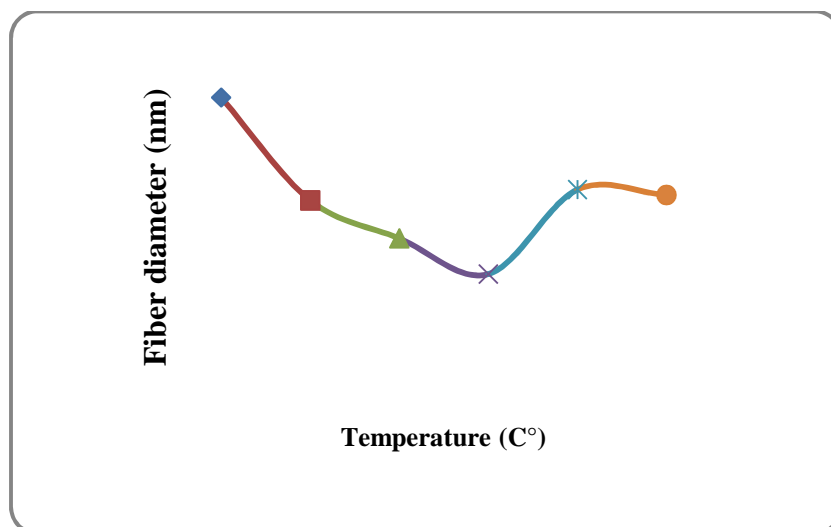


Figure (4): Distribution of Pore size with various temperatures.

The results of (load-elongation) and (stress-strain) curves of two PVA membrane 25°C and 40 C which shown in fig.5 and illustrate in table (1).

Table (1): Tensile strength and elongation at break of electrospun membranes which were prepared under conditions, a flow rate of (0.2 mL/hr), an applied voltage of (15 KV).

Temperature °C	Porosity (%)	Membrane Thickness (µm)	Average porosize (nm)	Tensile Strength (MPa)	Elongation (%)
25	83	64	295	1.449	9.04±3.81
40	78	52	132	3.657	42.02±1.02

From results shown in Table (1), It is found that tensile strength of electrospun membrane prepared at 40°C ambient temperature has porosize of (132 nm) exhibited the highest tensile strength (3.657 Mpa), when compared with the electrospun membranes that has porosize (295 nm) which prepared at 25C ambient temperature with tensile strength of 1.449 MPa .Fig.5 show J-shape stress strain curve which indicate high strain with randomly fiber orientation in initial stage of test flowed by elastic behavior and high strength after oriented fibers in the stress direction[3] . The elongation at break shows an increasing trend. In general nanofiber membrane showed high tensile strength and high elongation which indicated ductile behavior and improving its mechanical properties[9-11].However, the relations between the porosity and tensile strength of electrospun membranes also are shown in Table (1). It indicated that the tensile strength of electrospun membranes decreases with increasing porosity as well as decreasing porosize and membrane thickness.

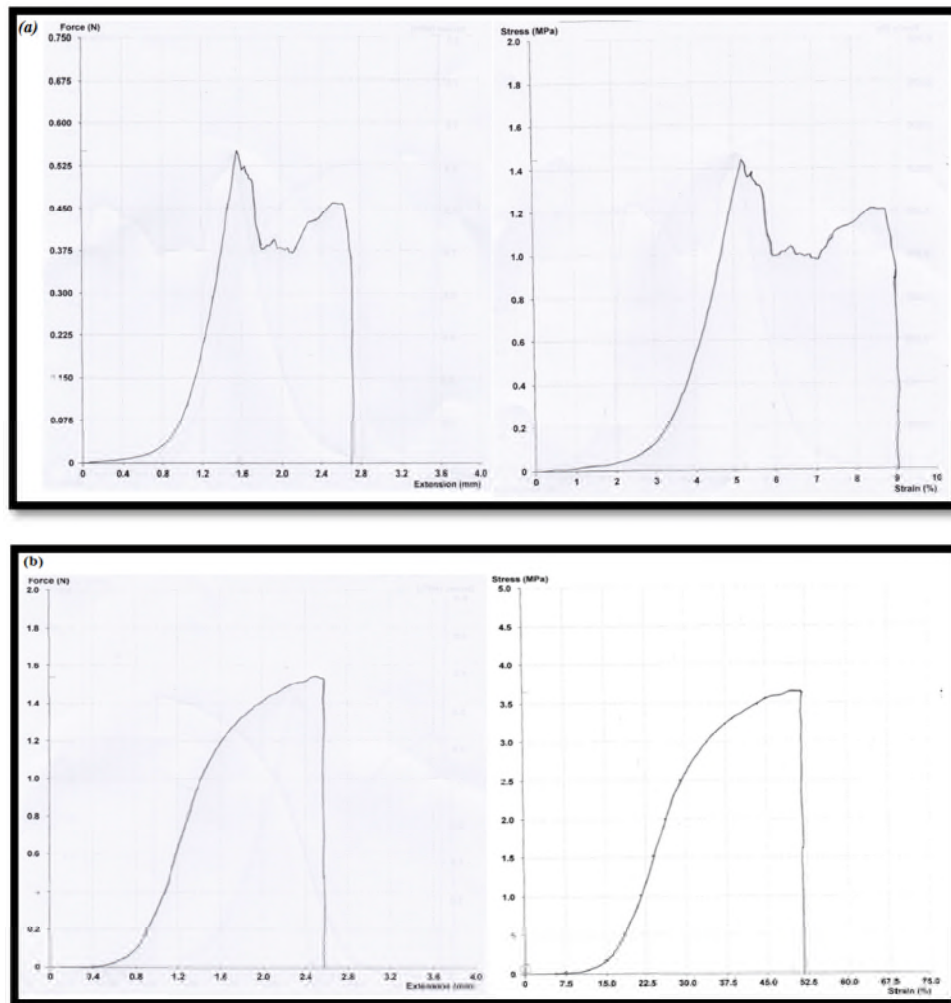


Figure (5): Mechanical properties of (PVA) nano fiber tissues (a)25C,(b)40C ambient temperature.

### Conclusions

Increasing ambient temperature, average poresize decreased. Decreasing ambient temperature will result in reduction of evaporation rate of the solvent and longer solidification time of the jet and all lead in decrease in poresize. Tensile strength increase as ambient temperature increase due to decreasing the average porosity.

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