PAPER PRESENTATION
14TH NOVEMBER, 2009

Shareef

PH08D022

Alignment of Electrospun Nanofibers Using Dielectric Materials

Hui Wu, Yao Sun, Dandan Lin, Ru Hao Yan, Luqi Liu, and Zhong Zhang

National Center for Nanoscience and Technology and Graduate School, Chinese Academy of Sciences, China

Appl. Phys. Lett. 95, 143114 (2009)

Published 7 October 2009

Relevance of the work

•Electrospun fibers have several potential applications like nanocatalysis, filtrations, tissue scaffolds, composites, nanoelectronics, and many other fields

•To exploit the fibers in application purposes, it is important to fabricate various fiber assemblies such as nonwoven, aligned and patterned fiber meshes, three-dimensional structures as well as twisted yarns

•Methods developed so far for the alignment are rotating drums, disk collector, parallel electrodes and ring collector

•The distribution of electric fields is perturbed due to the varying electrodes configurations

•The electrospun jet movement also disturbed as it was close to the electrodes, and finally the nanofibers were deposited onto the surface of electrodes in order to form uniaxially aligned nanofiber arrays

Factors affecting alignment

- Direction of electrostatic force in the spinning process due to electrode array (configuration effect)
- Material property of the collector; the dielectric constant reflects the concentration of field lines
- The field lines are denser around the collector having higher relative permittivity

Present work

•The relationship between the relative permittivity of various parallel collectors and the alignment of the electrospun nanofibers

•2D Simulation model for the electric field lines by replacing collectors with different dielectric materials

•Similar shaped collectors are used to avoid the influence of their shape

•To get the influence of dielectric property on the electric field profile, the collectors kept ungrounded

Experimental section

•PVA used as reference sample with 9% by weight in water

•The temperature range is 19 - 24 °C at ambient humidity

•A glass slide used as an insulating layer, and the collector with a certain relative permittivity was put onto the top of the glass slide

•Parallel arrayed nanofiber meshes are obtained across the collector by adjusting the typical electrospinning processing parameters such as the gap distance between the collector, the distance of the spinneret to the collector and the applied voltage

Observations

•For epoxy resin as collector (ε_r= 4), nanofibers deposited as nonwoven mesh across the gap with a distance of 4 cm

•For ferrite as collector (ε_r= 12), aligned fibers are obtained even when the gap distance is more than 6 cm

•For a wooden collector, alignment is there for (ε_r = 10 ~ 30) and it disappears if the (ε_r= 2 ~ 6)

•These results shows that the dielectric constant of the collector is the key factor to determine the alignment

•Most of the collected nanofibers were deposited perpendicularly to the edge of the collector within ±10° region

•Further increase in dielectric constant doesn't improve the alignment beyond a limit; water (ε_r= 81), ethanol (ε_r= 25) and isoamyl alcohol (ε_r= 15.3)

