

4.3 Effect of Concentration

The polymer solution of solute PVDF in solvent DMF at 16%, 18% and 20% concentration is considered to study the effect of concentration on the diameter and morphology of nanofibers. From Table-II, it is seen that concentration of solution increases, the thicker fibers are formed. The SEM images of the samples are as shown in Figure-9, at more concentration of solution the beads-free nanofibers can be fabricated. The main effect plot of concentration of solution versus mean diameter of PVDF nanofibers at each level is as shown in Figure-5. From the nature of graph it is concluded that as the concentration of solution increases, thicker nanofibers are formed.

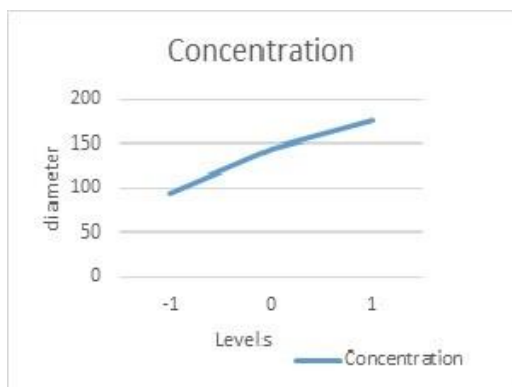


Figure 5: Main Effect plot of diameter versus concentration of solution

4.4 Effect of Distance (distance between syringe tip and collector)

The main effects plot of distance and the mean diameter of nanofibers at each level is as shown in Figure-6, which suggests that there is not much effect of distance on the nanofibers diameter. The nature of graph is almost parallel to horizontal axis. But as the distance increases, solvent gets more time for evaporation and the beads free nanofibers are deposited on drum collector covered with aluminium foil used for ease in handling nanofibers.



Figure 6: Main effect plot of diameter versus distance

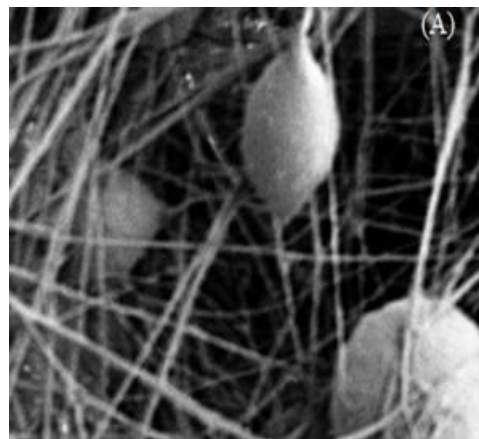


Figure 7: Effect of concentration on the morphology of nanofibers, (A)16% concentration

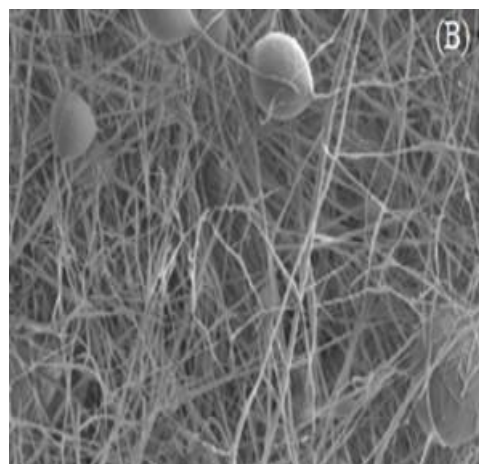


Figure 8: Effect of concentration on the morphology of nanofibers, (B) 18% concentration

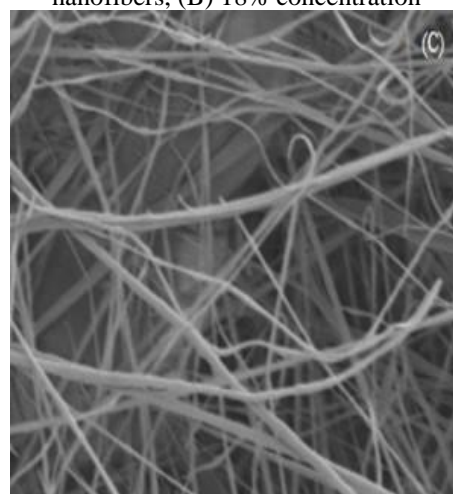


Figure 9: Effect of concentration on the morphology of nanofibers, (B) 18% concentration and (C) 20% concentration

The Table-VI shows the summary of effects of different process parameters affecting the morphology and diameter of PVDF nanofibers fabricated using electrospinning technique.

