COATING ONTO OPEN CELLED FOAM

Heng Zhang, Wieslaw J. Suszynski, Lorraine F. Francis and Michael Tsapatsis

Department of Engineering Department of Chemical Engineering and Materials Science
University of Minnesota, Minneapolis, MN 55414

Presented at the 15th International Coating Science and Technology Symposium,
September 13-15, 2010, St. Paul, MN[1]

Foams have three-dimensional structures with open or closed cells. They are made from organic or inorganic materials including metals, ceramics and carbon.[1-3] Foams are used in heat exchangers, flow diffusers, filters, fuel cells and as many lightweight structural materials for building construction, aerospace, catalysis and impact absorption. Our research focuses on open cell carbon foam as shown in Figure 1.

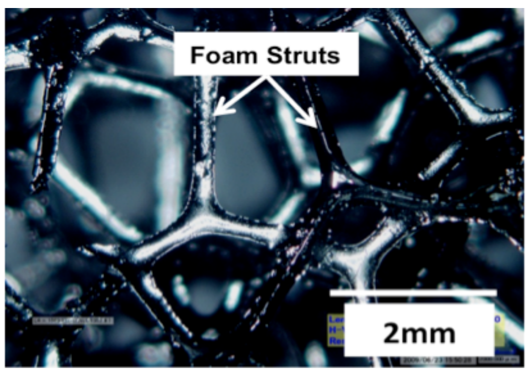

Figure 1 Optical microscope image of carbon foam with 10 pores per inch (10 PPI).

In some applications foams are coated to provide desired final product functionality.[4-6] Because of their complicated 3D structure, dip coating is a good choice for applying the coating. Compared with other coating methods, dip coating most equally applies coating to external and internal foam structures. However, there may be complications from trapped air that would prevent full coverage and from gravity-driven flow after deposition that would tend to produce a non-uniform coating. Because of these factors, prediction of final coating thickness by using the dip coating theory, which is applicable to flat substrates, is not possible.

In this research, a weight monitoring system attached to the linear stage of the dip coater was used to monitor the coating weight during the dip coating process. The sample weight is monitored throughout the coating process and subsequent draining. This information can be used to estimate average coating thickness and to compare with microscopy data that reveal actual local coating thicknesses at various places on the foam.

Figure 2 shows the relationship between final weight gain and dip coating speed for a foam with porosity of 10 PPI (10 pores per inch) coated with a model liquid – 90 wt% glycerol/10 wt% water. The weight roughly scales with speed$^{1/2}$. Interestingly, this result concurs with the expected trend for dip coating on flat surfaces. In foams, the weight gain also includes liquid trapped in the pores. With increasing speed, more liquid is trapped and there is the possibility of drainage after the foam emerges from liquid. Weight gain results in Figure 2 were not affect by this post-coating drainage.

The effect of foam porosity and coating liquid properties was also explored. Preliminary results show that foams with higher PPI and solutions with higher viscosity and surface tension tend to lead to greater final weight gains. The higher PPI foams have small pores that have a greater tendency to trap liquid.

