IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

The role of polymer relaxation in the beading of electrospun fibers

Project number: IMURA0016

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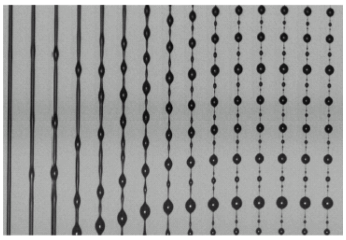
The problem

Electrospinning, wherein electric fields are employed to draw a thin microscopic jet of polymeric excipient from the meniscus emanating from the orifice of a microneedle, is an extremely versatile and powerful method for generating long fibers. These fibers can be assembled into one, two or even three dimensional architectures such as enhanced strength composite fibers, membranes and scaffolds, which can then exploited for a vast array of applications such as sacrificial templates for tissue/orthopaedic engineering, microfiltration, catalysis, lightweight and breathable textiles for military suits, and, smart materials for aerospace vehicles, amongst others.

Despite a large body of experimental work on electrospinning, little, however, is understood about the complex physicochemical hydrodynamics that are associated with the phenomenon. In particular, there exist various electrical and hydrodynamic instabilities that interact not only to generate the fiber, but also to produce effects such as bending/whipping, pinching and beading, some of which are desirable in some circumstances and undesirable in others.



The peculiar effect of beading has only been recently understood in the context of the mechanical extensional stretching of polymer jets and has been attributed to the finite extensibility of the polymer molecules. In fact, at long times, generations of higher-order bead effects are observed due an iterated elastic recoil effect, as shown in the figure.

The project

In this project, we will develop models that couple the effects of the electric field to the hydrodynamics of the viscoelastic thread. The beading effects, which also occur in electrospinning (the primary beads, at least), can then be captured by incorporating a finite extensible nonlinear elastic (FENE) dumbbell model. Part of the project will also involve theoretical and experimental investigations to determine whether the secondary and higher order beading effects can be obtained through electrospinning, and if so, the conditions under which they occur. Scaling theory of the dominant effects (viscous, capillary and inertia) that act on the thread will be employed to determine the relevant time scales under which the various phenomena (spherical drops, straight fibers, beaded fibers) occur. This will allow selective tuning of the applied AC frequency to produce the desired drop/fiber effect.