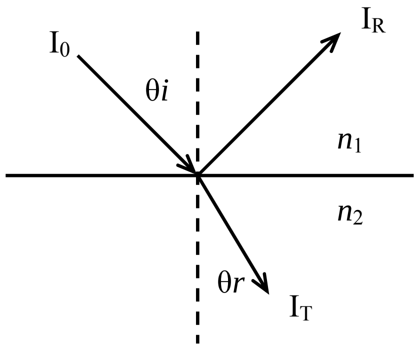
# Brewster Angle Microscopy

## 1. Principle of The Technique




$I_0$: intensity of incident light
$I_R$: reflected intensity of light
$I_T$: transmitted intensity of light

$$n_1 \sin\theta i = n_2 \sin\theta r$$

- $\mathbf{I_R}$ is function of : **incidence angle**, $\theta_i$;
  **polarization of the light**;
  **details of interface.**
- Reflectivity: $R = \frac{I_R}{I_o}$
- for p-polarized incident beam (electric field in the plane of incidence)

$$R_p = [\frac{\tan(\theta i - \theta r)}{\tan(\theta i + \theta r)}]^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

for S-polarized incident beam (electric field perpendicular to the plane of incidence):

$$R_s = [\frac{\sin(\theta i - \theta r)}{\sin(\theta i + \theta r)}]^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

■ $R_s$ and $R_p$ are functions of incident $\theta_i$ .

When the light is incident from air ($n_1$=1) to water ($n_2$=1.33)

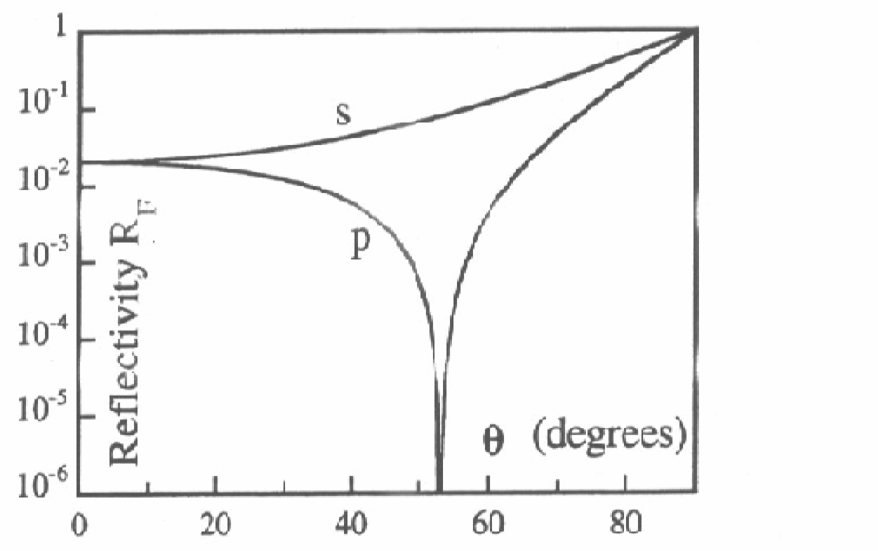



Fig. 1 The reflectivities $R_s^F$ and $R_p^F$ as a function of the incidence angle $\theta_i$ for a Fresnel interface between two media of refractive indices $n_1 = 1$ and $n_2 = 1.33$.

■ At an angle of incident $\theta_B$ (called Brewster Angle), $R_p \to 0$

from Eq.(1), $\tan(\theta_i+\theta_r) = \infty$

$\to (\theta_i+\theta_r) = \pi/2$, with assistance of ($n_1\sin\theta_i = n_2\sin\theta_r$)

$\to \tan\theta_B = \frac{n_2}{n_1}$

for air /water, $\theta_B = 53.06°$

■ For real interface, $R_p$ decrease to a minimum value at Brewster angle but does not vanish. (Due to the discrepancy between an ideal interface and a real interface)

➢ Real interface

→ the refractive index varies smoothly from $n_1$ to $n_2$, thickness $\ell$.

