Were do I get more information about foaming/defoaming of hydrocarbons?

Hydrocarbon surfactants can't lower the already-low surface tension of hydrocarbons very much, so hydrocarbon foams are generally transient, sometimes called evanescent. The exceptions occur when the surfactant is at high enough levels to form lyotropic liquid crystals.[1] The stability is not a reduction of surface tension but the stabilization of the thinning foam films by the presence of liquid crystal phases. The liquid crystals are dispersed as small drops which both adsorb at the air/hydrocarbon interface and retard the draining of the hydrocarbon from the thin foam films. (See also http://plc.cwru.edu/tutorial/enhanced/files/llc/Apps/apps.htm)

If liquid crystal drops are adsorbed at the air/liquid interface they will stabilize a draining film by the repulsion between liquid crystals adsorbed at the approaching surfaces. This mechanism is similar to the stability of particle-stabilized emulsions. (See Morrison and Ross, pp. 426f).

Liquid crystal drops also can "thicken" the flow of liquid in thin, draining foam films. One important mechanism has been described by Wasan (contact information below). He proposes a mechanism of the build-up of layers of inverse micelles or liquid crystals in the thin films. The films can only thin further by the removal of layer after layer of surfactant phases, a kinetically slow process.

These mechanisms have been studied systematically by Stig Friberg (contact information below). An understanding of the phase diagram for the surfactant is essential in understanding the stability of the foam. Abrupt changes in foam stability occur when phase boundaries are crossed: say by changes in concentration of surfactants, concentrations of co-surfactants, and temperatures. Friberg has also reported evidence of surface activity of the liquid crystal phases themselves.

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[1] "Lyotropic" means soluble. Lyotropic liquid crystals are large, complex, stable surfactant structures formed at high concentrations.

When the hydrocarbon portion of the surfactant is replaced with a silicone, then the surfactant is much more likely to be able to lower the nonaqueous surface tension since silicones have inherently low surface tensions. Many of these materials are commercially available. The limitations seem to follow from the limited solubility of silicones in oils. Once the surfactant becomes insoluble (generally at higher molecular weights or changes in temperature), it becomes a defoamer. This is an well-studied problem in airplane lubricants.

And, of course, when the hydrocarbon portion of the surfactant is replaced with a fluoroalkyl, the surface tension can be lowered even more. The main manufacturer of fluoro-surfactants is 3M who markets them as Novec® Fluorosurfactants.

A great place to look for information about foaming in nonaqueous liquids is a review paper by Schmidt in a book edited by Profs. Prud'homme and Khan. These men do research in this field, are knowledgeable, and approachable.

> **Schmidt, D.L. Nonaqueous foams**; in *Foams: Theory, measurements, and applications*; Prud'homme, R.K.; Khan, S.A., Eds; Marcel Dekker, Inc.: New York; **1996**; pp 287 – 310 with 10 pages devoted to nonaqueous foams in detail. The section is divided into a discussion of the three types of surfactants found in nonaqueous foams: hydrocarbon-based, silicone-based, and fluoroalkyl-based and a discussion of "solid" foams.

Other sources for help:

Surfactant Associates: "Surfactant Associates, Inc. (SA) is a small private corporation formed by University of Oklahoma faculty members with expertise in surfactant science and applications. SA performs contract research for industry and government agencies and has trained thousands of scientists and engineers worldwide with our Short Course in Applied Surfactant Science and Technology, for those in industry requiring surfactant training to expertly optimize product processes and formulation." - http://www.surfactantassociates.com

Prof. Stig Friberg, Consultant on surfactants, long time short course instructor for the ACS, currently at the University of Virginia, sf6z@Virginia.EDU

Prof. Saad Kahn, North Carolina State University, http://www.che.ncsu.edu/faculty_staff/sak.html

Prof. Bob Prud'homme, Princeton University, http://chemeng.princeton.edu/people/prudhomme.shtml

Prof. "Som" Sommasundaran, La von Duddleson Krumb Professor at Columbia Univeristy, www.columbia.edu/~ps24/

Prof. Darsh Wasan, Motorola Chair Professor of Chemical Engineering and Vice President for International Affairs, Illinois Institute of Technology, long time consultant on surfactants and foams: http://www.chbe.iit.edu/faculty/wasan.htm

Fun reading: *Sidney Perkowitz, Universal foam: From cappuccino to the cosmos*; Walker & Company: New York; **2000**.