Assembly of Two-dimensional Monolayers from Micro- and Nanoscale Particle Dispersions

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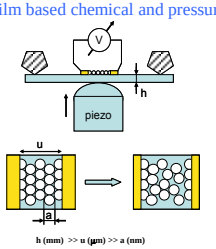
1. Motivation

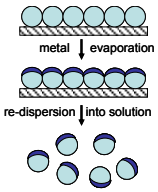
Particle monolayers are useful for:

Particle-film based chemical and pressure sensors:



Ref [1] Janes et al., Superlattices & Microstructures, **18** 275 (1995).

Catalytic membranes:



Ref [2] Love et al., Nanoletters, **2** 891 (2002).

2. Objectives

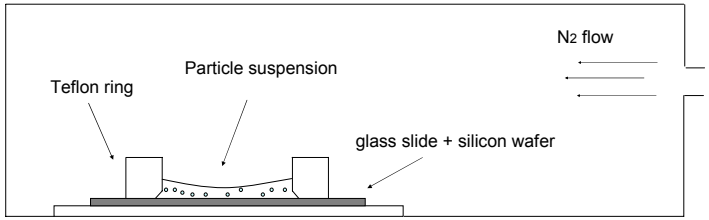
- to achieve the reproducible formation of large areas of monolayers
- to minimize the number of defects within the monolayers

3. Sample Preparation and Characterization

Materials:

- *Particle Suspension*: sulfonated polystyrene particles from IDC (2.4 ± 0.1 mm)
- *Substrate*: (100) single-crystal silicon wafer with natural oxide layer
- Teflon rings with 10 mm hole
- Microscope glass slides

Experimental Set-Up:



Experimental Procedure:

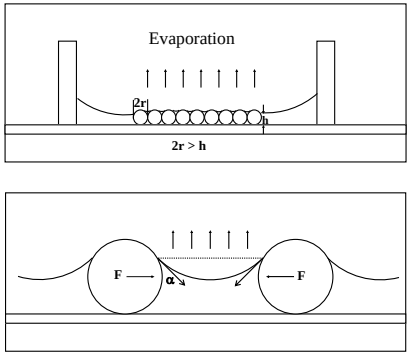
1) Crystallization cell is placed in N_2-chamber.

2) Crystallization cell is loaded with 30, 25 and 20 μl of working solution that contains different particle volume fractions (0.005-0.0008).

3) Sample is left to dry for about 90 min.

Ref.[3] N. D. Denkov et al., Langmuir **8** 3183 (1992)

4. Experimental Technique: Convective self-assembly



$$F_c = -\pi(2r\sigma\sin\theta - r^2 P_c)$$

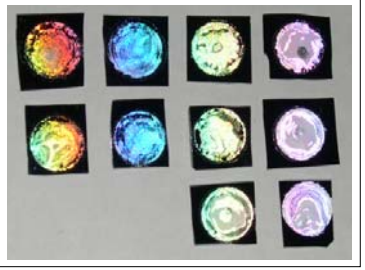
$F \propto (R^6/\sigma) K_1(qL)$ for flotation force

$F \propto \sigma R^2 K_1(qL)$ for immersion force

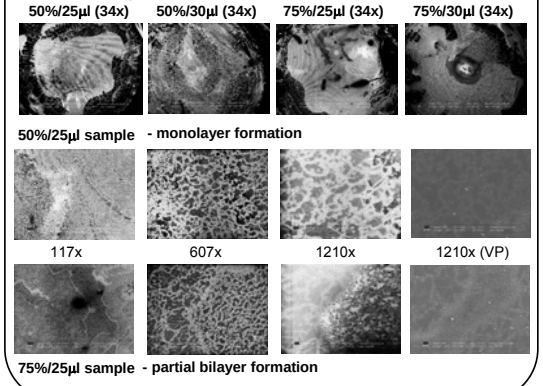
5. Experimental Results

Optical Images

A / B	25%	50%	75%	100%
30 μl				
25 μl				
20 μl				

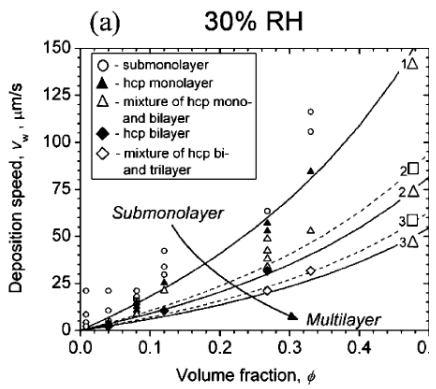


SEM Images (Zeiss EVO 40)



6. Theoretical Predictions

Crystal Growth: model and phase diagram



$$v_C = \frac{K\phi}{h(1-\epsilon)(1-\phi)}$$

Vc: growth speed of the array

Vw: deposition speed

h: thickness of arrays

ε: porosity of arrays

K: fitting parameter

Operational "phase" diagram shows that the type and quality of the layers are determined by suspension volume fraction (Φ) and deposition speed (v_w).

Ref. [4] B. G. Prevo; O. D. Velev, *Langmuir*, **20** 2105 (2004)

8. Conclusions

- The particle volume fraction and the evaporation rate are the determining factors in the convective assembly of particles.
- We are able to form large area monolayers. The monolayers show packing defects (grain boundaries) due to very small domain size.
- Best monolayer crystals are obtained with: ϕ = 0.002, t_{drying} ~ 90 min, and a cell load of 25 μl.

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