→ rough (not exact uniform)

→ optical anisotropic (due to preferential orientation of molecules in the interface)

- for a surfactant monolayer at water surface, $n \sim 1.4$, $\ell \sim 20$Å,
  $\rightarrow R_p(\theta_B) \approx 5 \times 10^{-5}$ (see figure below)

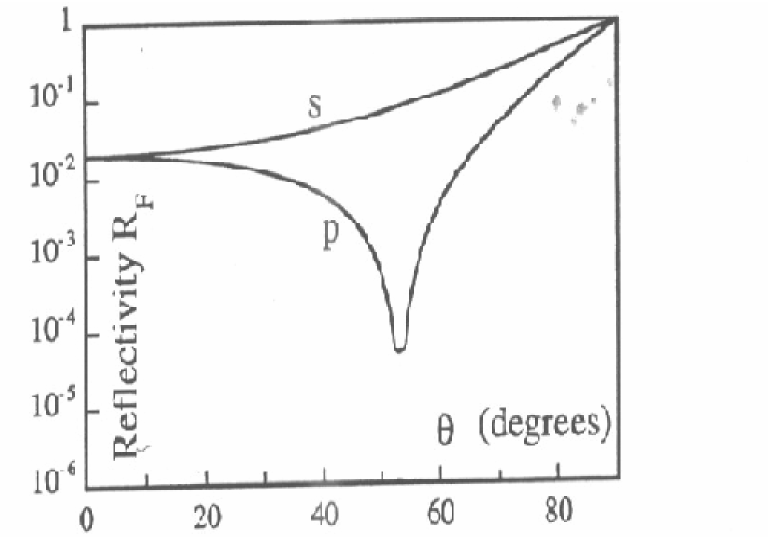
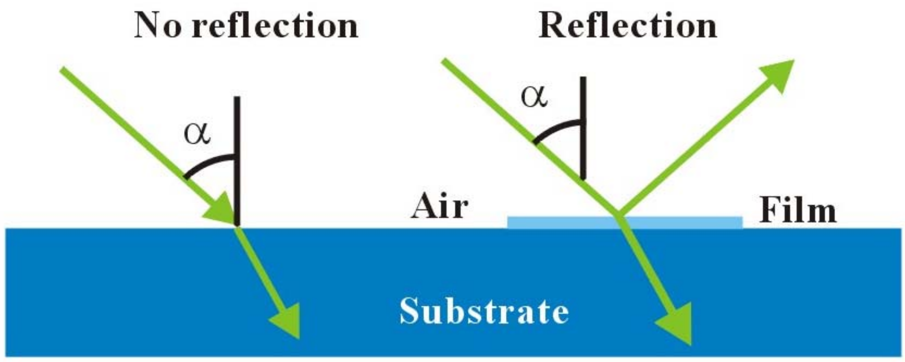


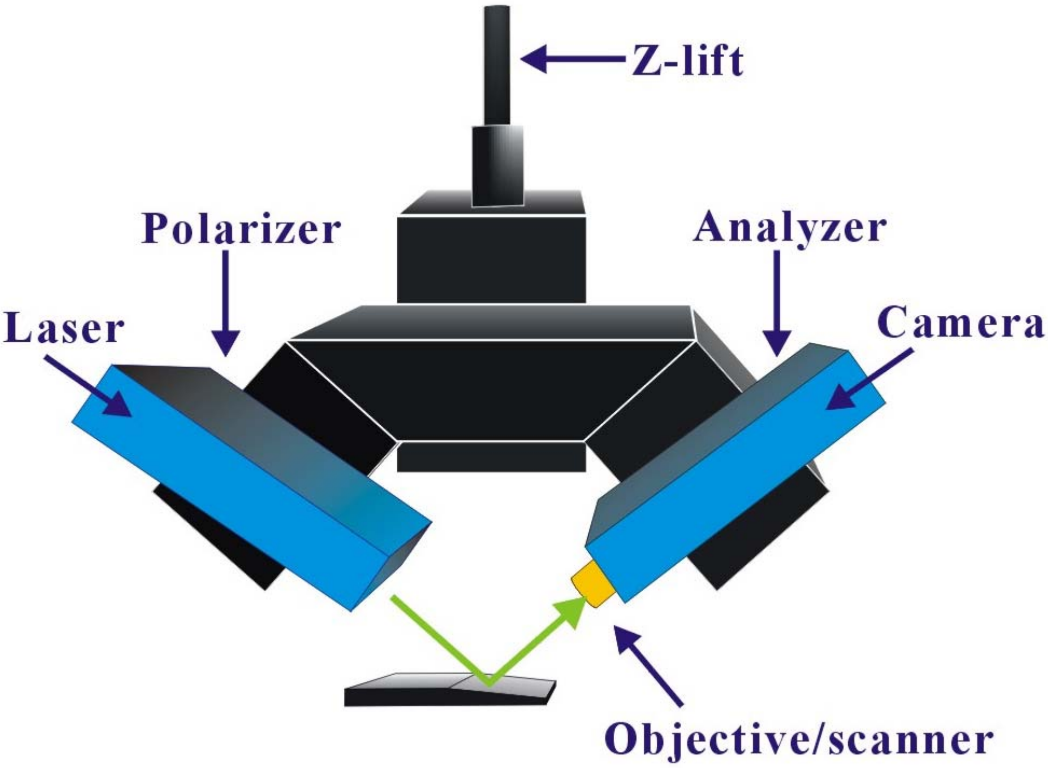

Fig. 2 The reflectivity $R_p$ as a function of the incidence angle $\theta_i$ for a flat layer of refractive index 1.5 and thickness $l = 20$ Å at an interface between two media of refractive indices $n_1 = 1$ and $n_2 = 1.33$.

