SAND2015-5841C

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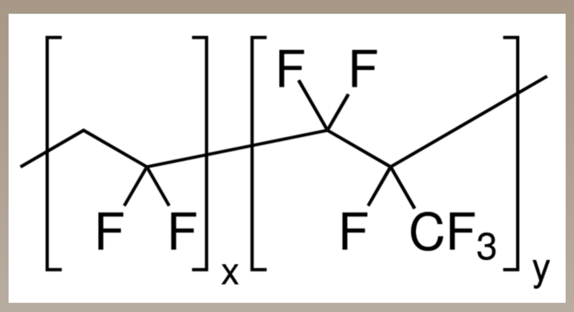
Mechanical Properties of PVDF Latex Skin Layers by Tension Induced Wrinkles



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Abstract: When a polymer film dries, a thin skin layer is formed on the top and bottom interfaces with different mechanical properties than the film's bulk. The thin thickness of this skin make it difficult to study by traditional techniques. However one of the effects resulting from the skin-bulk modulus mismatch is the formation of nanoscale wrinkles when the film is under compression. Here we aim to study the mechanical properties of polyvinylidene fluoride (PVDF) skin layers by inducing wrinkling patterns under uniaxial tension and observing the surface topography by Atomic Force Microscopy (AFM). Preliminary result show a nested, random distribution of wrinkle amplitude and spatial frequency, most likely due to the imperfections of the sprayed latex film. Further investigation of different film preparation conditions will be studied.

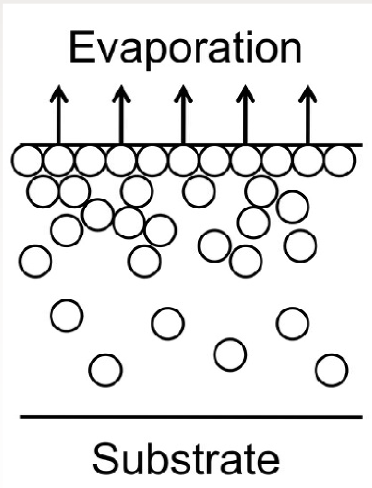
Skin layer formation

Drying process is mainly controlled by two time scales :

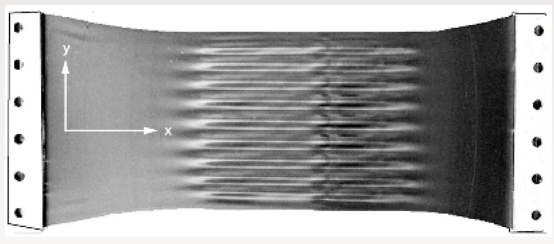
- t_{evap}: solvent evaporation time
- t_{diff}: solute diffusion time

Peclet number : $Pe = \frac{t_{diff}}{t_{evap}}$

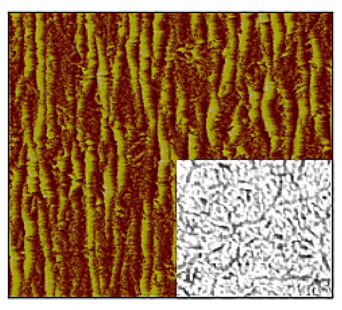
- When Pe < 1, fast solute diffusion produces dense homogeneous film.
- When Pe > 1, fast solvent evaporation causes early skin formation.



Accumulation of particle at top surface as diffusion rate is slower than evaporation rate. Skin layer is then formed.



Wrinkles formed on a stretched film macroscopically



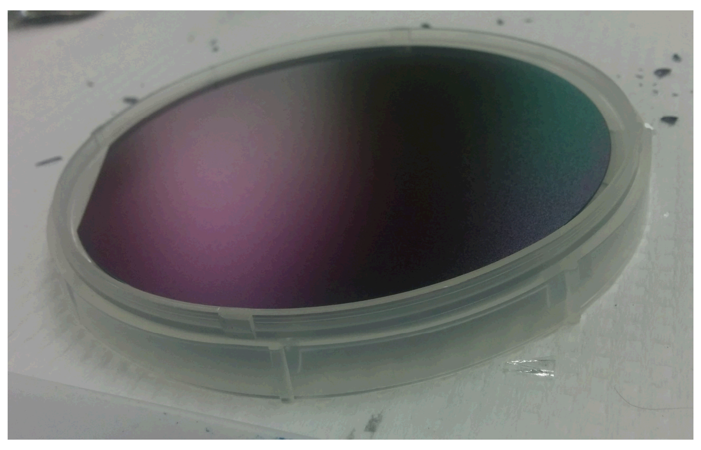
Wrinkles in microscopic scale

Wrinkling mechanism

The mechanism of wrinkling is understood as a stress-driven instability. When an elastic material of thickness t, modulus E, and Poisson's ratio ν is deformed with applied strain, the surface remains flat until the critical strain for buckling is reached. Material is then contracted in the transverse direction due to Poisson ration.

