Experiments on Friction

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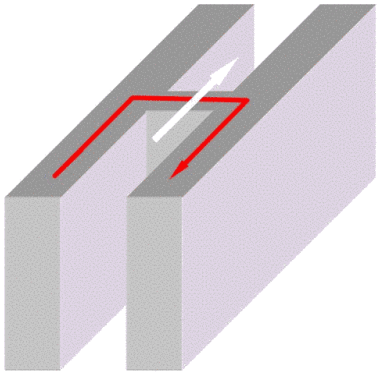
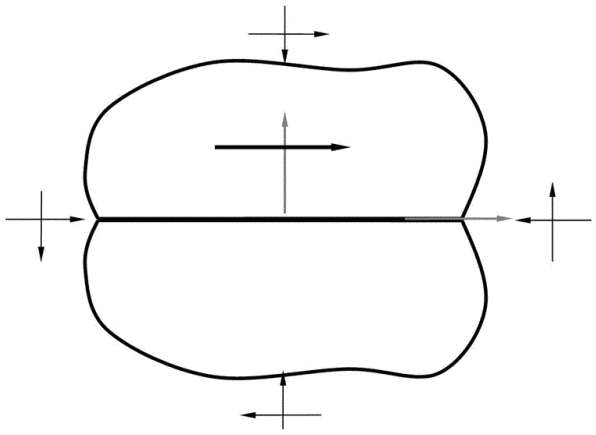
High Speed Sliding



Technical Challenges

- High speed sliding ~ km/s
- High temperature – melting, gouging
- High pressure contacts – 600 MPa
- High current densities ~10^6 A/cm^2

Constitutive Law for Friction



What is the appropriate constitutive law for the interface?

Influence of electric currents?

How can this be determined?

$$f(\mathbf{t}, \Delta\dot{u}_1, \cdots) = 0$$

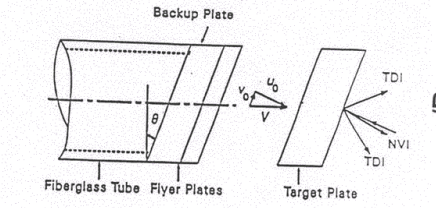
Dynamic Friction Model

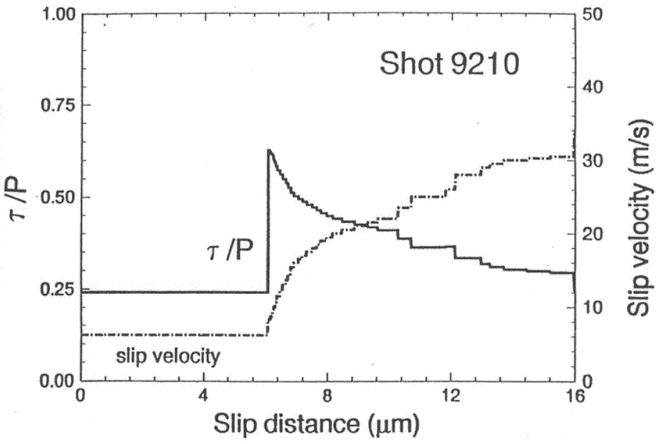
- Dieterich and Ruina models: friction depends on "state" of the interface and the rate of slip

$$\tau = \left[\mu_0 + a\ln\left(\frac{V}{V_0}\right) + b\ln\left(\frac{V_0\theta}{L}\right)\right]\sigma, \qquad \dot{\theta} = 1 - \frac{V\theta}{L} \qquad \dot{\theta} = -\frac{V\theta}{L}\ln\left(\frac{V\theta}{L}\right)$$