$\rightarrow$ $R_p$ is very low in a narrow range of $\theta_i$ near the Brewster angle ($\theta_B$), which is different from that of an ideal interface only in the vicinity of $\theta_B$.

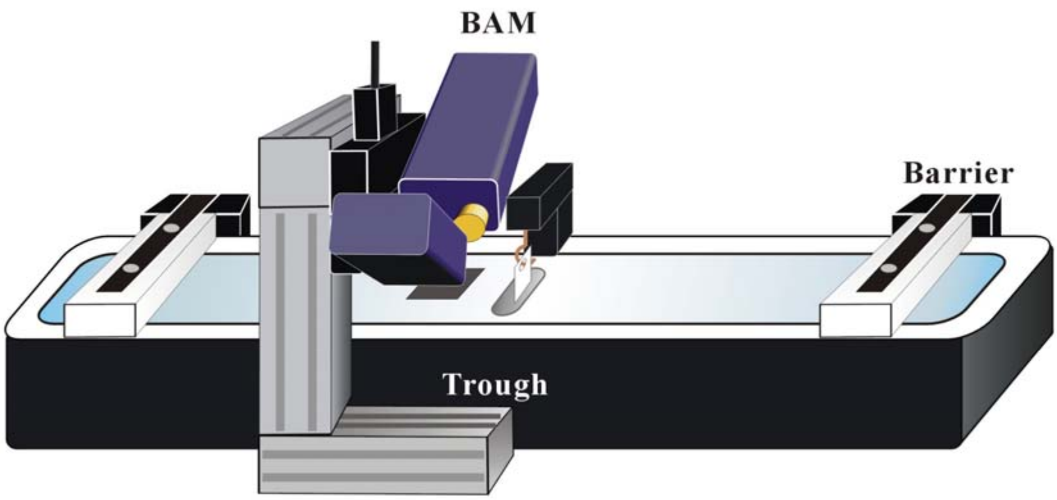
## ■ Equipments of BAM

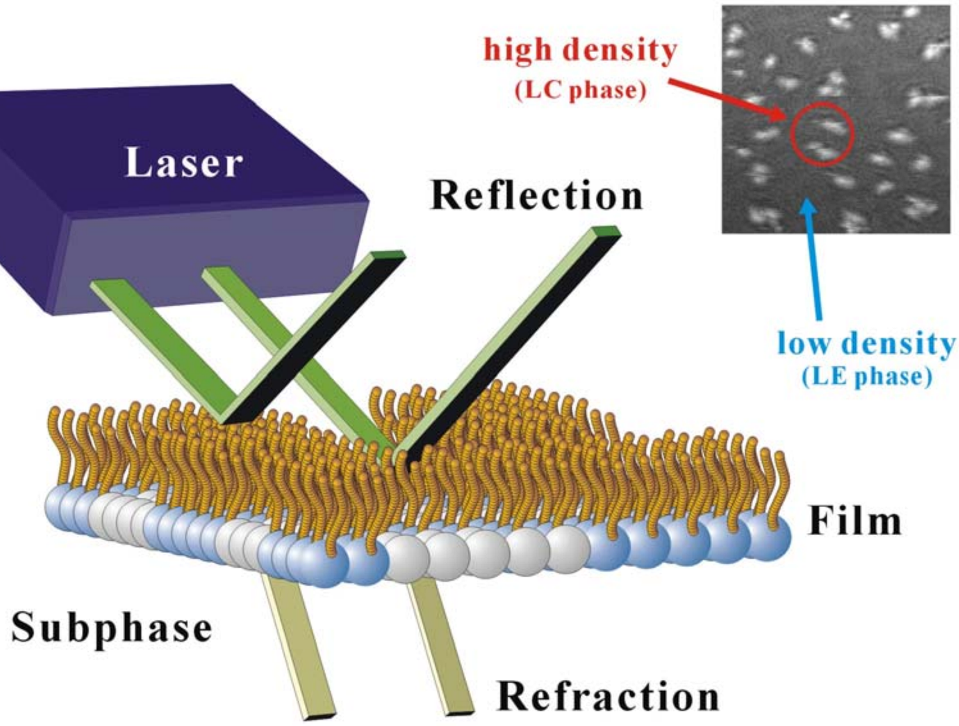


