Pore Structure Characterization of Barrier Coatings for Paper and Paperboard

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Western Michigan University has active research characterizing coatings for paper and paperboard which provide barriers for gases and liquids in addition to printable surfaces. Barrier-coated packaging is an extremely large and important area of interest to industry(1-4), government(5,6), and the consumer(1,2). It is expected to grow rapidly as industry expands its market offerings of ethnic and specialty foods, nutraceuticals and functional foods, extended shelf life products(7-9), and convenience foods and products. Consumers are demanding longer shelf life, safe(5), and added value packaged products(10). To package these products, there is a need for better barrier systems due to the conversion of many product applications from rigid container to flexible container systems.

Barrier packaging is used in multi-layer food packaging (a "juice box" is one example), microwavable popcorn bags (grease proof paper used for packaging popcorn is one example), in "quick service" wrapping paper (a fast-food hamburger wrapper is one example), and numerous other applications where a product must be protected from the ambient environment, or vice versa(1-4). Barrier packaging materials and coatings include not only the obvious materials and coatings necessary for barrier properties, but also those needed for the printing and converting.

Our research on barrier coatings has been facilitated by our extensive measurement capability for coated and printed paper. We can determine flow (fluid permeability) characteristics(11), moisture vapor transmission(12), macro and micro roughness(13,14), and pore size and surface area(15,16) associated with barrier coatings. The latter capability regarding pore properties is facilitated using Micromeritics' TriStar gas adsorption and AutoPore IV instruments.

Recently, we compared the use of impregnation(15) to apply a barrier coating containing nanosized clay particles(17) to application with a conventional size press(18). Impregnation technology is currently being used by flooring, molding compound, impregnated textiles, and decorative film manufacturers. An impregnator, in essence, is a shoe press with a pressurized coating delivery system. To impregnate the sheet, the coating is put under pressure, 10-100 psi, and then forced into the sheet as it passes through the shoe (nip). Controlled penetration depths of 20-80% are typical and have found commercial benefits to corrugated board manufacturers seeking strength and stiffness improvements while leaving one side available to bond to the medium.

The essential raw material of nano-clay is montmorillonite, which is a 2:1 layer smectite clay mineral with a platey structure. Individual platelet thicknesses are just one nanometer, but surface dimensions are generally 300 to more than 600 nm, resulting in unusually high aspect ratios. The aspect ratio is defined as the particle's length-to-thickness ratio. Most clays used in paper coatings are reported as having aspect ratios ranging from 10-25. Nano-clays have aspect ratios ranging from 150-400.

Four different coatings were prepared with a low molecular weight ethylated starch, Penford Gum 290. The nano-clay was added to determine its influence on the porosity of the paper in comparison to just starch alone. All coatings were applied at approximately 20% solids at 90° F. The viscosities of the coatings were all below 100 cP. The coatings were applied to an unsized (HST 0.4 sec), 70 g/m^2 unbleached Kraft basepaper using an impregnator coater.

The pore size of the untreated basepaper was analyzed using a Micromeritics AutoPore IV mercury porosimeter. After treatment, resulting pores were analyzed using a Micromeritics TriStar BET gas adsorption analyzer. The basepaper pore size distribution is given in Figure 1.

After coating, the pore size was reduced so much that Hg gave no useful results, so the TriStar was used with nitrogen gas to determine the pore size distributions of the coated paper. These are shown in Figure 2 for two different coat weights applied with the impregnator compared with the same coat weights applied with a conventional flooded nip size press (15,18). Note the extremely small volume of pores between 1 and 10 nm for the impregnated papers relative to the size press treated samples. The highest coat weight also shows a smaller tail on the pore size distribution of the base paper (Figure 1). This is indica-