- L critical slip distance; order of tens μm

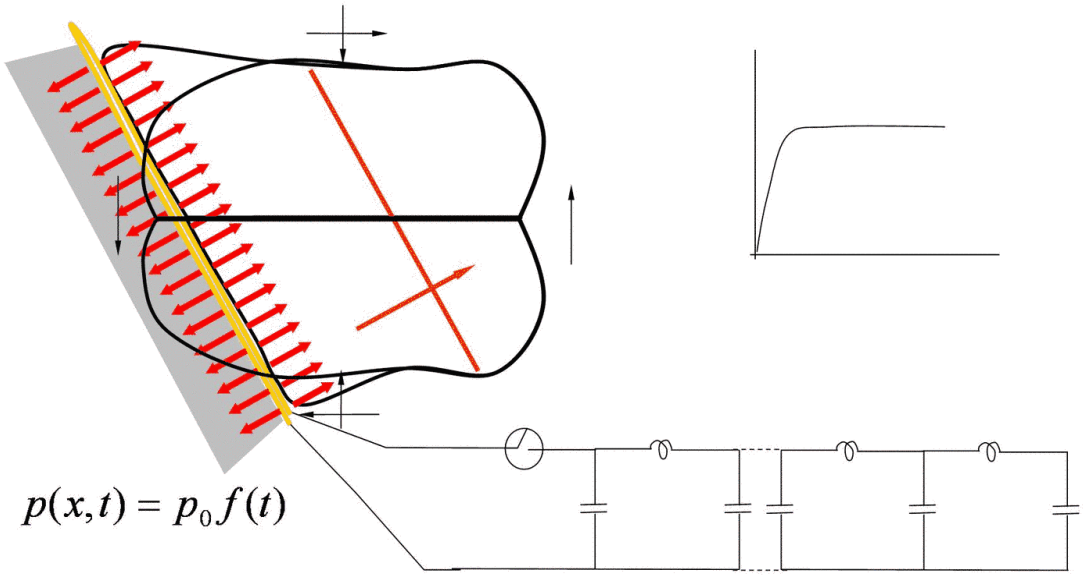
Normal Stress Dependence





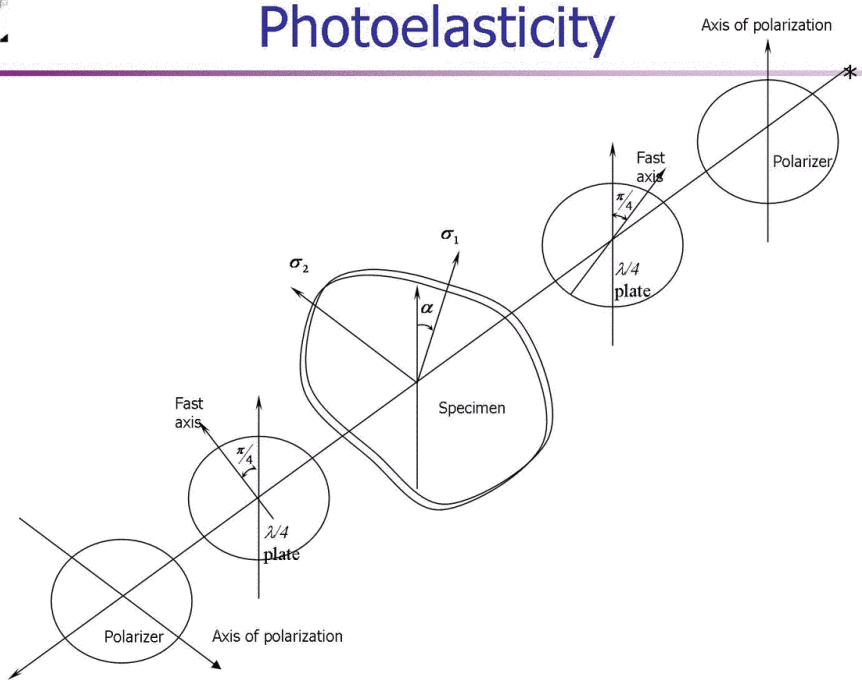
Prakash and Clifton, ASME-AMD-Vol.65, 1993