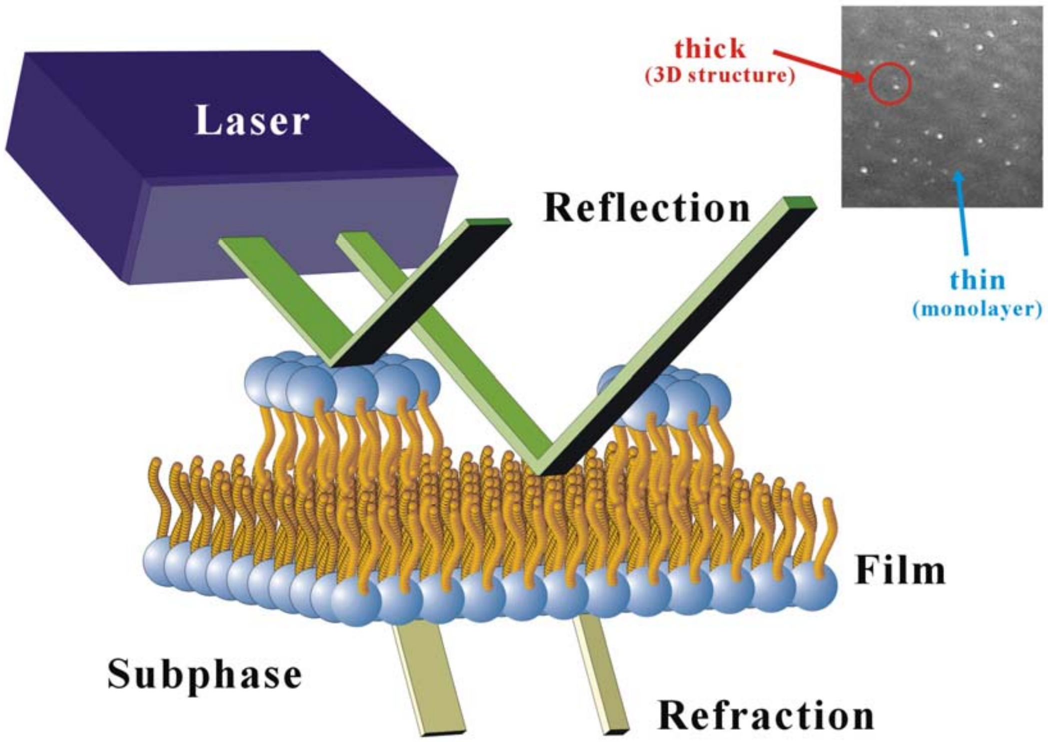

$$\tan\alpha = \frac{n_{substrate}}{n_{air}}$$



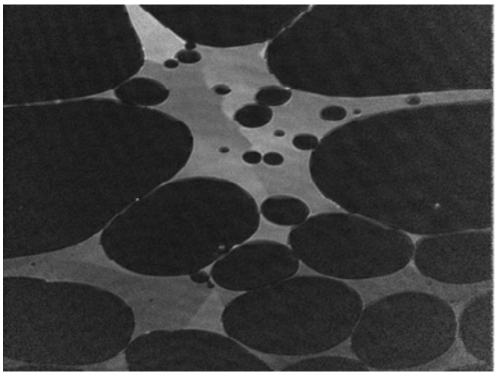

■ BAM on trough

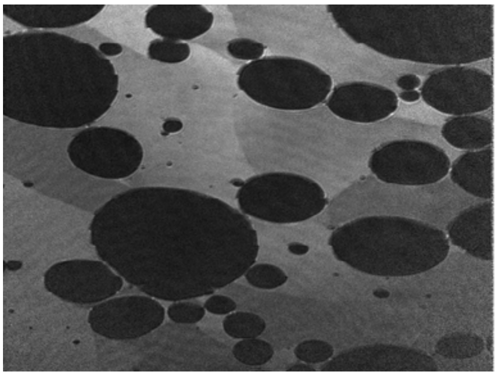


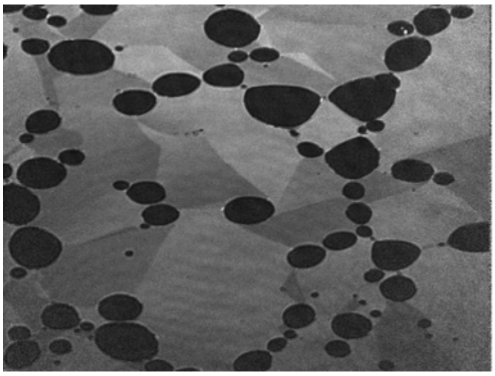

high density
(LC phase)
Laser
Reflection
low density
(LE phase)
Film
Subphase
Refraction

