Pressure Sensitive Adhesives with Porosity

Eugene G. Joseph, Research Professor, Institute for Critical Technology and Applied Science (ICTAS) and Department of Chemical Engineering, Virginia Tech, Blacksburg, VA.24060

Introduction

Pressure sensitive adhesives (PSAs) are materials that are used routinely for the purpose of attaching different substrates together. They are mostly based on polymeric materials; some of the common polymers used in PSAs include styrene –diene block copolymers, acrylic copolymers, polyolefins, silicones and natural rubber. While some of the polymers are inherently tacky, other polymers are formulated with tackifiers and other additives to produce the final PSA that meet the Dahlquist criterion (1).

In general, the key property requirements for PSAs are tack, peel strength and shear resistance. Tack is defined as the ability of an adhesive to form a bond of measurable strength to another material under conditions of low contact pressure and short contact time (2). The peel test is used to evaluate the strength of adhesive bonds and the material requirements are similar to that of tack measurements. Shear resistance is related to the ability of the adhesive to resist flow under static, long-lasting stresses.

In the case of PSAs that are used in adhesion to skin applications, an additional feature is desired, namely moisture vapor transmission. PSA tapes that have high moisture vapor transmission rates adhere better to skin surfaces than occlusive tapes and also show a reduction in skin lesions caused by moisture accumulation (3). The presence of porosity in the tapes allows for penetration of air to the wound surface and promotes eschar formation (4). It is also desirable for the tapes to remain on the wound during the entire healing process so that eschar is not removed due to tape removal caused by moisture accumulation. Moisture vapor transmission can be achieved by one of the following methods

(a) Develop PSAs that have a hydrophilic component built into the base polymer
(b) Incorporate a hydrophilic component as an additive into the PSA formulation or
(c) Create pores within the adhesive so that moisture transport becomes feasible

An example of a PSA with good moisture vapor transmission characteristics is described in European Patent 501124 and uses a copolymer of 2-ethyl hexyl acrylate, methyl acrylate, glycidyl methacrylate and hydroxylethyl acrylate (5). This PSA had a moisture vapor transmission value of ~ 1200 grams / square meter / 24 hours. Other approaches used to impart hydrophilic character and subsequent moisture vapor transmission include,

(a) The use of alginates blended with polyisobutylene (6) or
(b) Gel adhesives based on acrylate polymers (7)

One of the earlier methods of creating porosity in PSAs was to blow air through a porous woven backing, which in turn allowed for good moisture vapor transmission (8). Another approach used lamination of a porous backing fabric to a partially dry solvent coated adhesive layer to create an overall microporous structure (4).The purpose of the partially-dry adhesive layer was to prevent wicking through the porous backing but at the same time have sufficient solvent to produce the microporous structure during lamination. The use of two adhesive layers, a thin layer and a thicker layer, was an alterntive to the lamination approach that also produced a microporous overall structure (9). This allowed for using a thin layer of a “soft” (i.e. low modulus) adhesive for good initial contact and a thicker “firm” (higher modulus) adhesive to prevent oozing and subsequent loss of porosity. Porosity in adhesives has also been achieved by hot embossing which generates “holes” in the coated adhesive layer and provides moisture vapor transport.

Pressure sensitive adhesive tapes with good adhesion and high moisture vapor transmission rates have been described where porosity of the adhesive was obtained by a pattern coating method (10). The moisture vapor transmission rates were in the 2000 – 7000 g/m²/24 hour range for “adhesive free” areas of 5% to 25%. Within the past year, hydrophilic porous PSAs have been described where the adhesive layer contains uniformly distributed pores (11, 12). The pores are open cells, are in the 300 to 500 micron size range (see Figure 1) and have porosity in the 30 - 50 % range for film thicknesses of 2 - 8 mils.

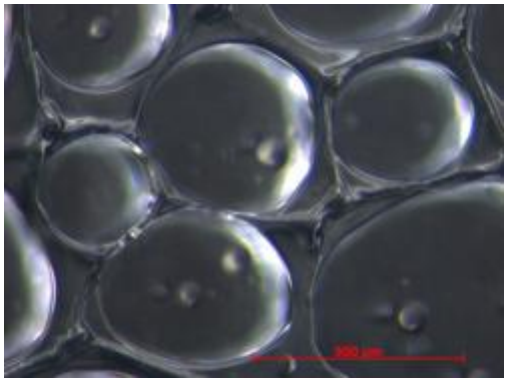

Figure 1. Porous pressure sensitive adhesive with open cells that are in the 200 to 500 micrometer size range

The work described in this paper deals with pressure sensitive adhesives in fibrous form. Recently, work has been done on the p[rocess of melt-blowing pressure sensitive adhesives in single layer and multi-layer forms. One of the attractive features of melt-blown PSAs is that it provides an adhesive that is porous and that can be produced using a “solvent – free” process. Melt-blowing of PSAs in combination with co-extrusion allows for a wide range of materials with novel properties, as will be presented in this paper.

