SPINNING OF SUBMICRON DIAMETER FIBERS

Hills, Inc. of West Melbourne, Florida has been involved in the development of fiber spinning equipment for specialty fibers for over 28 years. Much of this work has been in the area of melt spinning bicomponent fibers. Recently, the techniques used to spin bicomponent fibers have been refined and extended to allow the production of submicron or nanometer size fibers. Although not yet demonstrated in all areas, these techniques can be easily applied to filament, staple, spunbond, and melt blown processes. Some of this work is very new, and much of the information such as costs, yields, and fiber properties have yet to be confirmed.

Splittable Fibers One of the oldest methods used to make micron sized fibers is to spin a splittable segmented pie bicomponent fiber (Figure 1). These fibers are presently commercially available either in staple or filament form. The most common product is spun with 16 segments using polyester and nylon. Because of cost, the amount of nylon used is only 15 to 20% and the amount of polyester used is 80 to 85%. Filament sizes of 2dpf (~12 microns) can easily be produced. When split, this results in wedge shaped filaments of varying sizes ranging from 0.5 to 2 microns across to 6 microns in length (Figure 2). It seems feasible to spin segmented pie filaments of only 1 denier (~8 microns across) and/or to have 36 segments (Figure 3). After splitting, most of the resulting filaments will have cross dimensions less than one micron. Some customers are also using newly developed polymers such as modified polyesters that are water dissolvable or easily dyable to make these fibers.

Other possibilities with this technology is to spin a hollow segmented pie fiber (Figure 4). This product is easily split into small micron size rectangular segments using an air jet. Hills presently has a customer in Europe which is commercial with this product in filament form using polypropylene and polyester as the two polymers.

Development work has also been done to apply this technology to the slot draw spunbond process (Figure 5). In this case 16 segment pie fibers are spun at high filament speeds into a web, lightly bonded and then hydroentangled in a secondary process to produce a fabric composed of micron size filaments.

Although the segment pie technology has not yet been applied to the melt blowing process (Figure 6), it appears to be an easy step. Since melt blown filaments are already in the range of 1 to 5 microns in diameter, only 4 segments would be needed to reach the submicron size after spinning. Commercial application has already been made with sheath/core melt blown fibers (Figure 7) which contain almost exactly the same technology as needed for a 4 segment pie melt blown filament. Since it is not a requirement with this technology to spin round fibers; square, rectangular, or even cross-shaped fibers before splitting are feasible.

Dissolvables The other method used to spin submicron filaments is called "islands-in-the-sea" (Figure 8). In this case one polymer is fed in individual streams inside of a sea of another polymer. The spun filaments have a total denier of 2 to 5 dpf (12 to 20 microns) after drawing. The sea polymer is dissolved away generally after the fibers are knit or woven into fabric to leave small submicron island filaments on the surface of the fabric. 24 and 32 islands-in-the-sea fibers have been around for a number of years and are used to make products such as ultra-suede and artificial leather. Hills has customers presently in commercial operation with 64 islands for both staple and filament yarns. The island polymer is generally polyester and the sea is usually a water-soluble polymer, such as PVA or a co-polyester. Typical polymer ratios are 20% sea and 80% islands. When the island polymer is greater than 65% of the total filament mass, the island filaments become square in shape due to the packing density.

This technology has not been applied commercially to spunbond or melt blown processes. Extension to a spunbond process seems feasible although the application is unknown. Extension to a melt blown process will need further development.

Within the past few months, new developments have allowed the islands-in-the-sea technology to be greatly extended. We started with trying to spin a hundred or so islands and quickly learned a new technique in pack design that allowed the island count to approach 1000, and the technology does not appear to be limited to even that number (Figures 9 & 10). The amazing feat is that this can be done in fibers with a total denier as small as 2dpf (12 microns). After being fully drawn and the sea polymer dissolved away, the island fiber diameters range from 100 to 800 nanometers. Interestingly, the spinning and processing of the fibers up and until the dissolving process are almost identical to standard spinning of melt extrudable polymers.

This technology was developed internally at Hills and is looking for an application. Certainly filtration is an excellent prospect. The technology is now at a point where fibers, either round or square, uniform or nonuniform, of any size down to submicron can be produced commercially at reasonable costs.

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