Experimental arrangement - 1



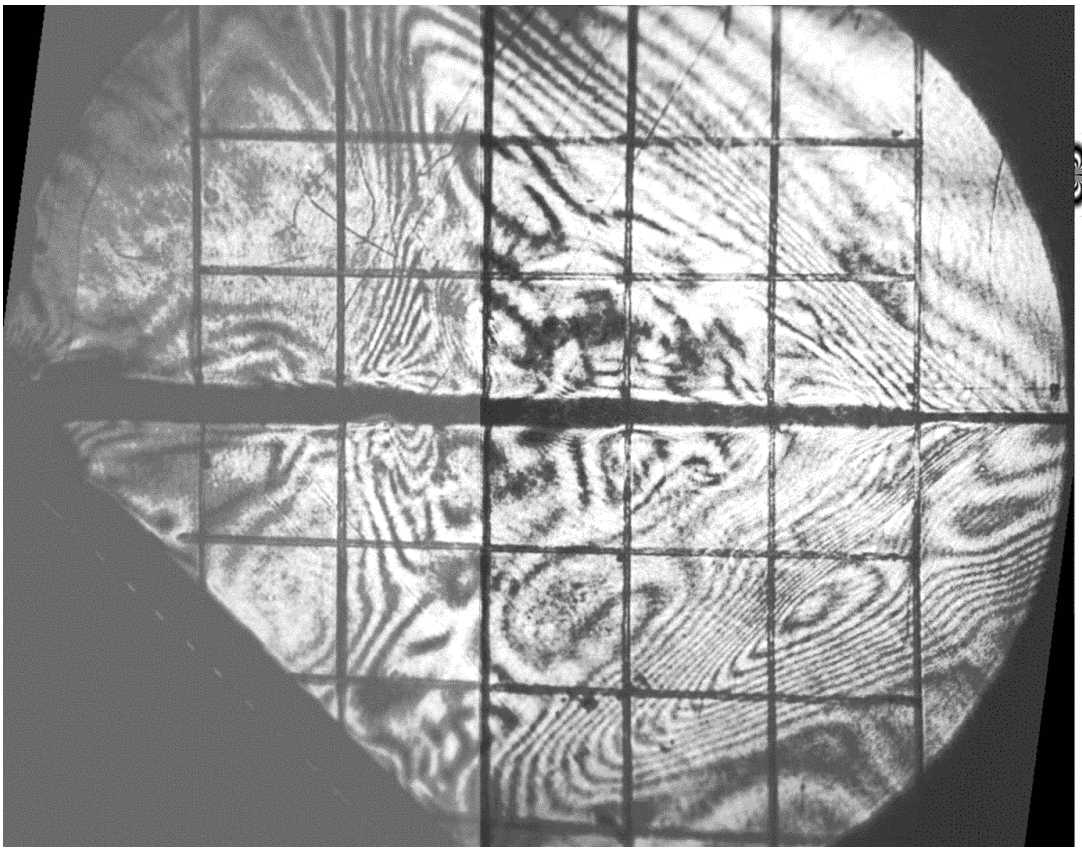
$$p(x,t) = p_0 f(t)$$