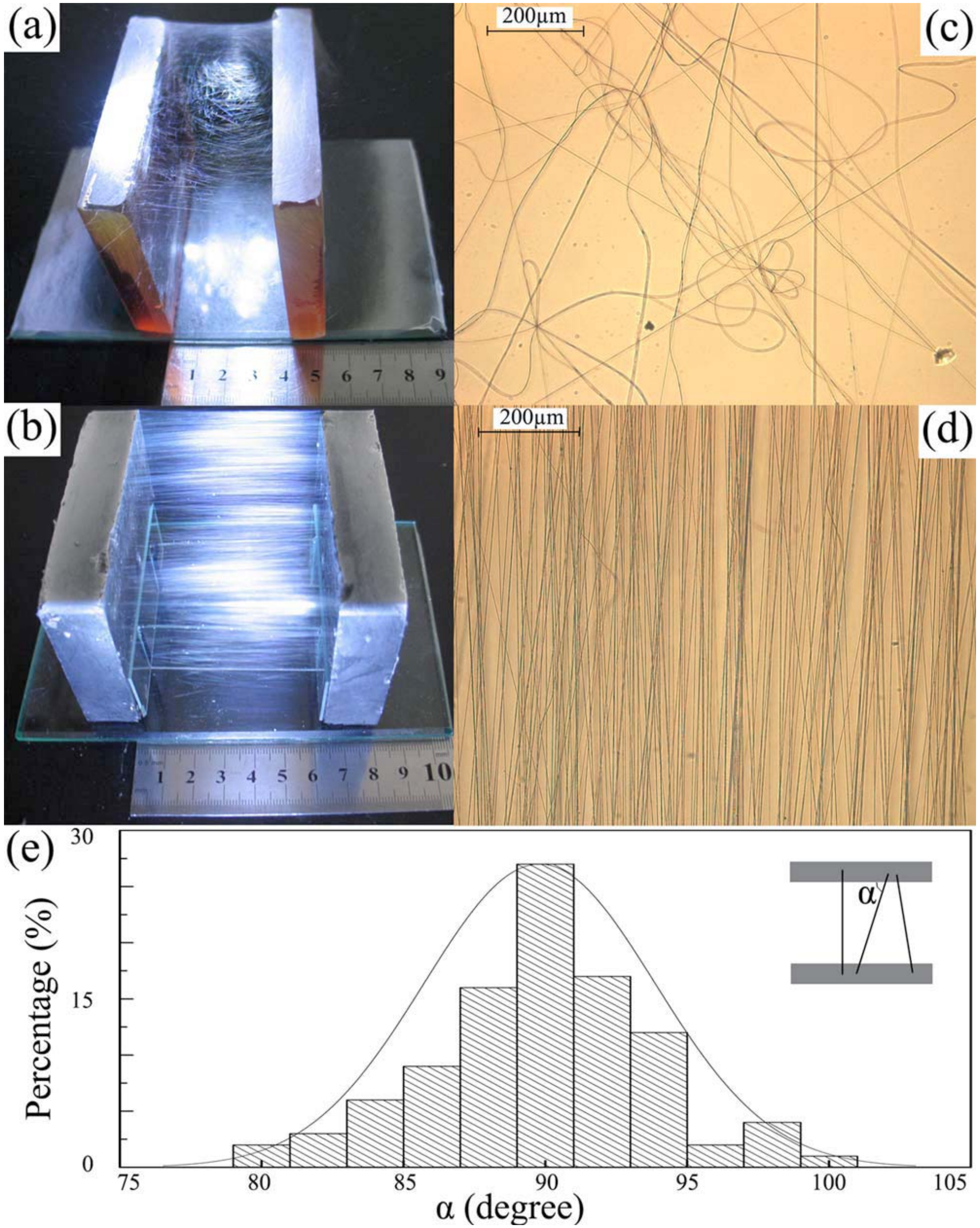


Fig 1

(a) and **(b)** Digital camera images of prepared nanofiber meshes using epoxy and ferrite as the collectors respectively

(c) and **(d)** Optical micrographs of (a) and (b)

(e) The distribution of the electrospun nanofiber alignment from (d)

Observations

• Dielectric constant of the collector material is the key factor to determine the nanofiber array

•There is a threshold value of the dielectric constant beyond which there is no further improvement in the alignment ,present case it is 5 – 10