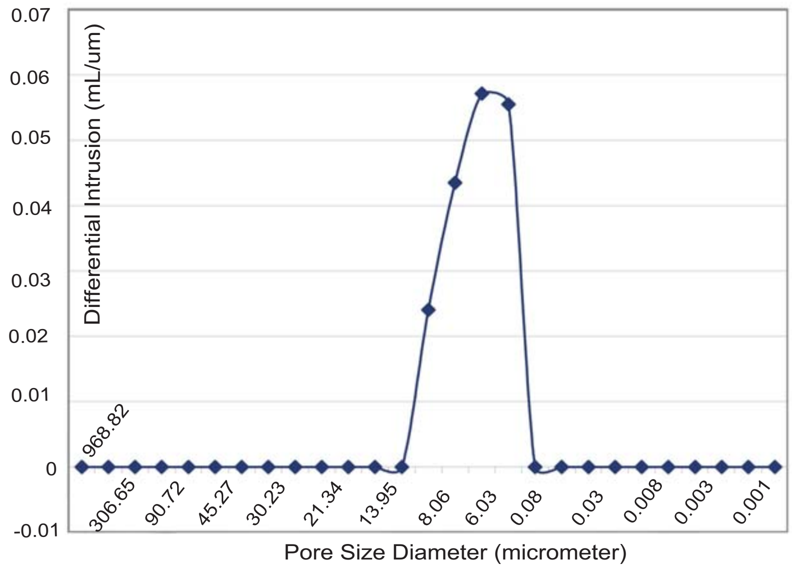

Figure 1.

Pore size distribution of base unbleached Kraft paper obtained from a Micromeritics AutoPore IV Mercury porosimeter.

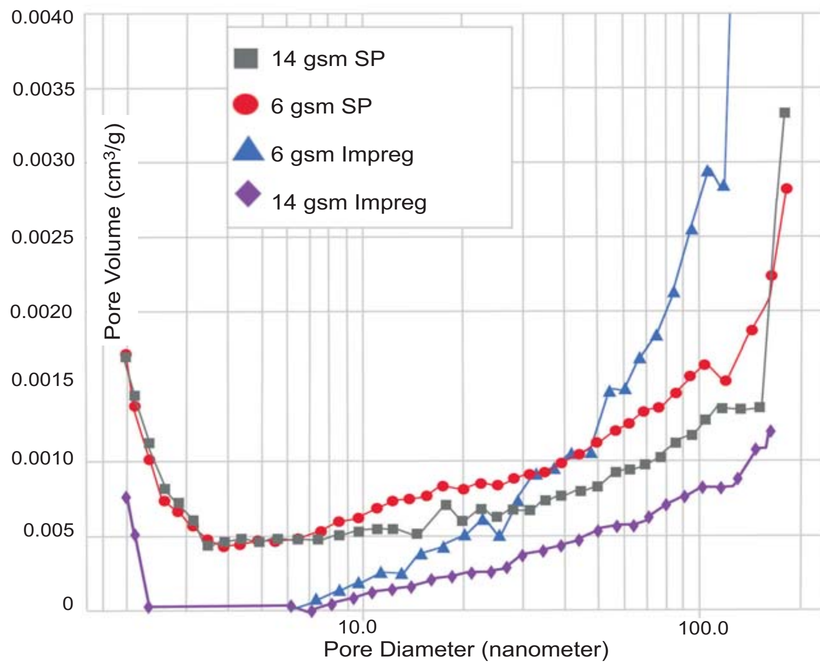

Figure 2.

Pore size distribution of impregnator-coated and size press-coated paper with two different coat weights.

tive of the very effective barrier properties of these coatings. This is corroborated in the measurement of other barrier properties[15]. Because of these sorts of characterizations of barrier coatings of paper and paperboard, Western Michigan University, in collaboration with Michigan State University, has been chosen by the National Science Foundation to establish the Barrier Packaging Materials and Coatings Center as an IUCRC (Industrial University Cooperative Research Center) site[19]. This Center will serve as a focal point for barrier packaging research in collaboration with suppliers and consumers of these materials.

