AC Electrospinning

- Fibers produced do not contain as much interfacial charge as those obtained from DC electrospinning
  - ⇒ Higher diameter of the fiber (1 - 10 μm)
  - ⇒ Less whipping instability
- Every half cycle in AC electrospinning at low frequency fibers ejected intermittently with each successive fiber ejected has opposite charge to its predecessor.
  - ⇒ Electrostatic attraction between successive fibers
  - ⇒ Individual fibers are likely to fuse into interconnected networks (this is not possible in case of DC electrospinning)
  - ⇒ A monolith of interwoven fibers would be spun directly from the meniscus (POROUS MAT)
  - ⇒ Potential use as, scaffold for blood vessel
    - " matrices for tissue engineering
    - " porous membrane

AC Electrospinning ... Contd.

Critical Polymer Concentration

- Below the critical value, solidified particles form after evaporation
- Close to the critical value, both particles and fibers are formed simultaneously

Encapsulation of biomolecules

- In case of AC electrospinning, the entrained bulk charge neutralizes rapidly at the ground electrode
- The penetration depth of charge into the core of the fiber is small at high frequency AC voltage
- The method is ideally suited for encapsulation of proteins, DNAs, cells, organisms, and other therapeutic molecules without causing any major damage ~~due~~ of biomolecules due to penetration of charge.

Evaporation vs. polymerization/crosslinking/curing

- A fiber can solidify due to evaporation, depending on critical polymer concentration.
- A fiber can also form due to polymerization (through a focused beam of UV light, and prior addition of initiator and catalyst in the fluid)
- A fiber can form due to further cross linking of polymer network through covalent bond formation (suitable crosslinker to be added apriori to the formulation)
- Curing of polymer fiber (completion of polymerization) through focused application of heat (by IR lamp).

Encapsulation through electrospray / electrospinning

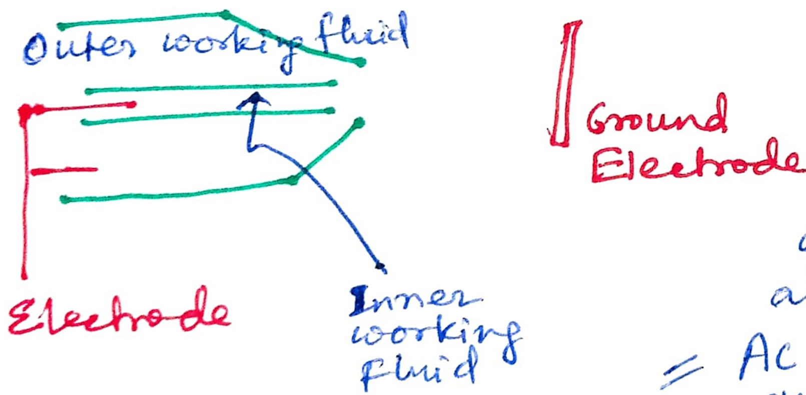
- Blended fiber/droplet
- Core-sheath form of fiber / capsule

Blended fiber/droplet

// First, a stable microemulsion is formed where the substance to be encapsulated (biomolecules) is the dispersed phase, and the polymer is the continuous phase

// Next, electrospray / electrospin the emulsion

Core-sheath fiber / Microcapsule



// Use of co-axial concentric annular nozzle set-up

// DC electrospinning will result in core-shell composite fiber or microcapsule depending on choice of polymer concentration above or below the critical polymer concentration.

// AC electrospinning at polymer concⁿ above the critical value will produce mat of core-shell composite fiber.

Encapsulation (Electrohydrodynamic method) .... contd.

Core-sheath fibers / Microcapsule .... contd.

/ Use of photopolymer with initiator and catalyst as encapsulating fluid that can be cured by application focused UV beam at the outlet of the nozzle — (other method of composite fiber/capsule formation apart from evaporative process)

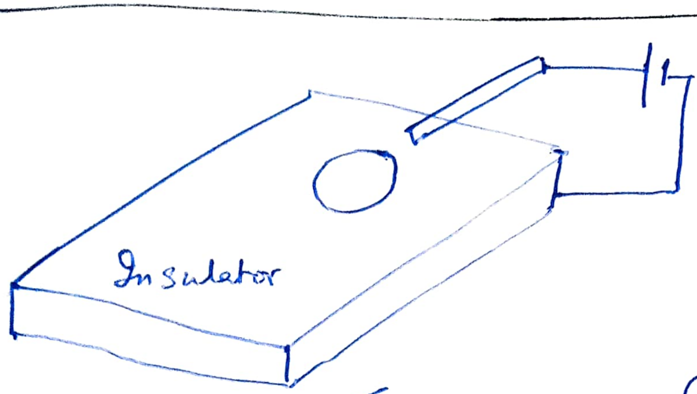
// Use of a crosslinker with the polymer, where the crosslinking process continues on the flight for fiber/capsule

/// Use of a crosslinker bath, and collection of microcapsule through ring electrode in the bath where outer layer gets crosslinked

In case of composite fiber/capsule, both fluids need not ~~be~~ be conducting ⟹ Insulating liquids, which cannot otherwise be electrosprayed with DC electric field can be ejected by the help of inner sheath of conducting fluid.

Because, outer insulating fluid has to form a conical meniscus as a result of viscous shear and maxwell stress imposed on the inner conducting fluid.

Discharge - driven Vortices



(*) Liquid is housed in a shallow cylindrical cavity (~ few mm depth)

(*) Sharp metal tip is raised to a voltage beyond the threshold ionization voltage of atmosphere

(*) Co-ions, repelled from the tip collides with electro-neutral air molecules, and produces bulk electrohydrodynamic air thrust, known as ionic or corona wind.

(*) when the metal tip (also referred as corona electrode) ~~...~~ is mounted vertically above the liquid surface ⟹ interfacial deformation (slight depression will be observed

(*) when the corona electrode is inclined, the tangential component of air leads to interfacial shear, which when overcomes the viscous forces produces secondary recirculation in the bulk liquid (Microfluidic Mixing)

(*) With an AC field, permanently entrained plasma cloud is produced at each half AC cycle. Frequency must be less than a threshold value, so that the plasma gets sufficient time to diffuse away from the tip.

(*) Minimum AC voltage required is 500 V at 150 kHz. In case of DC, the voltage requirement is 2000 V.

(*) Advantages : No electrode contact ⟹ No joule heating, no electrolytic reaction and sample contamination, no penetration of charges into bulk, less destruction of biomolecules due to field penetration.