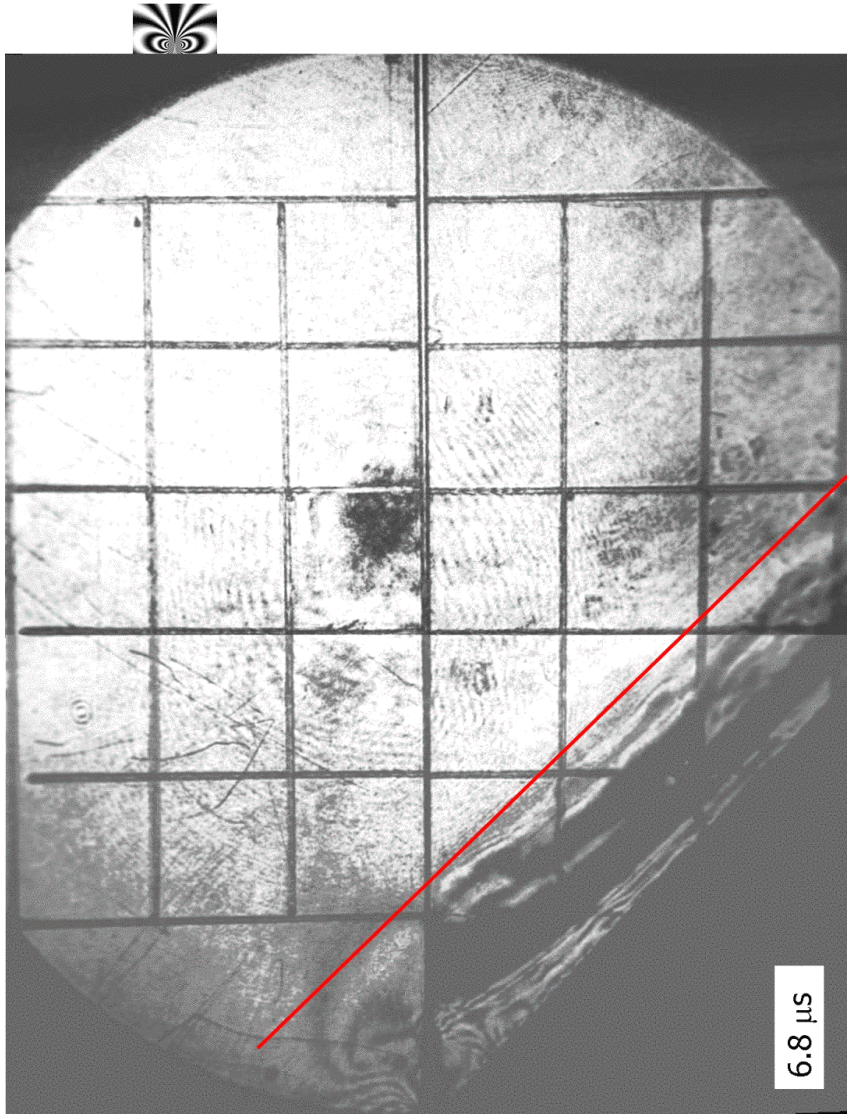
Photoelasticity

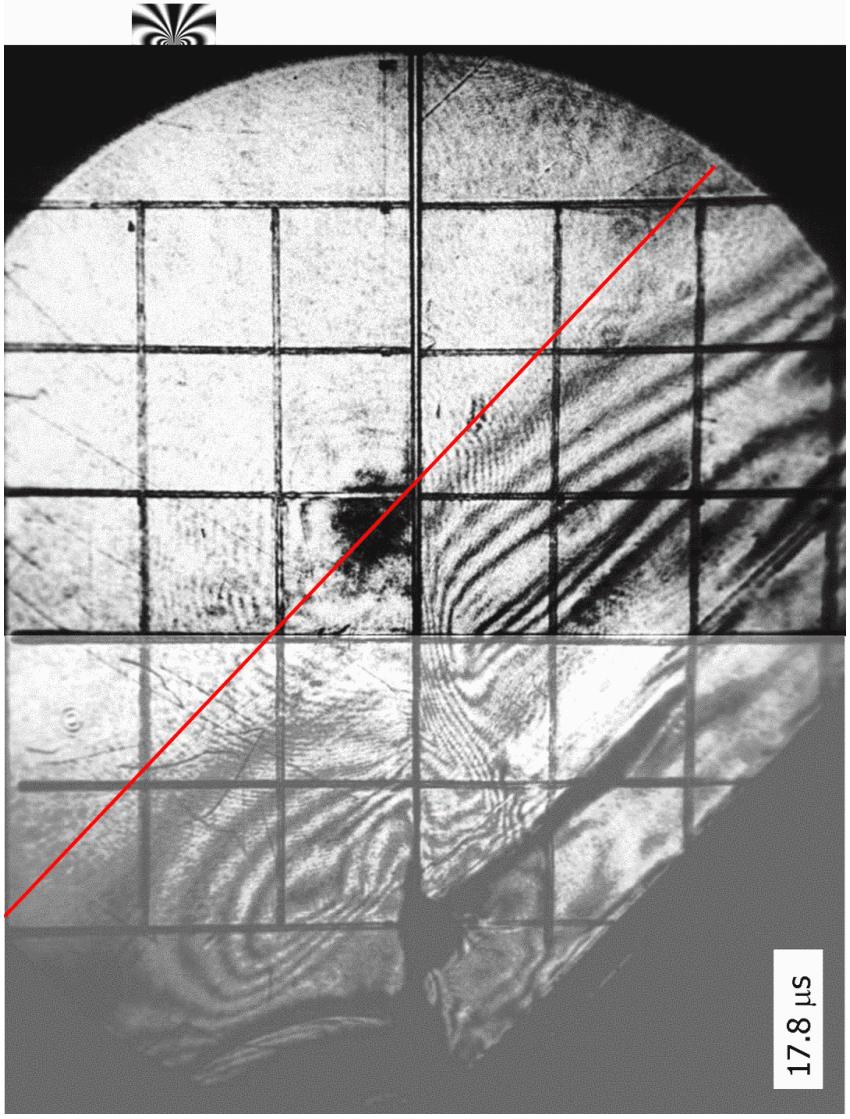