Table 6: Effect of process parameters affecting the morphology of PVDF nanofibers

Sr. No.	Parameter	Effect on morphology of PVDF nanofibers
1	Concentration	Increase in fiber diameter as concentration increased, disappearance of beads
2	Voltage	Decrease in fiber diameter as voltage increased
3	Flow rate	Decrease in beads formation as flow rate increases and fiber diameter increases
4	Distance	Decrease in beads formation as distance increases

5. Conclusion

From the main effect plot of diameter versus individual parameters, it can be seen that high voltage supply and flow rate are the more influencing parameters on the diameter of nanofibers. From the Figure-3, as the voltage increases the minimum diameter nanofibers can be fabricated which is same in case of flow rate as shown in Figure-4. Whereas the concentration of polymer solution and the distance (distance between spinneret and collector) are the parameters which are affecting the morphology of nanofibers as shown in Figure-9. With proper viscous solution, beads-free nanofibers can be fabricated. In this present study from the Table-II, the minimum diameter of nanofibers of PVDF are fabricated at following parameters,

- 35KV voltage (high voltage D. C. power supply)
- 1ml/hr flow rate
- 17.5 cm distance (distance between spinneret and collector)
- 16% concentration of PVDF in DMF.

6. Future Scope

Polyvinylidene fluoride (PVDF) nanofibers is the polymer material having the piezoelectric properties. In future scope, the nanofibers would be tested for piezoelectric properties feasible applications of nanofibers related to energy are envisage. There are hundreds of polymer variants from which nanofibers are produced by electrospinning, but very few publications are available related to study of electrospinning based on ANOVA or DOE.

References

- [1] L. filipponi and D. Sutherland, *Introduction to nanoscience and nanotechnologies*. Arhus University Denmark, ch. 1, pp. 19–40, 2013.
- [2] Z. M. Haung, Y. Z. Zhang, M. Kotaki, and S. Ramakrishna, “A review on polymer nanofibers by electrospinning and their applications in nano composites,” *Composites Science and Technology*, vol. 1, pp. 2223–2253, 2003.
- [3] S. Ramakrishna, K. Fujihara, W. E. Teo, T. Yong, Z. Ma, and R. Ramaseshan, “Electrospun nanofibers solving global issues,” *materials today*, vol. 9, pp. 100–115, 2006.

- [4] D. Li and Y. Xia, “Electrospinning of nanofibers: Reinventing the wheel,” *Advance Materials*, vol. 2, pp. 1153–1167, 2004.
- [5] J. Fang, X. Wang, and T. Lin, *Functional applications of electrospun nanofibers*, T. Lin, Ed. InTech, 2014.
- [6] J. Chang, M. Dommerand, C. Chang, and L. Lin, “Piezoelectric nanofibers for energy scavenging applications,” *Nano Energy*, vol. 1, pp. 356–363, 2012.
- [7] C. Ribeiro, V. Sencadas, J. L. G. Ribelles, and S. L. Mendez, “Influence of processing condition on polymorphism and nanofiber morphology of electroactive polyvinylidene fluoride electrospun membranes,” *Soft Materials*, vol. 8, pp. 274–287, 2010.
- [8] Dr. S. M. Shendokar, S. S. Chavan, and P. V. Londhe, “Assessment of electrospun nanofibers properties in two phase composites,” in *International Conference on Nanotechnology Materials and Composites for Frontier Applications Nanocon 010*, Oct 2010.
- [9] S. Shendokar, A. Kelkar, R. Mohan, and R. Bolick, “Parametric investigation on the effect of electrospinning process variables on the macroscopic properties of hybrid composites,” *Processing and Engineering Applications of Novel Materials*, vol. 14, pp. 351–358, Nov 2009.
- [10] M. Tascan, “Optimisation of process parameters of wet-spun solid pvdf fibers for maximising the tensile strength and applied force at break and minimising the elongation at break using taguchi method,” *Journal of Engineered Fibers and Fabrics*, vol. 1, pp. 165–173, 2014.
- [11] D. G. Montgomery, *Design and Analysis of Experiments*, L. Ratts, Ed. John Wiley & Sons, Inc., 2013.
- [12] J. O. Rawlings, S. G. Pantula, and D. A. Dickey, *Applied regression analysis A Research tool*, G. Casella, S. Fienberg, and I. Olkin, Eds. Springer, 1998.