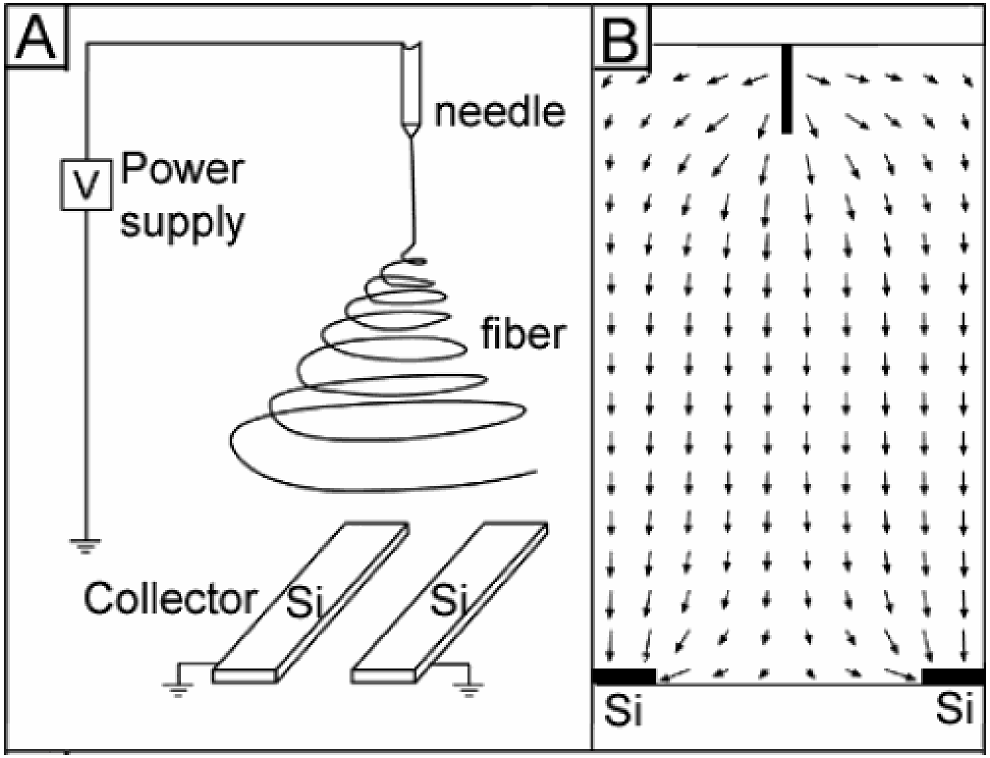
•The threshold value depends on the experimental conditions including shape and position of the collector

•Unidirectional nanofiber array can be easily fabricated by using high dielectric constant materials as collectors rather than low ones

Conventional set up for alignment

Fig. 2

- Schematic set up to generate uniaxially aligned nanofibers. The collector contained two pieces of conductive silicon stripes separated by a gap.
- Calculated electric field lines in the region between the needle and the collector.



Nano Lett., Vol. 3, No. 8, **2003**

Theoretical simulation for the alignment of nanofiber

•The dependence of the electric field on the relative permittivity of materials including electric field vectors and magnitude

•The simulated model is for the parameters: distance between the spinneret and collector is 10 cm, the gap distance of the collector is 5 cm, the applied voltage is 15 kV and the collector's relative permittivity is 81

•Simulated field lines split into two sides of the collector although the collector is ungrounded which is similar to its distribution to the grounded collector

•So the electric field profile is mainly determined by the geometrical configuration of the collector.

•Further quantitative analysis could reveal the influence of the collector's relative permittivity on the electric field strength