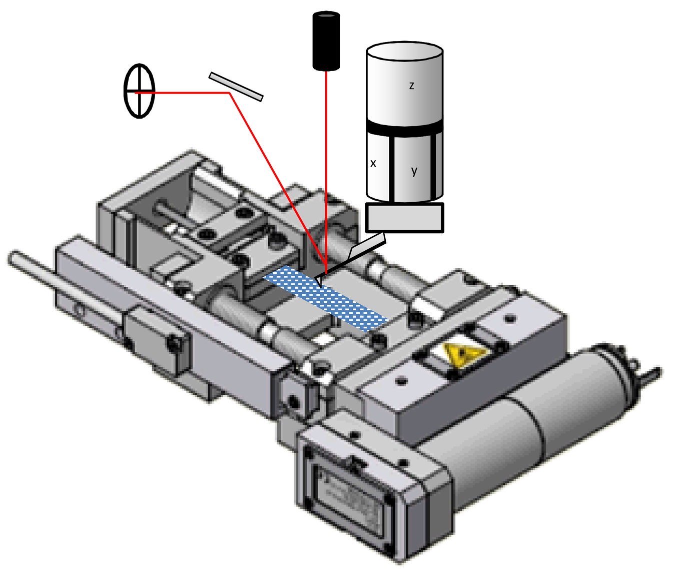
Approach: in situ observation of film deformation under tension

- Topography: Atomic Force Microscopy (AFM)
- Mechanical properties: MTII/FULLAM Semtester micro-tensile load frame with a 10lb load cell



PVDF sample on substrate

Sample preparation:
- Spray latex paint with PVDF on silicon oxide plate
- Dry plate overnight, bake in oven at 65^{o} for at least 1 hour
- Extract a small piece of film for tensile tests.



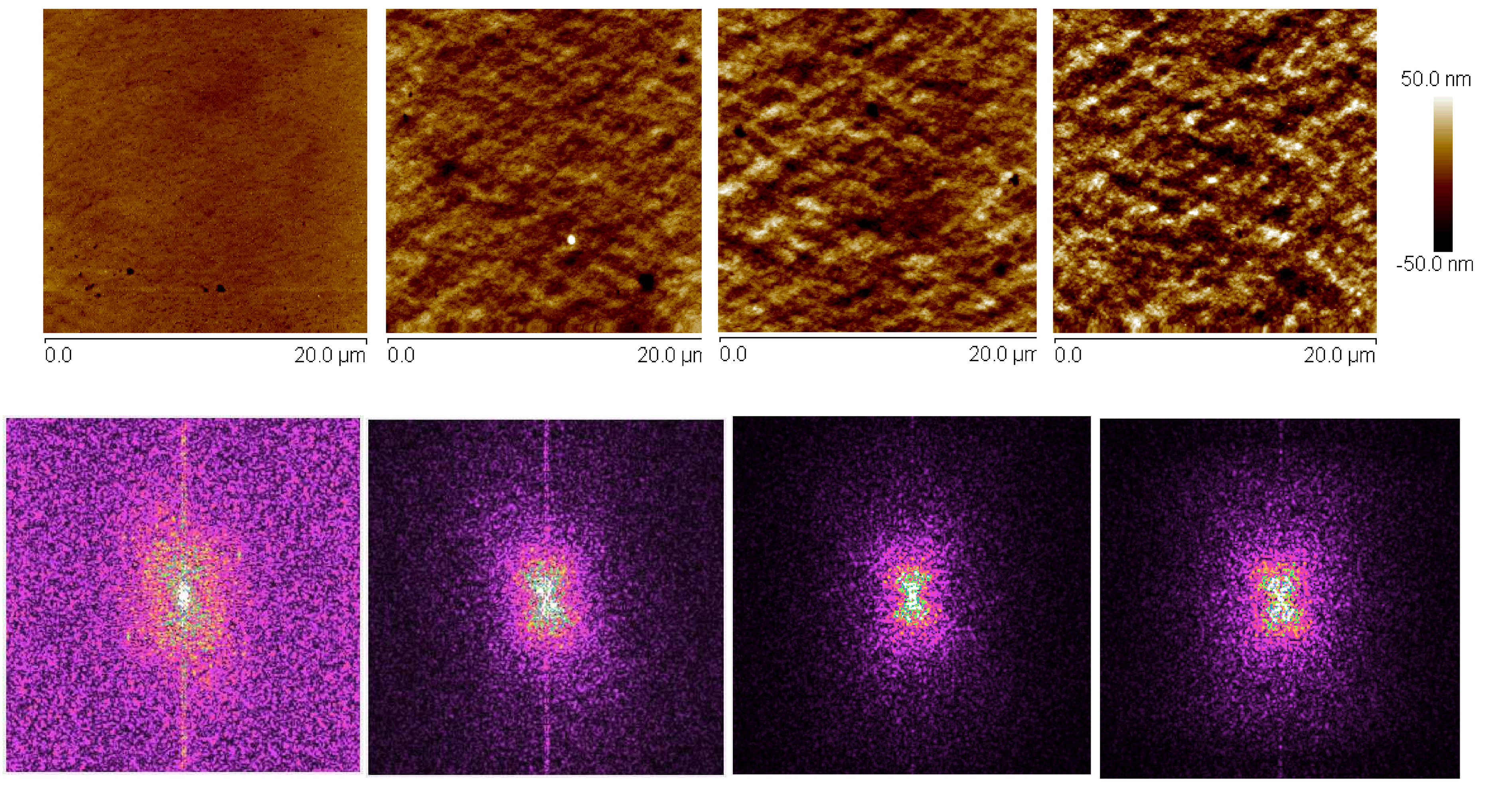
AFM and load frame

Preliminary Results

- Wrinkles show random orientation and frequency distribution
- Wrinkles amplitude increases as strain increased

Future Work

- Run tests on different drying conditions, which yield difference skin layer thickness
- Verify skin stiffness and thickness
- Correlate skin thickness/ stiffness and interfacial interactions
- Characterize skin formation as a function of processing conditions



Top: 2D representation of the sample's surface; Bottom: PSDF of the sample's surface with different elongation

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NNSA National Nuclear Security Administration

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SAND No. 2011-XXXXP