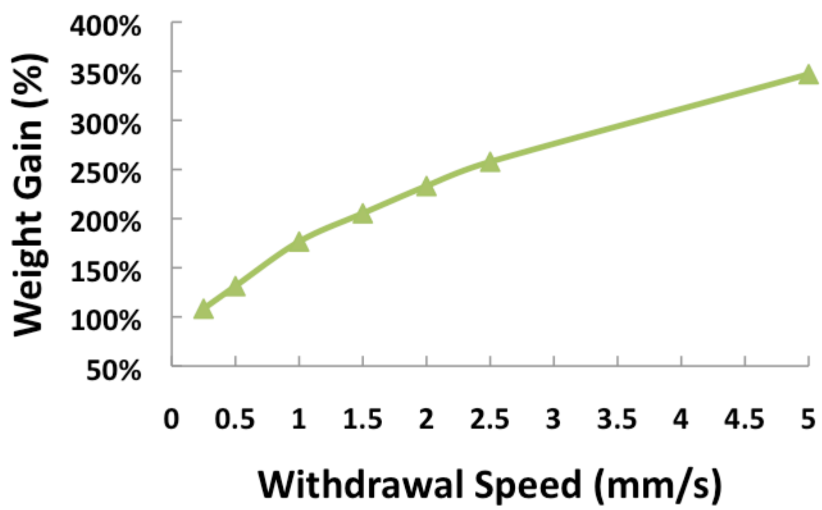

Figure 2 Effect of withdrawal speed on final weight gain for a 10PPI foam coated with a solution of 90 wt% glycerol and 10wt% water.

For most applications, only the foam struts (Fig. 1) should be coated with no liquid trapped between them. At high dip coating speed, more liquid is trapped within pores of the foam (Fig. 3a). In the case of coating solutions containing dissolved or dispersed solids, the trapped liquid can solidify and block pore passages, as shown in Fig. 3b.

To remove the trapped liquid and avoid these problems, we explored a spinning treatment after dip coating. The dip coated foam is inserted into a specially designed holder placed on the spin coater spindle. The whole assembly is then spun and the trapped liquid is removed.

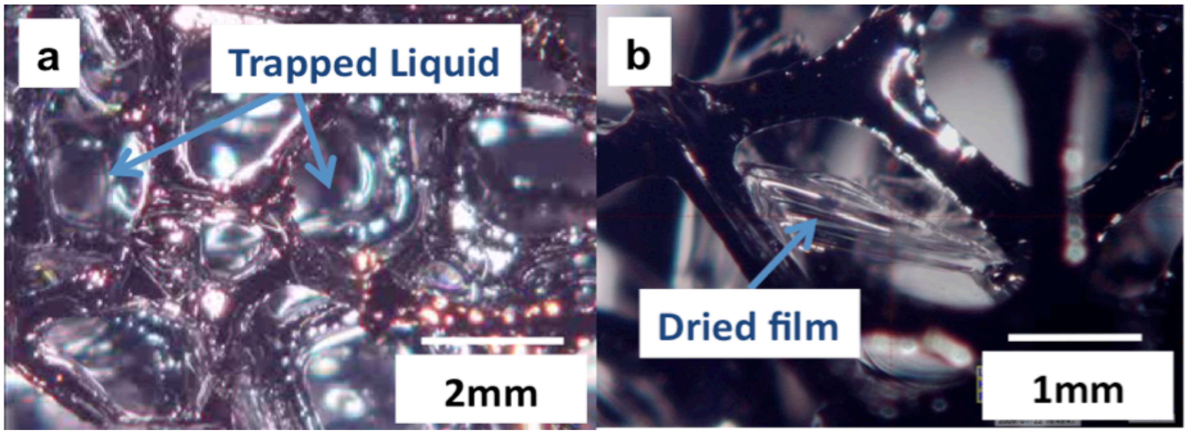

Figure 3 Optical microscope image of (a) liquid trapped within carbon foam pores (10PPI) and (b) dried coating (alumina) trapped in the pore space.

Figure 4 shows weight gain after spinning treatment. Most of the weight loss due to spinning treatment occurs in less than half a minute. And if there is any further weight loss, it is mainly due to drying and is relatively small. The weight gain is inversely proportional to spinning speed. After spinning treatment, trapped liquid is almost always removed and the coating liquid remains on the foam struts. The final weight gain depends on the coating solution and the porosity of the foam.