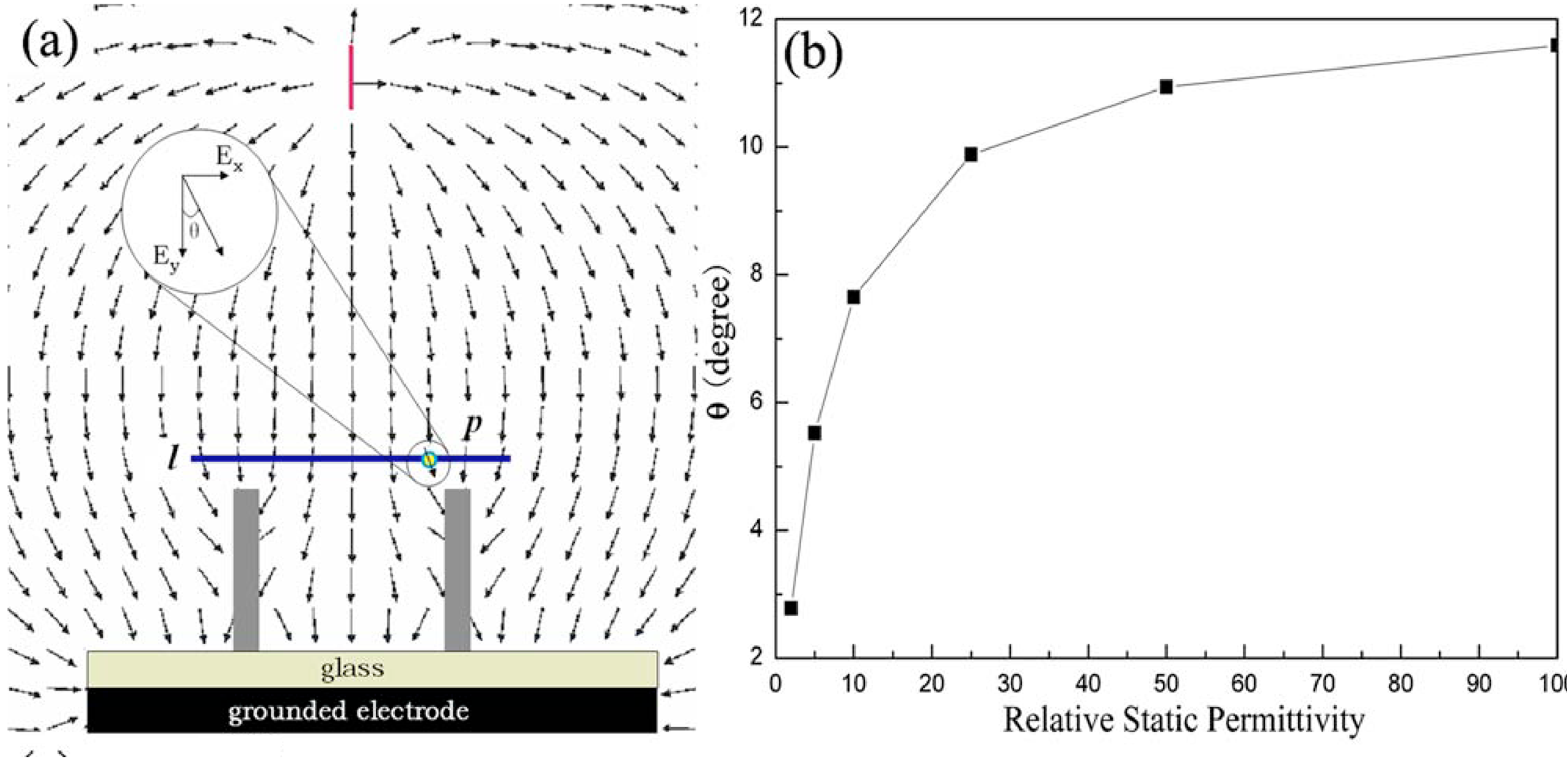


Fig. 3(a) The simulated electric field vectors in the region between the spinneret and the grounded electrode. The arrows denote the direction of the electric field vectors. The electric field *E* was resolved into *Ex* and *Ey*, respectively

(b) Plot of angle, $\theta = \tan^{-1} Ex / Ey$ vs relative permittivity at the point *p* of Fig.a

Effect of dielectric constant on the field lines

•Both *Ex* and *Ey* values show a dependence on the relative permittivity of materials and vary along the reference line

•*Ey* shows a nonlinear increase along the reference line and reaches to the maximum on the top of collector while *Ex* increases from 0 to the maximum once it is close to the collector

•Since *F*=*Eq*, (if the charge density is uniform) the horizontal force is too low to stretch the fibers straight in case of lower dielectric collectors while it will be large enough to stretch the fiber straight in case of higher dielectric materials as was obtained for epoxy resin ($\varepsilon_r = 4$) and ferrite ($\varepsilon_r = 12$)

•It focus that both the direction and magnitude of horizontal electrostatic force *Ex* has influence on the alignment of the fibers

•*Ey* directly draw the fiber into the collector and has less effect on the alignment of the fiber

