Figure7 field strength along the microneedle surface

Figure7displays the electric field along the z-axis in the central line for the foursystems with various microneedle hole radius, outer radius and length that setas 10, 20, 30 and 40µm for microneedle hole radius and 50, 100, 150 and 200µm formicroneedle outer radius and 25, 50, 75 and 100µm for microneedle length. it showed that with the increase distance frommicroneedle, the field intensity decreased slowly except for theposition beside the microneedle apex. At the end fixed and low electric fieldwas received on the collector. It was clear that the microneedle with the smaller hole and outer radius and larger length madethe larger electric field in the region close the microneedle and displayed a betterTaylor cone in the spinning path.

Also, It caused the long jet direction andthinner nanofibers. So it was better to use microneedle with the lower hole andouter radius and bigger length. Accordingto the limitations of the fabrication process, a microneedle with 20µm holeradius, 50µm outer radius and 100µm length was used. From the simulationresults are shown in figure8(a), we can observe that the microneedle with smaller outer radius makes a strongerelectric field strength along the microneedle surface at the differentmicroneedle outer radius.

So, Taylor cone and nanofibers were improved and thisresult proved the outcome of figure7(b). So, effective parameters such asvoltage, the distance between microneedle and collector, length of themicroneedle and inner hole and outer radius of the microneedle effected on theelectric field and electric potential. At the end, the suitable conditions forfabricating microneedle was followed to achieve the best results. Electric field andelectric potential simulation for design microneedle: The electric potential(V) was applied to an aluminum sheet that microneedle array was mounted on it.

Thesurface that microneedle was extruded from it and microneedle tip were coatedwith a 30nm gold layer. Potential of zero was put on the copper sheet that thelam glass plate as the fiber collector was straddled on the copper surface. therelationship between electric field and electric voltage with altering distance betweenmicroneedle surface to horizontal line graph with z= 250, 500, 750 and 1000μm(on the collector) are shown in figure4. As the distance microneedle todetachment horizontal line increases, the electric potential decreases As shown in figure5(a). it was indicated thatmax and min electric potential related to the microneedle tip and collector, respectively.

Taylor cone was made due to thevariation of electric potential. As a result, nanofibers was been formed. analyzeof the electric field is done at different horizontal line z= 0, 100, 300, 500, 700, 900 and 1000μm in the XY plane as shown in figure5(b). the max electricfield was at the edges of the microneedle and collector and the min amount wasat the hole of microneedle along z= 0.

Microneedle with edge was caused the maxfield intensity around it. So polymer solution was stretched because ofconcentrate charges. As the distance microneedle to horizontal line enhancesthe electric field decreases slowly as long as it reaches to the collector withconstant and low electric field. Extension of the field was happened byincreasing the distance from the microneedle surface. So distance causeddifferent field strength. Also vertical lines with y=-500, 0, 500μm in the YZ plane is displayed various electricpotential along increasedistance from microneedle upto collector as shown in figure6(a). the equal distribution of electric potential onthe microneedle was caused the fine nanofibers.

()(). E= -? V (1)The 3D electric fieldand electric potential of the electrospinning system was examined using thefinite element method (FEM). The display of the electric field on Arrow and theelectric potential on contour were exhibited in figure1(b). So the distributionof electric field was mentioned upgrade and electrospinning will be done withthe best results. The figure2 shows the distribution of the electric potentialon surface. The electric potential on surface at the microneedle tip with heightis displayed in interpolation of figure3(b) that a concentrated point ofvoltage is observed. Max electric potential at microneedle surface is placed onthe microneedle because of microneedle? s length as shown in figure3(b). Thecenter region of the collector has smaller field intensity contrasted to thecorners of the collector as shown in figure3(a).

The electric potential at thecollector surface with height in the microneedle system exhibits in theinterpolation of figure3(a). The electric field (E) was computed by thegradient of electric potential (V), as shown in equation 1. The system was simulatedusing Comsol ® Ver 5. 2 add-on AC/DC module under Windows 10 operating systemthat microneedle electrospinning system was modeled for forming of spiral shapesingle nanofiber and a spherical-shaped air environment was been modeled.

Atfirst, the physical geometries of the setup, such as microneedle, collector andthe electrode were determined based on their experimental dimensions, positionsand substance properties. The configuration of a microneedle spinneret wasshown in figure1(a). The processing parameters were summarized in table 1.