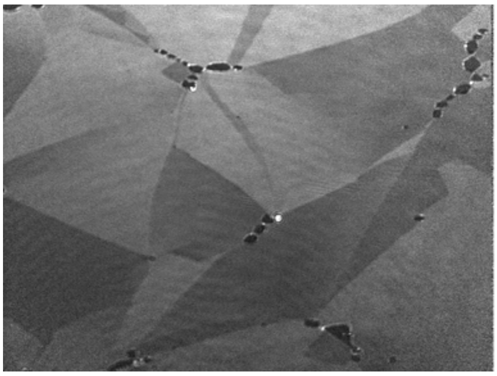

thick
(3D structure)
Laser
Reflection
thin
(monolayer)
Film
Subphase
Refraction

■ BAM images of stearic acid at gas phases (π ≈ 0)

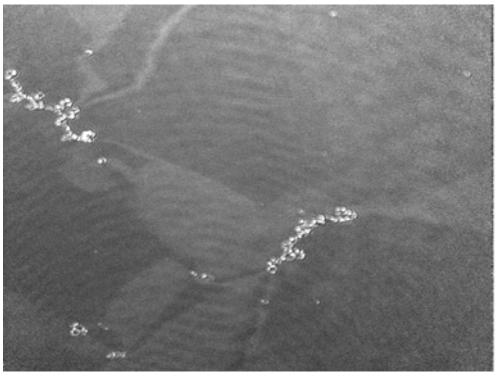




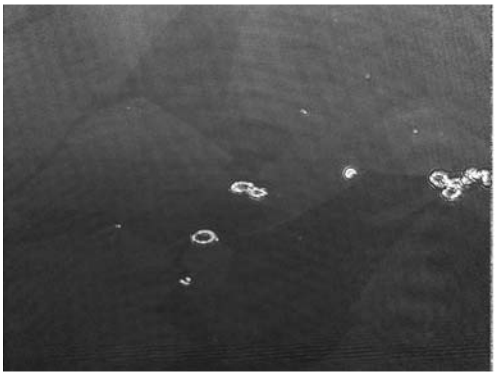




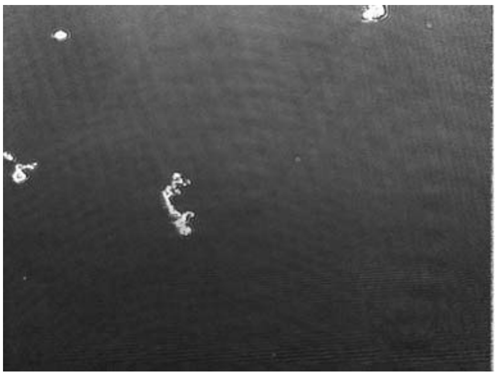
π ≈ 5 (A=24.1)



027, π ≈ 14.8 (A≈22.1)

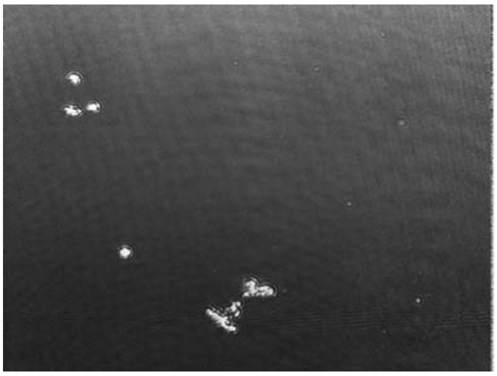


π ≈ 21.8 (A≈ 20.6)

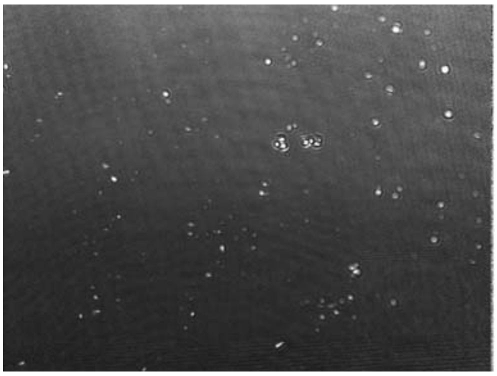


π ≈ 30 (A≈20.5)