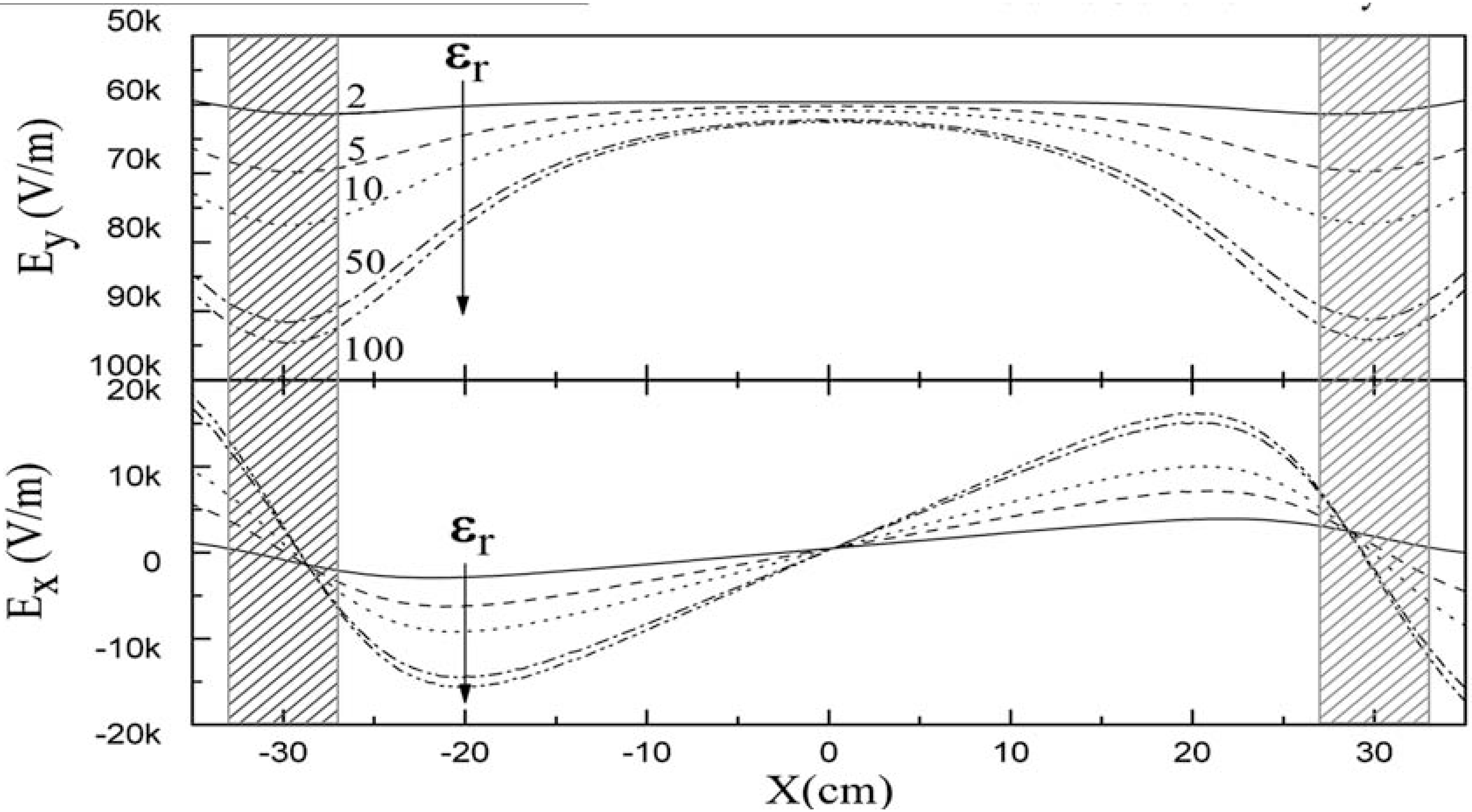


Fig. Varied trend of electric field strength *Ex* and *Ey* along the reference line x using different dielectric materials as collectors.

Effect of applied voltage on alignment

•The electrospinning parameters which affects the magnitude of *Ex,* will influence the fiber alignment

•*Ex* vary linearly with the applied voltage and align the fibers

•The increased trend of *Ex* becomes more apparent when high dielectric constant materials are used as collectors.