Materials and Experimental

Pressure sensitive adhesives were melt-blown in single-layer or multilayer constructions. The number of layers within the multilayer microfiber PSAs ranged from 2 to 5 (see figure 2). In addition to varying the number of layers, for the same polymer pair the layer sequence was also varied. Some of the non-PSA materials used to produce the multi-layer webs include poly-ethylene(PE), poly-propylene(PP), poly-ethylene terephthalate(PET), poly-urethane (PU), poly-vinylalcohol(PVA) and poly-4-methyl-1-pentene(PMP). The PSA’s were based on inherently tacky acrylate polymers or tackified styrene – isoprene block copolymers (e.g. tackified Kraton 1112). The thermomechanical properties of the webs were measured using a Rheometrics Dynamic Analyzer. Scanning electron micrographs (SEM) of the microfiber cross-sections and web surfaces were obtained using a JEOL scanning electron microscope after appropriate sample preparation. The peel adhesion properties were measured from either a glass or stainless steel surface at 12 inches/minute at 180 degrees.

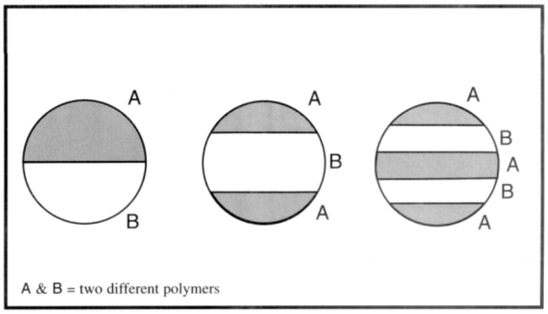

Figure 2. Schematic diagram showing the cross-sections of multi-layer microfibers. The layers are made up of alternating layers from two different polymers. Component "A" can be either the outside layers (for > 3 layers) or inside layers. One or both of the polymers could be PSAs

RESULTS AND DISCUSSION

Scanning electron micrographs representing the top surface and cross-section of a melt blown PSA are shown in figures 3 and 4. It is evident that the fibrous and porous structure of the PSA is maintained without a noticeable amount of cold flow. This is due to reinforcement of the styrene domains, which occurs due to phase separation in styrene – isoprene block copolymers and hence in the PSA. It is also evident from the cross-section of the SEM that the melt-blown PSA has porosity in the lateral direction (in addition to the thickness direction), which will allow for flow of air even when used in a tape construction with a non-porous film backing. Peel adhesion values to glass of a tackified Kraton 1112 melt-blown fibrous PSA, when compared to the corresponding continuous coated form, is lower, and this can be attributed mainly to a decrease in the contact area between the adhesive and the smooth glass surface. Shear adhesion values of the same melt-blown PSA, when compared to a smooth stainless steel surface versus a rough fiberboard surface, show that higher values are obtained from the fiberboard surface (see Table 1). One of the reasons for a higher shear value to fiberboard is probably due to better mechanical interlocking between the two fibrous surfaces.

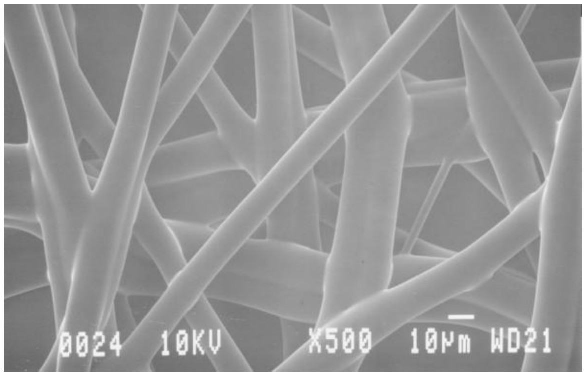

Figure 3. Scanning Electron Micrograph representing the top surface of a melt blown PSA based of a tackified styrene-isoprene block copolymer.

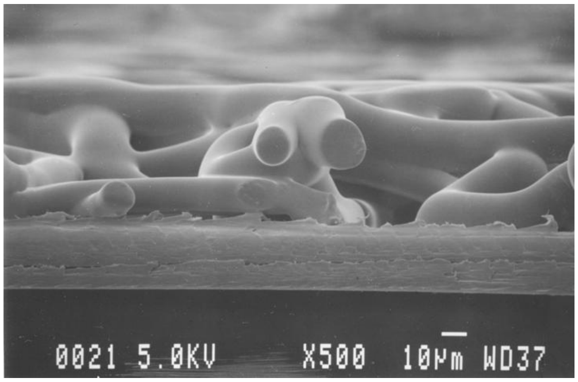

Figure 4. Scanning Electron Micrograph representing the cross-section of a melt blown PSA based of a tackified styrene-isoprene block copolymer

Table 1 – Comparison of shear adhesion of a BMF PSA to Stainless Steel (smooth) and Fiberboard (structured) surfaces. Load used was 500 grams.

