BARRIER FABRICS OF SPUNBOND SPECIALTY FIBERS FOR MEDICAL APPLICATIONS

The first recorded use of fibers being used in medicine was mentioned in the "Surgical Papyrus" nearly 4000 years ago. The description is of the use of stitches to repair wounds. Of course, it is quite likely that hand-woven cloth or spider webs were used even earlier to stop bleeding. In the "Susanta Sambita" of Indian literature, written approximately 2500 years ago, a variety of suture materials are mentioned including horsehair, leather strips, cotton, animal sinews, and fibrous tree bark.

Today it is unlikely that any man-made fibers exist that have not at some time been considered for use in the medical field. Hospital rooms are floored, curtained, and furnished with similar materials to those in our homes. The staff needs uniforms and patients need clothing. Thus, the largest use of fibers in the medical industry is for items which do not differ significantly in the chemical type or physical specifications for those in our domestic surroundings. For many of these applications, spunbond fabrics are preferred because of their low cost which allows one time use and thus minimizes sterilization procedures.

Non-Wovens

When I first started speaking at this seminar approximately seven years ago, I knew of very little activity directed towards development of special fibers for the areas of medical textiles where spunbond and non-woven fabrics are widely used. Since these textiles are not generally thought to come into contact with body fluids and are generally inexpensive, it did not seem likely that research in this area would make economical sense. Today that has certainly changed in the area of barrier fabrics. With the rapid increase in blood borne diseases such as Hepatitis C, the need to provide medical workers with inexpensive protective garments that provide a barrier to fluids such as water, blood, and alcohol has become critical.

To meet these needs, work is being done in many areas. In some cases special coatings and/or films are being added to fibers and fabrics. In other cases, ingredients are added directly into polymer being used to make the fibers. Melt blown, low denier fibers are being layered in the middle of spunbonds. Bicomponent fibers are also being used in the production of spunbonds and other non-wovens. In other non-wovens, splittable fibers are being used that results in fibers of 0.2 dpf after splitting in a hydroentanglement process. With bicomponent technology it is also feasible to put extremely expensive additives in a polymer sheath on a sheath/core fiber to give the desired surface properties required without the high cost that would be incurred if the additive was included throughout the fiber.

The major technologies used to manufacture non-woven fabric materials are:

Hydroentangling or needling
Carded Thermal bonding
Spunbonding

Meltblowing

All of these processes are used to make non-woven fabrics that compete in the medical marketplace.

Thermal bonded fabrics are generally made by carding staple fiber into a wide web that is then compressed and bonded with heat (Fig. 1). The basic fiber can be made from polypropylene, polyester, or other fibers including bicomponent fibers. When homopolymer fibers are used, thermal bonding can be achieved by adding a low melting material into the web which promotes the bonds or by selective melting of small areas of the sheet which can be seen on the resulting pattern in the material. When bicomponent fibers are used, only the lower melting polymer is used to make the bonds. The most common bicomponent fibers used today for this application are 50/50 sheath/core PP/PET fibers.

Hydroentangled and needled non-woven fabrics are also produced from a carded web of fibers (Fig. 2). However, in these processes the bonding or consolidation of the fiber web into a sheet is accomplished by entangling the fibers by needle punching or water jets (hydroentangling). In the case of hydroentangling, water jets are used for the needling process. A scrim or backing can also be used. The backing may be another non-woven product, a paper product, or even a woven fabric. In the product made in this fashion, the backing material is what generally determines the barrier properties.

Spunbond processes (Fig. 3) are direct from polymer to sheet process with high mass production per production unit that results in very low commercial costs. They are often combined with melt blowing (Fig. 4) to give improved barrier and cover properties with very low fabric weights. Coatings, fibers, and other additives can be applied in secondary processes. The fiber produced in spinning can be either homopolymer or bicomponent. Fiber diameters are often as low as 20 microns for the spunbond process and as low as 2 microns for the meltblown process.

Techniques to Improve Barrier Properties

The "Holy Grail" of barrier fabrics for medical applications would be a low cost non-woven material that is breathable, sterilizable, flexible, and extremely resistant to blood and viral penetration. The following is a discussion of techniques being considered to produce such a fabric.

- Increased basis weight
- Coatings and films
- Lower denier fibers
- Meltblown layers
- Bicomponent fibers
- Sheath/core
- Additives
- Splittable

The easiest way to increase the barrier properties of a non-woven fabric is to increase the basis weight. In reality this may have little effect on the barrier properties but will definitely have a major effect on the cost and comfort of the fabric or garment. A better approach is to use a more hydrophobic fiber to make the fabric. Another approach is to increase the bonding; however, this will reduce the flexibility of the fabric and can give the garment a stiff, "boardy" feel. For example, Tyvek has excellent barrier properties but is extremely inflexible even in thin sheets.

A similar approach is to add coatings or even bond a film to the non-woven fabric. A continuous film or coating will obviously give excellent barrier properties, but like a heavily bonded fabric, will be stiff and boardy. Generally, a coated fabric will not breathe since normal films are not breathable, but breathable films are being developed. A better approach is to use a coating that is hydrophobic to change the surface tension of the fabric to resist the penetration of water and also fill the pores of the fabric to decrease the size of the openings available for penetration.
Another approach is to lower the denier or size of the fibers used to make the non-woven fabric. This decreases the size of the openings in the fabric assuming the same basis weight and also increases the surface area of the fibers. If the fiber or the coating on them is hydrophobic, this can result in a great improvement in the barrier properties. Although there is some increase in cost with the use of smaller diameter fibers, the major obstacle to going to lower denier fibers in thermal bonded non-wovens has generally been their unavailability due

to fiber spinning complications and increased difficulties in carding or web forming of low denier fibers.
Kimberly-Clark had good commercial success with the development of SMS fabrics (Fig. 5). These fabrics have a layer of meltblown fibers sandwiched between two layers of spunbond fabric. The meltblown fibers have a fiber diameter of approximately 2 microns and provide an excellent barrier layer while still leaving the fabric breathable. The major disadvantage to the approach is the cost of the equipment required to produce the fabric and due to the low throughput limitation of the meltblown process.
When this technology is combined with bicomponent spinning, even more enhanced properties can be obtained. For example, a 30/70 sheath/core PE/PP fiber (Fig. 7) can be spun with low denier to give improved softness as well as good barrier properties and cover in very low basis weight fabrics. Because of the low amount of polymers in the sheath, additives such as polytetrafluoride products can be used to improve water penetration properties without a major increase in cost. Also because the PE has a low melting temperature, the process can be run at high processing speeds even with a high mass rate of product per unit length. Bicomponent structures of radiation stable polymers (such as PET & PE in the sheath of a core/sheath structure) are being developed into medical fabrics.

In another bicomponent approach, a splittable fiber such as a segmented pie **(Fig. 8)** can be provided as a staple fiber, carded, and then hydroentangled. The fibers split apart during the hydroentangling process give a soft, highly pliable fabric with excellent barrier properties. In the near future it is expected that this process will also be combined with spunbond fabrics to improve the cost even further for throwaway, light weight fabrics with excellent barrier properties.

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