•The combined effect of higher dielectric material at high voltage has more effect on the alignment

•The orientation can be obtained at low voltage if the collector has high dielectric constant and its vice versa is limited by high voltage power supply

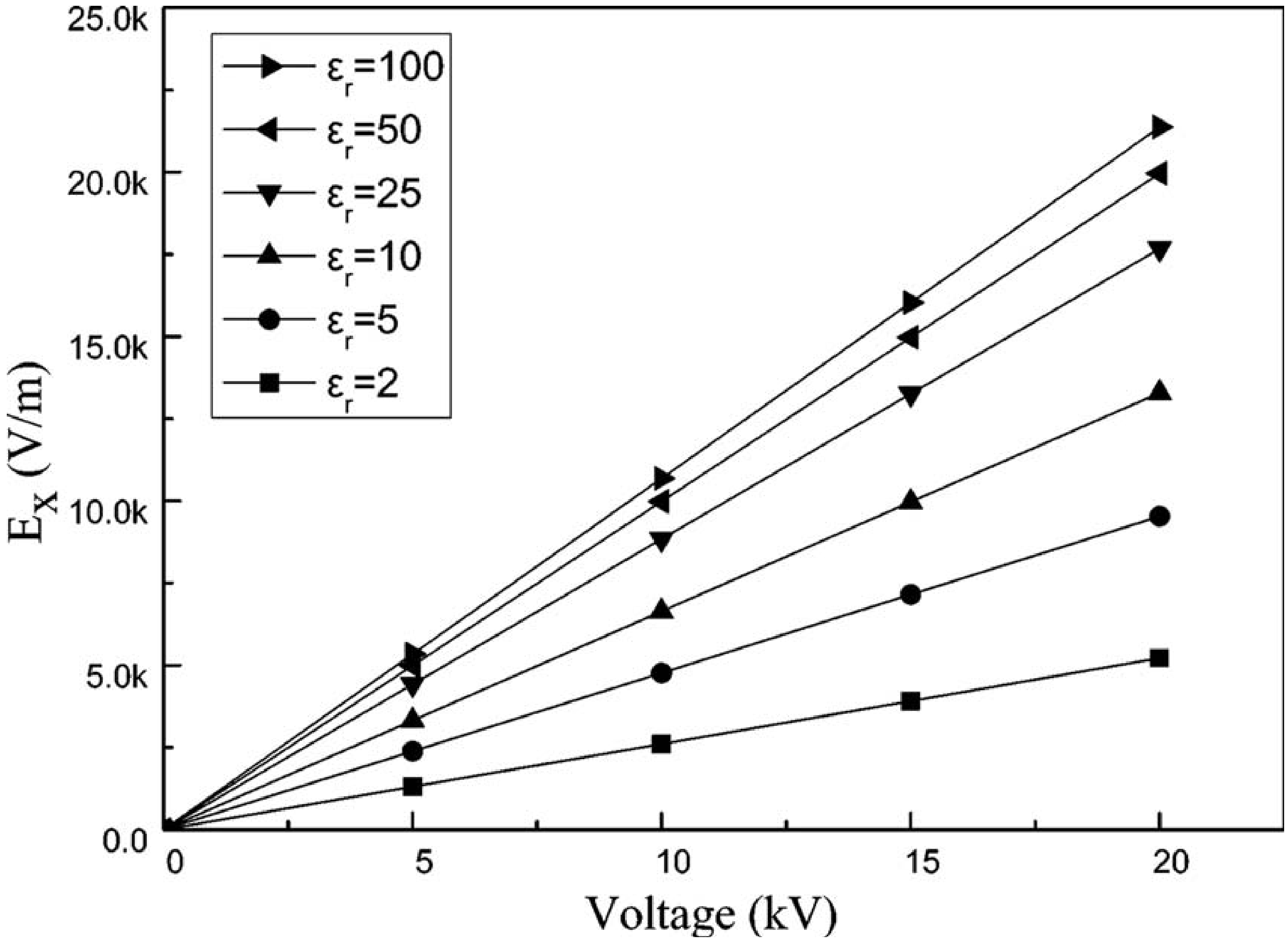


Fig. 3. A plot of *Ex* vs applied voltage at different relative permittivity ε_r of the point *p* in Fig. 2a.

Conclusion

•Well-aligned nanofiber meshes are achieved by manipulating the electric field profile with various dielectric materials as collectors

•This simulation model can apply for other polymers also like PAN, PVP and PMMA

•Materials with a given relative permittivity could have a profound influence on the deposition behavior of the electrospun nanofibers.

•Theoretical simulation suggests that the magnitude of the horizontal electric field strength Ex is the major factor to stretch electrospun nanofibers across the gap, and to eventually prepare aligned nanofiber meshes

Thank you