Flexible Polyurethane Foam with Well Characterized and Reproducible Smoldering

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INTRODUCTION

Smoldering is a self-sustaining heterogeneous oxidation reaction that induces a slow, low temperature, flameless combustion.[1] Flexible polyurethane foams (PUF) are prone to smoldering due to their high air permeability and low density. In this study we investigate the effect of PUF cell structure and morphology on smoldering. Our preliminary results show that above a threshold value of air permeability, the specific surface area of PUF might be used to assess smoldering.

EXPERIMENTAL*

All foams were produced in a batch process on a pilot plant production line with an automatic metering system. A toluene diisocyanate/polyether polyol standard formulation was used for preparing PUF with controlled morphology. The typical density of the foam was 29±1 kg/m^2. The polyether polyol was a glycerol-derived poly(propylene oxide) polyether with a poly(ethylene oxide) polyether end-cap. The processing parameters (water, tin catalyst and head pressure) were varied in order to produce foams with different cell structure (open *vs.* closed), cell size and air permeability.

The air permeability of the foams was assessed by means of an electronic high differential pressure air permeability measuring instrument (FAP 5352 F2, Frazier Instrument Co. Inc.). Permeability measurements are reproducible to within ±5%.

Smoldering was measured on mockup assembly for upholstery cover fabric smoldering ignition.[2] At least three specimens per formulation were tested.

Optical images were acquired on a confocal microscope (Zeiss LSM510) at a 5x magnification.

BET surface measurements with Argon were carried out at Micromeritics Instrument Corporation, GA. BET measurements are reproducible to within ±1%.

DISCUSSION

Air permeability and air supply in PUF control the amount of oxygen that reach the smoldering front and are considered the overriding material properties that controls smoldering.[3,4] Despite the validity of this finding, empirical evidence (Figure 1) show that air permeability is a necessary requirement, but does not fully explain the differences in smoldering propensity of foams with high permeability.

In a heterogeneous reaction the surface area is critical. In particular, in a smoldering reaction, the surface area of PUF determines the amount of char available for oxidation. Figure 2 shows the effect of specific surface area (defined as surface per unit volume) on mockup mass loss for foams with air permeability above 260 cubic feet/minute (cfm). These data suggest that at high values of air permeability, oxygen supply is not a limiting factor anymore and surface area plays a key role.

*Certain commercial equipment, instruments or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for this purpose.

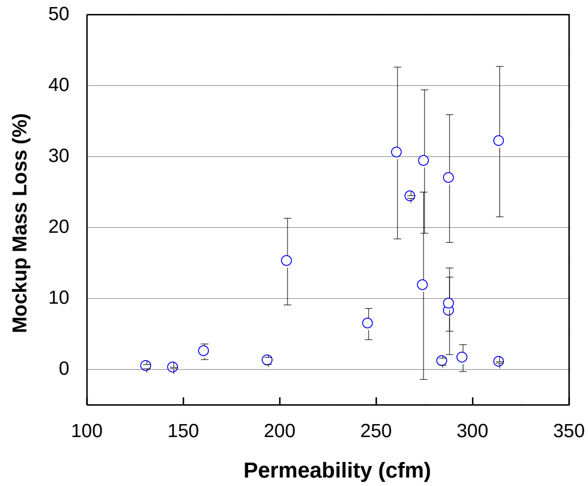

Figure 1. Mockup mass loss *vs.* permeability.

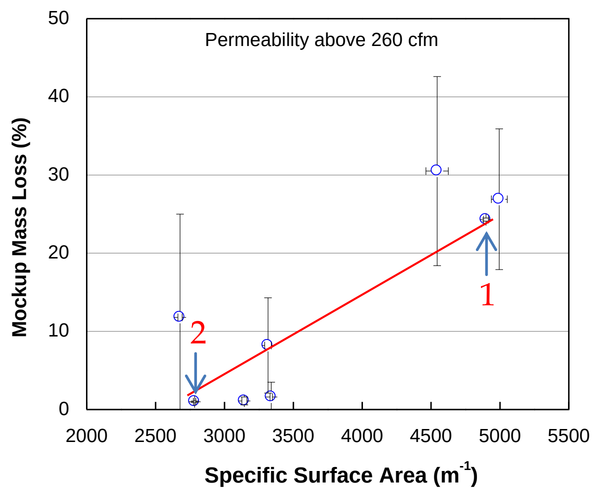

Figure 2. Mockup mass loss vs. specific surface area.

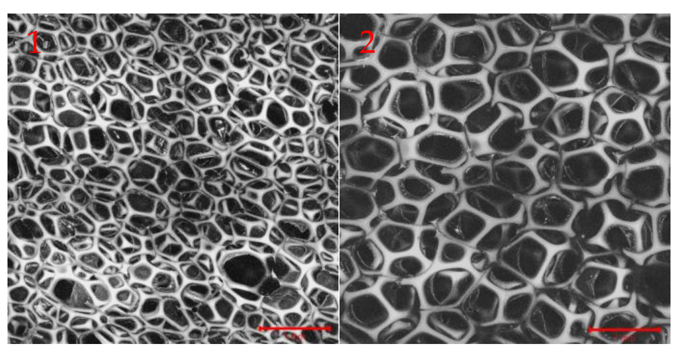

Figure 3. Confocal images for: a smoldering foam (on the left – sample 1 of Fig. 1) and a non-smoldering foam (on the right – sample 2 of Fig. 2). The two foams have an identical formulation but a lower head pressure for foam 1 induces a higher surface area. (Bar size shown is 1 mm).

Proceedings Published 2012 by the American Chemical Society

Adjusting the head pressure during foaming is a feasible approach for tuning the specific surface area, and thus reducing smoldering propensity, in a PUF without any required change in formulation (Figure 3).

CONCLUSIONS

Our preliminary data indicate that for PUF with high permeability (above 250 cfm) oxygen supply to the smoldering front is not a limiting factor and smoldering is controlled by surface area. PUF with reduced smoldering propensity can be prepared by controlling the head pressure during the foaming process: an increase in pressure induces an increase in cell size, a decrease in surface area and a decrease in smoldering propensity.

ACKNOWLEDGEMENTS

The authors thank Shivani Mehta, Linda Fansler and Jacqueline Campbell at Customer Product Safety Commission for their technical support.

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