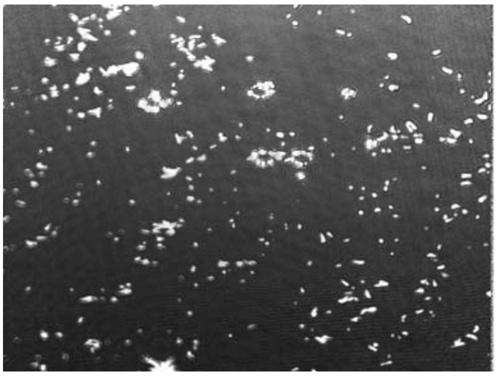
2035, A=19.5, π =40



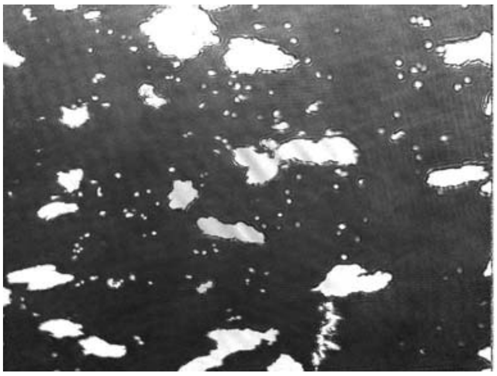
2036, π =44



2040, π =25



2054, π =19