AutoPore IV Mercury Porosimeter

References

1. C. P. Klass, "Emerging Barrier Coating Market Trends," Barrier Coating Symposium, Western Michigan University, Kalamazoo, MI, Oct. 8-9, 2002.
2. C. P. Klass, "Market Trends," Barrier Coating Symposium, Kalamazoo, MI, Oct. 12-13, 2004.
3. J. McCracken and V. Bell, "Worldwide Environmental Packaging Mandates," Barrier Coating Symposium, Western Michigan University Kalamazoo, MI, Oct. 8-9, 2002.
4. J. McCracken, "Worldwide Environmental Packaging Mandates," International Association of Packaging Research Institutes (IAPRI)-WORLDPAK Conference. East Lansing, MI, June 23-28, 2002.
5. USFDA, "Unavoidable Contaminants in Food For Human Consumption and Food-Packaging Material," Code of Federal Regulations, Title 21, Volume 2, Chapter 1, Part 109, 2002.
6. U.S. Congress, Office of Technology Assessment, Biopolymers: Making Materials Nature's Way-Background Paper, OTA-BP-E-102, Washington, DC: U.S. Government Printing Office, Sept. 1993.
7. R. Alves and S. Jaime, "Stability of 'Reqeijao Cremoso' in Difference Packages at Dark Storage," International Association of Packaging Research Institutes (IAPRI)-WORLDPAK Conference. East Lansing, MI, June 23-28, 2002.
8. G. Mortensen and J. Sorensen, "Reduction of Photo-oxidative Quality Changes in Cheeses by Proper Packaging," International Association of Packaging Research Institutes (IAPRI)-WORLDPAK Conference. East Lansing, MI June 23-28, 2002.
9. A. Begin and Sean Bouchard, "Control of the Effect of Ethylene on Maturation of Tomatoes Packed in Modified Atmosphere. Initiation of Oxygen, Carbon Dioxide and Ethylene and Mathematical Model Development," International Association of Packaging Research Institutes (IAPRI)-WORLDPAK Conference. East Lansing, MI, June 23-28, 2002.
10. P. Joshi, "Active Plastics Packaging," International Association of Packaging Research Institutes (IAPRI)-WORLDPAK Conference. East Lansing, MI, June 23-28, 2002.
11. Lokendra Pal, Margaret K. Joyce and P. D. Fleming, "A Simple Method for Calculation of Permeability Coefficient of Porous Media," *TAPPI J.*, August 2006.
12. Lokendra Pal, Margaret K. Joyce, Paul D. Fleming, and David E. Knox, "Shape Engineered Pigments Based Barrier Coatings for SBS Paperboard," manuscript in preparation.
13. Renmei Xu, Paul D. Fleming III, Alexandra Pekarovicova, and Valery Bliznyuk, "The Effect of Ink Jet Papers Roughness on Print Gloss and Ink Film Thickness," *J. Imaging Sci. Technol.*, 49 (6), Nov. / Dec. 2005, 660-665.
14. Renmei Xu, Alexandra Pekarovicova, Paul D. Fleming, and Valery Bliznyuk, "Physical Properties of LWC Papers and Gravure Ink Mileage," Proceedings of the 2005 TAPPI Coating & Graphic Arts Conference, April 17-20, in Toronto, ON, Canada.
15. Margaret K. Joyce, Thomas W. Joyce, Kapil Thomas, Tanuj Bajaj, and Jatetana Kunsriluksakal, "Using an Impregnation (Controlled Penetration) Sizing Method for Improving the Barrier and Strength Properties of Paper and Board," Invited Speaker, Internal and Surface Sizing PIRA Conference, Graz, Austria, 2003.
16. D Jayaraman, M. K. Joyce and T. W. Joyce, "Nano-Talc Pigment Based Barrier Coatings," *Surface Coatings International*, Sept. 2003, Vol. 86 Issue A07 p.281-284 Technical Updates.
17. *http://www.nanocor.com/nanoclays.asp.*
18. Dale R. Dill, "Control and Understanding of Size Press Pickup," *TAPPI J.*, 57(1): 97-100 (1974)
19. *http://www.wmich.edu/pci/latest/NSFIUCRC.html.*