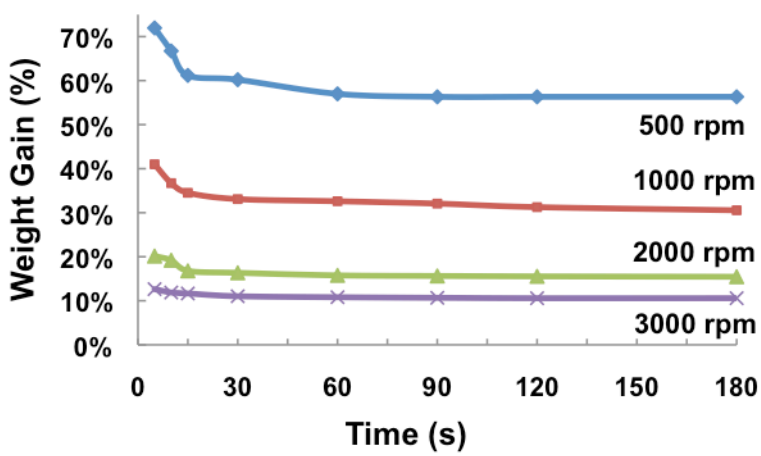

Figure 4 Effect of spinning treatment and speed on weight gain for a 10PPI foam coated with a solution of 70wt% glycerol and 30wt% water.

Figure 5 shows the weight gain after spinning treatment for two types of foams with different porosity and two coating solutions with different glycerol concentrations. The weight gain difference mainly depends on the foam type. Foams with higher PPI, and therefore smaller pores, have higher weight gain. Solution composition had a smaller effect. For the same foam, a higher concentration of glycerol, and hence a higher viscosity, leads to a higher weight gain. However, at higher spinning speed, the weight gain difference is reduced and at extreme high speed it is almost negligible.

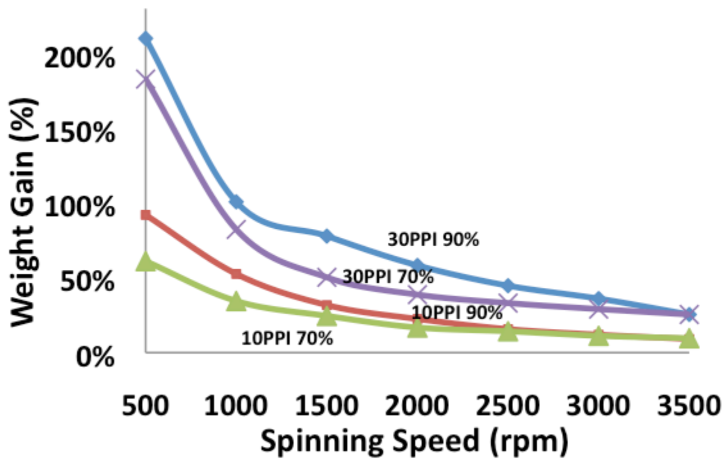

Figure 5. Effect of spinning speed on weight gain for different foams and coating solutions and the spinning time is 15 seconds.

Acknowledgements

We thank the Petroleum Institute Abu Dhabi for supporting this research through the ADMIRE grant to the University of Minnesota.

References

(1) Banhart, J. Manufacture, Characterisation and Application of Cellular Metals and Metal Foams. *Progress in Materials Science* **2001**, *46*, 559-632.

(2) Chen, C.; Kennel, E. B.; Stiller, A. H.; Stansberry, P. G.; Zondlo, J. W. Carbon Foam Derived from various Precursors. *Carbon* **2006**, *44*, 1535-43.

(3) Gallego, N. C.; Klett, J. W. In *In Carbon foams for thermal management;* Elsevier Ltd: 2003; Vol. 41, pp 1461-1466.

(4) Twigg, M. V.; Richardson, J. T. Theory and Applications of Ceramic Foam Catalysts. *Chem. Eng. Res. Design* **2002**, *80*, 183-189.

(5) Meille, V. Review on Methods to Deposit Catalysts on Structured Surfaces. *Applied Catalysis A: General* **2006**, *315*, 1-17.

(6) Huang, X. H.; Tu, J. P.; Zeng, Z. Y.; Xiang, J. Y.; Zhao, X. B. Nickel Foam-Supported Porous NiO/Ag Film Electrode for Lithium-Ion Batteries. *J. Electrochem. Soc.* **2008**, *155*, 438-41.