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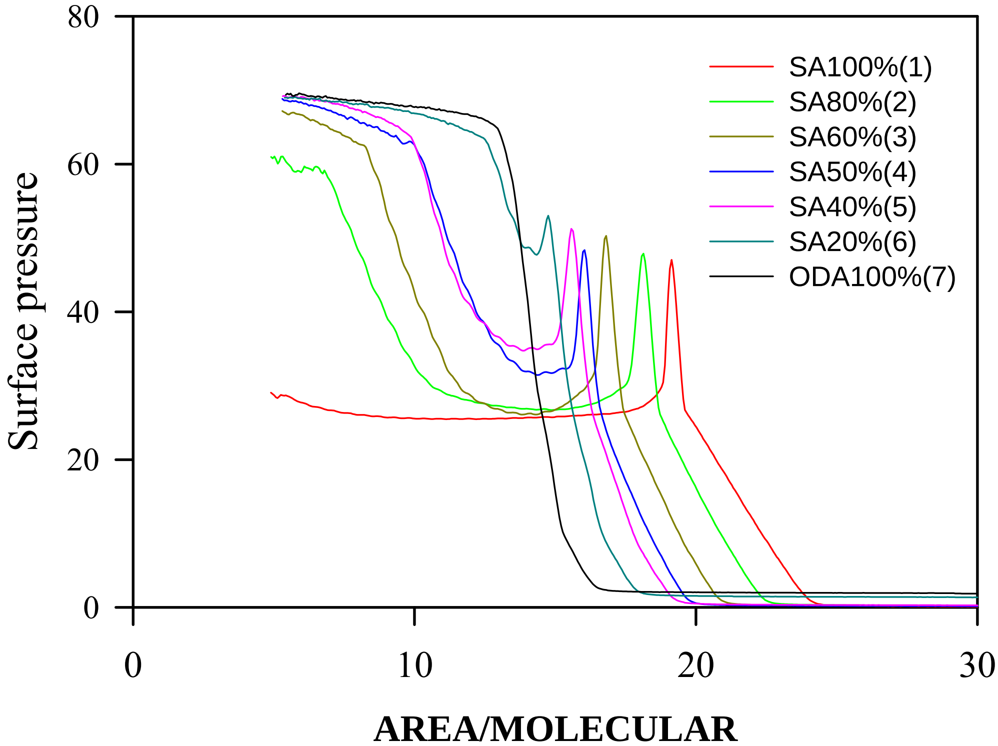
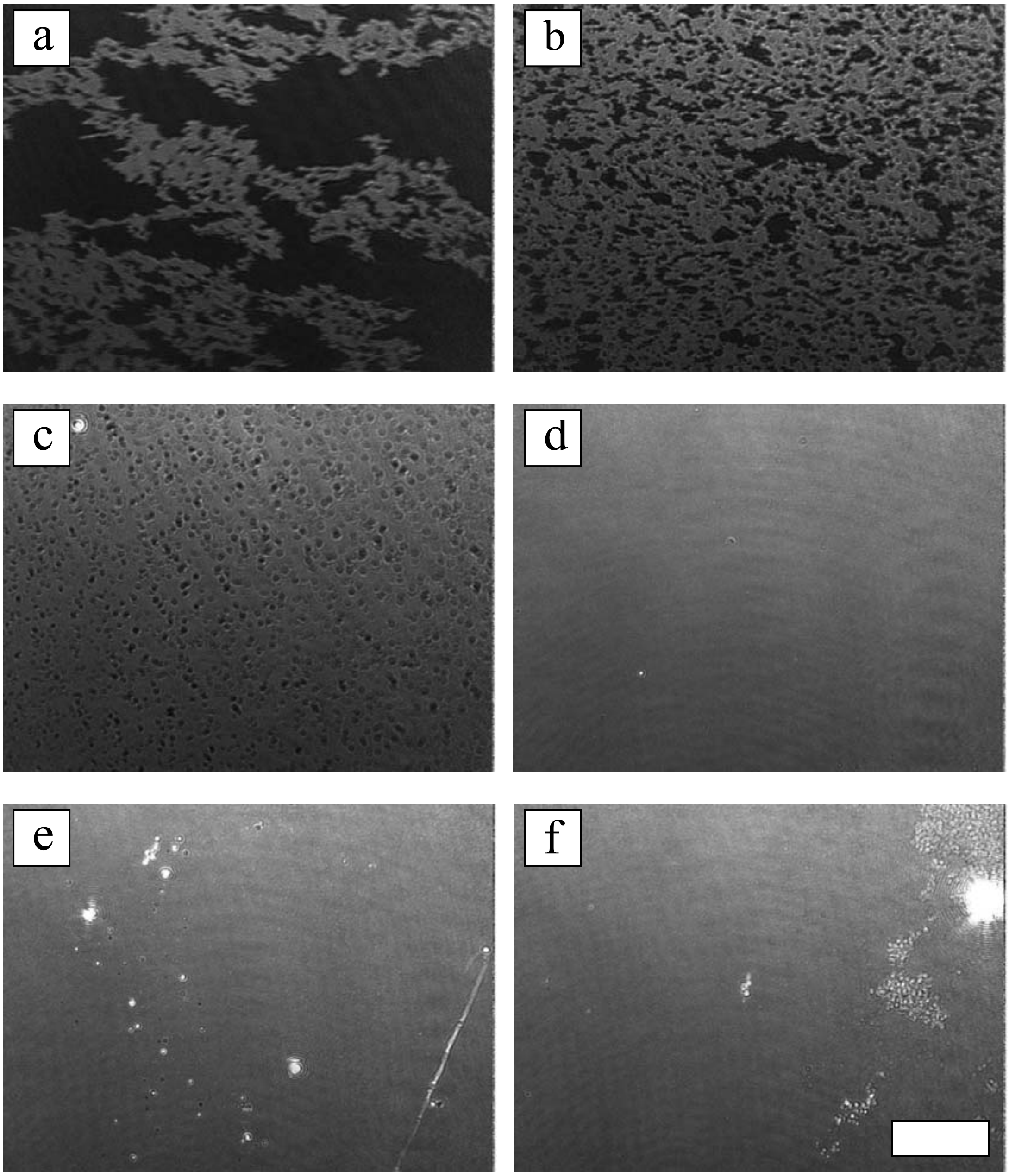
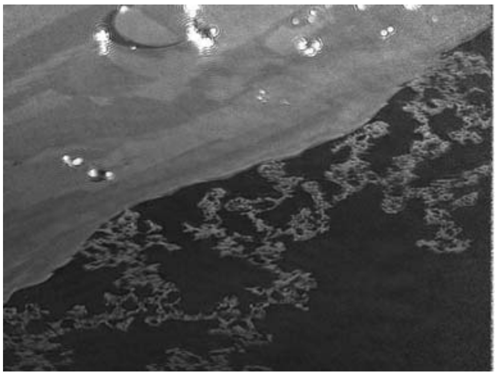