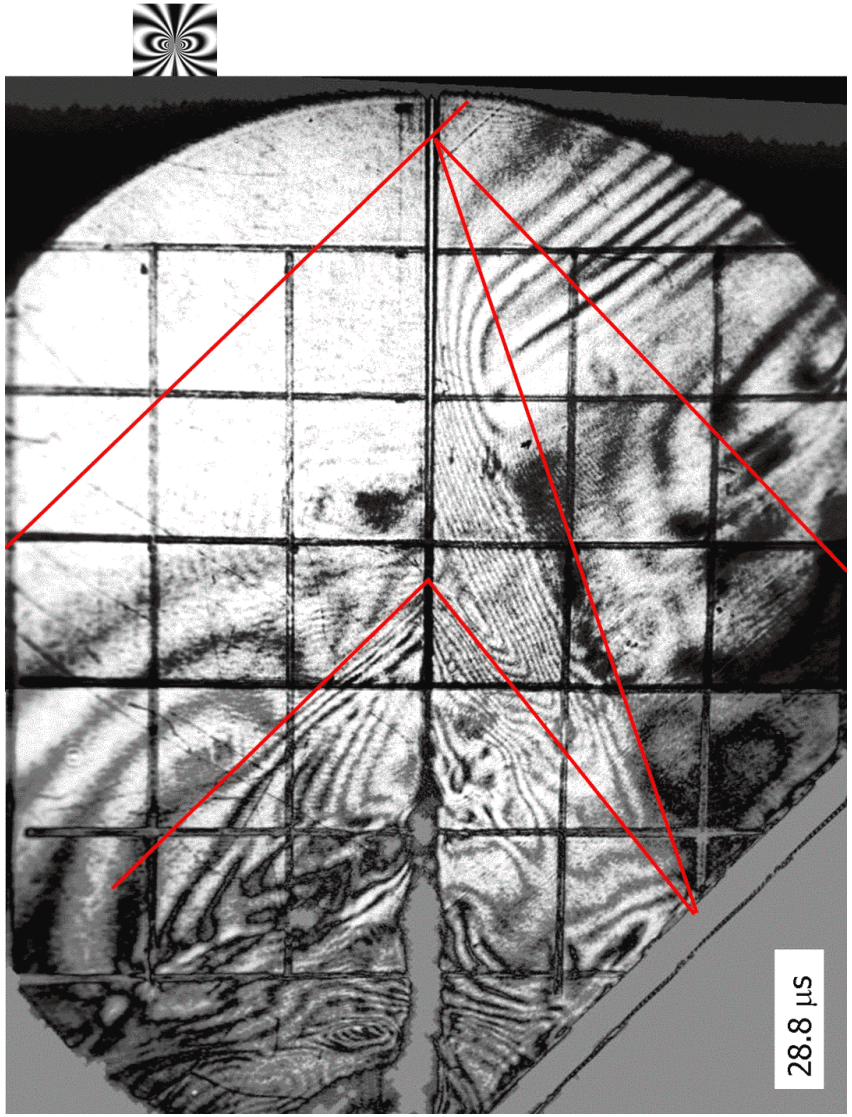
Material and speeds