Adhesive Coating Weight (GSM)	Time for failure in shear to Stainless Steel (Minutes)	Time for failure in shear to Fiberboard (Minutes)
50	126	1192

The use of PSAs in co-extruded melt-blown webs can lead to novel properties, as demonstrated below. For example, the adhesion characteristics of a melt-blown polyurethane web are improved by co-extruding the polyurethane with a Kraton 1112 PSA as the second component, with each microfiber having 2 layers. Table 2 gives peel adhesion values when No. 811 SCOTCH^{TM} Removable Magic Tape is adhered to different co-extruded backings and then peeled off at 30 inches/minute. When comparing the peel force values to that of the control that does not contain any PSA, it is clearly evident that the addition of a small amount of PSA into the co-extruded polyurethane melt-blown web greatly improves adhesion strength of the web to another adhesive surface. In other words, these results show that the PSA layers within the microfibers act as a "primer" within the web and can thereby enhance the bond strength between the web and the adhesive tape.

An example of the top surface of a multilayer melt-blown PSA web using two PSAs is shown in figure 5. The dark regions and light regions seen in the scanning electron micrograph represent two different PSAs and the porous nature of the adhesive web is also evident. Each microfiber has three layers and the styrene – isoprene-based PSA are the outside layers. The dark regions are a styrene – isoprene block copolymer-based adhesive, while the white regions are an acrylate based adhesive. The presence of both adhesives at the surface is noteworthy and implies that adhesion to a wide variety of surfaces will be possible.

Table 2 – Effect of incorporating a PSA component into the microfibers on the peel adhesion to 811 Scotch^{TM} Tape

Backing Composition	Peel Force (grams/inch)
Polyurethane (PUR)	19
PUR/PSA, 2 layers, (90/10)	47
PUR/PSA, 2 layers, (80/20)	67

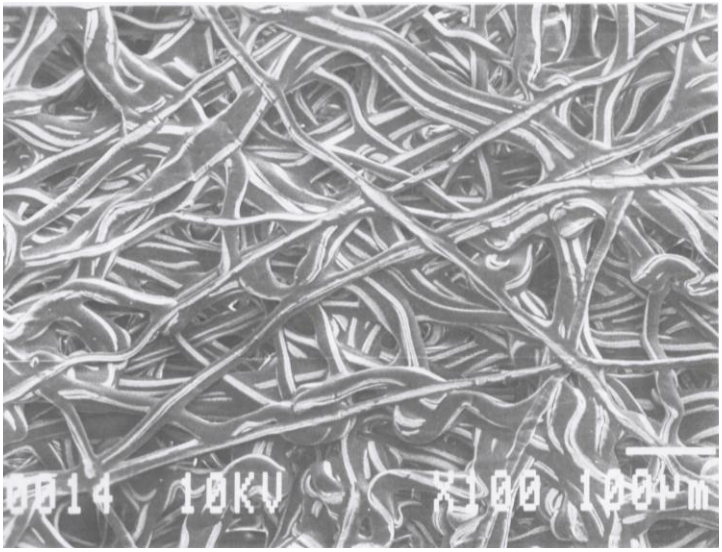

Figure 5. Scanning electron micrograph representing the top surface of a multilayer melt blown PSA web based on a tackified styrene-isoprene block copolymer PSA (dark regions) and an acrylate PSA (white regions). The number of layers within each microfiber is 3.

Summary

Pressure sensitive adhesives have been melt-blown to yield porous PSAs. In addition, melt - blown webs have been made with a layered structure within the microfibers. Using two different PSAs and co-extrusion, alternating layers ranging from 2 to 5 have been introduced within each microfiber. This approach allows us to vary and control the surface characteristics of the PSA webs and hence, obtain a wide range of PSA properties using the following variables: (i) PSA combination, (ii) PSA ratio, (iii) number of layers within the microfibers and (iv) layer arrangement for 3 or more layers. This approach is different from multi-layer films since, in this technology, both PSA components are present at the surface of each microfiber and can play a role in adhesion to substrates. The use of PSAs in melt-blown form and in combination with co-extrusion is an approach to obtain materials with a wide range of properties

Literature Citations

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Acknowledgements

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