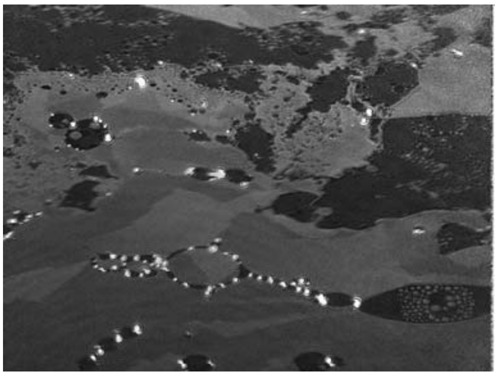
**BAM of ODA (octadecylamine, $C_{18}$-$NH_2$)**




BAM images of pure ODA monolayer on air/ water interface at 25 $^{o}$C. The images correspond to states of (a): A=24.7 Å$^2$/molecule, π=0 mN/m; (b): A=22.5 Å$^2$/molecule, π=0.3 mN/m; (c): A=20.2 Å$^2$/molecule, π=1.6 mN/m; (d): π=61.5 mN/m; (e): π=63.8 mN/m near collapse point; (f): π=65.0 mN/m after collapse point.

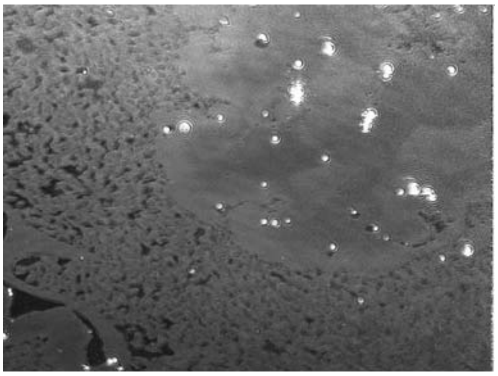
**SA 40% BAM images:** (1). 012, A=32.9, PI=0.2; (2)040, A=28.1, PI=0.3;

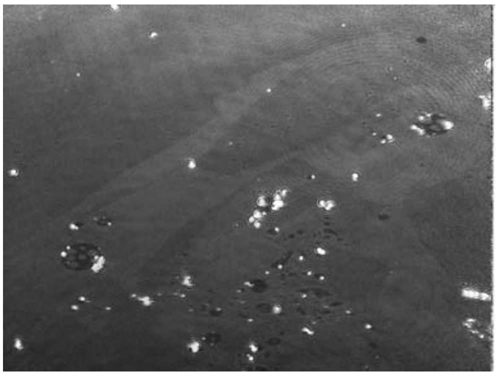




(3). 054, A=26.4, PI=3.9

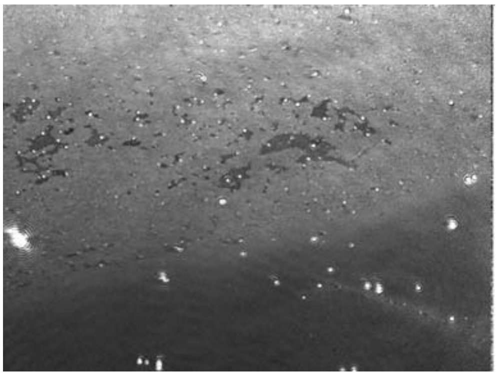
(4) 065, A=24.5, PI=14

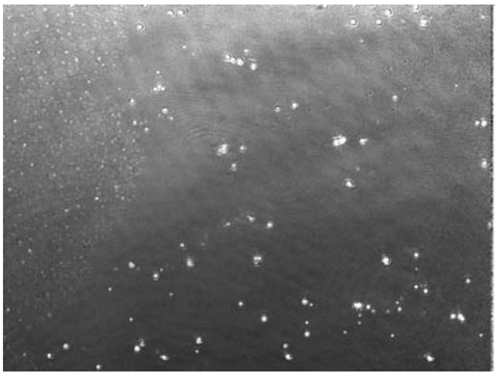




(5). 070, A= ,PI=18.8

(6).074, A= , PI=30.4



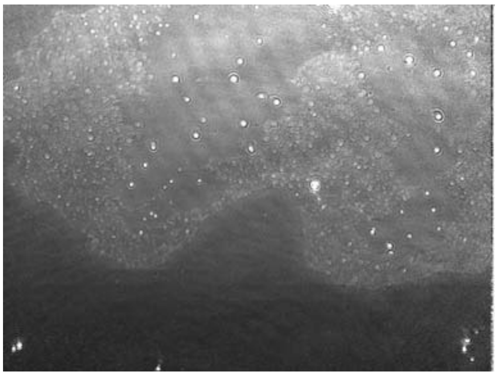


(7). 078, A= , PI=41.8

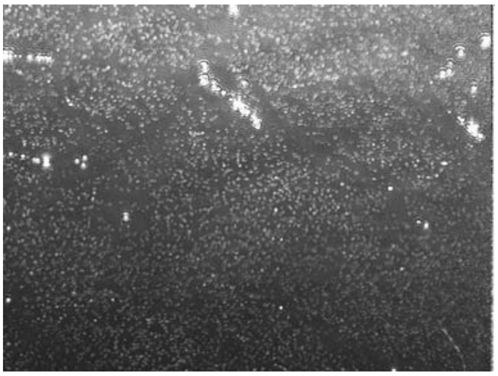
(8) 081, A= , PI= 47.2 collapse point

(9) 085, PI= 37.7, after collapse

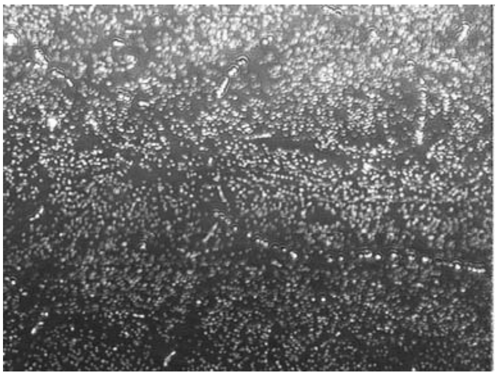
(10) 093, PI=33 (21.3), after collapse, 2 phases



(11) 097, PI=33.9 (A=20.7)



(12) 101, PI=35.5 (A=20.3)



038, A=28.3, PI=0.3