Nano Focus

Magnetic ferrofluid key to new take on spinning polymer fibers

Nanofiber polymers find use in both well-established industries including filtration, catalysis, and personal care products such as diapers and adsorbents as well as burgeoning industries such as biomedicine and composite materials. Nanofibers benefit from a very high surface-to-volume ratio and also have the potential for additional functionality. However, melt spinning—the current industrial standard for the production of polymer fibers—suffers from certain limitations in terms of the size and type of polymers that can be manufactured. This technique has difficulty generating fibers with nanoscale diameters and requires that the polymers melt before drawing, leading to potential degradation. According to Caroline Schauer of Drexel University, this means that "certain polymers such as natural polymers cannot be melt-spun, effectively eliminating an entire field."

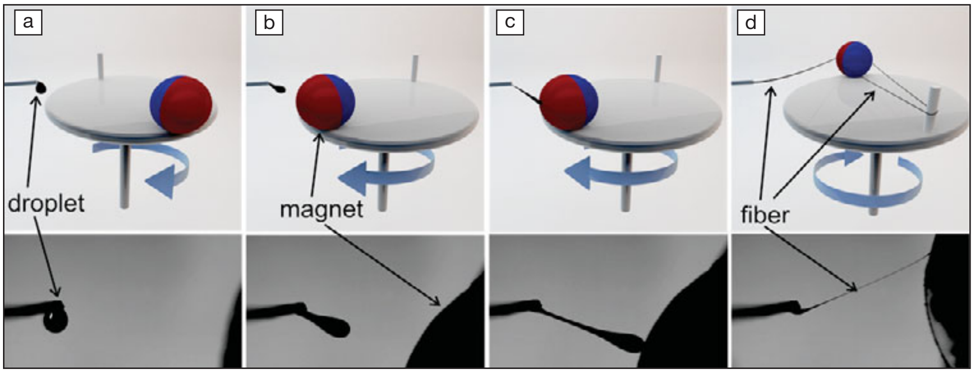
Now Sergiy Minko of the University of Georgia and colleagues from Georgia, the University of Oxford, and Princeton University describe the process of magnetospinning, a new technique for drawing nanofibers of virtually any polymeric material using an external magnetic field. This method, as reported in the June 11 issue of *Advanced Materials* (DOI: 10.1002/adma.201500374; p. 3560), begins with the addition of small amounts of commercially available Fe_3O_4 magnetic particles into a polymer material dissolved in solution. This essentially creates a ferrofluid, which is a liquid suspension of ferromagnetic particles. In the absence of an external magnetic field, ferrofluids behave as a normal liquid; but with the application of a magnetic field, these liquids will respond as if alive.

The researchers developed a simple setup using a small permanent magnet mounted on a spinning circular stage placed near the needle end of a syringe containing the polymeric ferrofluid. An automated pump system compresses the syringe, which forms a droplet of the ferrofluid on the end of the needle. As the magnet approaches the needle, the magnetic droplet is attracted, reaching out and forming a liquid bridge between the needle and the magnet. As the stage continues to rotate, the ferrofluid is drawn from the needle and wound around the outside of a series of spokes on the outer edge of the stage. Once drawn between these spokes, the solvent evaporates leaving the final polymer fiber. The angular velocity of the stage, liquid viscosity, and magnetic nanoparticle concentration can be easily varied to customize fiber diameter (50 nm to 5 μm).

This novel method of nanofiber synthesis was demonstrated experimentally by drawing thin fibers of a number of polymer materials including polycaprolactone (PCL), polyethylene oxide, polystyrene, and poly(methyl methacrylate) (PMMA). The researchers were able to pinpoint the ideal conditions, based on the polymer concentration in solution and angular velocity of the rotating stage, for successful magnetospinning. In this regime a stable liquid bridge is formed and polymer fibers are generated. In cases in which the liquid viscosity is too low or the stage is spinning too quickly, a stable bridge does not form and fibers are not drawn.

The researchers demonstrated the potential for magnetospinning to generate nanoscale polymer fibers with explicit control over fiber diameter and functionality. Furthermore, the magnetospinning process is able to draw fibers from the melt or avoid potential polymer degradation by drawing from solution. The resulting fibers can be made to be ferromagnetic, non-magnetic, porous, or even strengthened through the addition of carbon nanotubes. Magnetospinning offers new opportunities for advanced composite materials design that is both simple and inexpensive. The next step, however, for Minko and his team is scalability. "We try to commercialize because there are more and more applications for nanofibers. It's the scaling up, the major hurdle: if we want to scale up we need to design for it."

Ian McDonald



Schematic of the magnetospinning setup. (a) The polymer ferrofluid is pushed through the end of a needle while a small permanent magnet is set on a rotating stage. (b) As the magnet approaches the ferrofluid, the magnetic force attracts the droplet. (c) A liquid bridge is formed. (d) The magnet continues to rotate, drawing the fiber while the solvent evaporates. The droplets are a few millimeters in diameter. Credit: *Advanced Materials*.

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