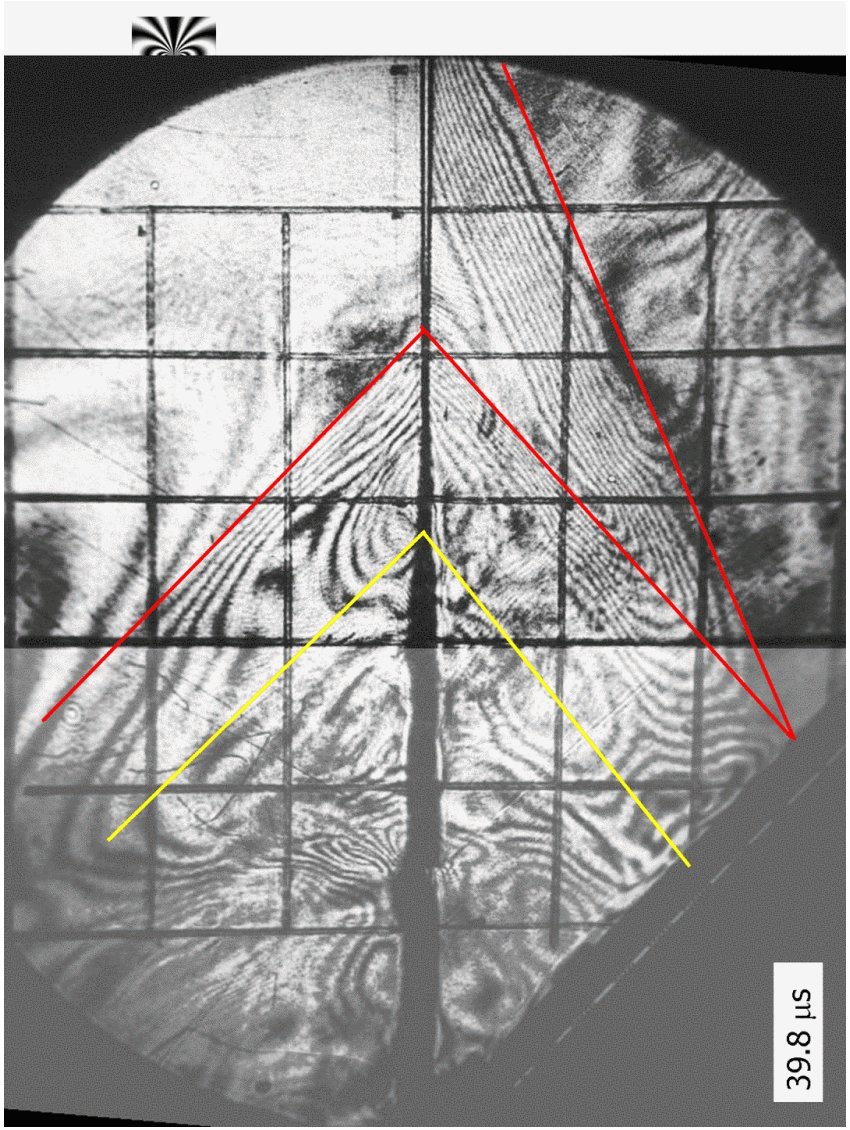
	H-100	PC	
C_d	2266	2106	*m/s*
C_s	1189	860	*m/s*
ν	0.31	0.4	

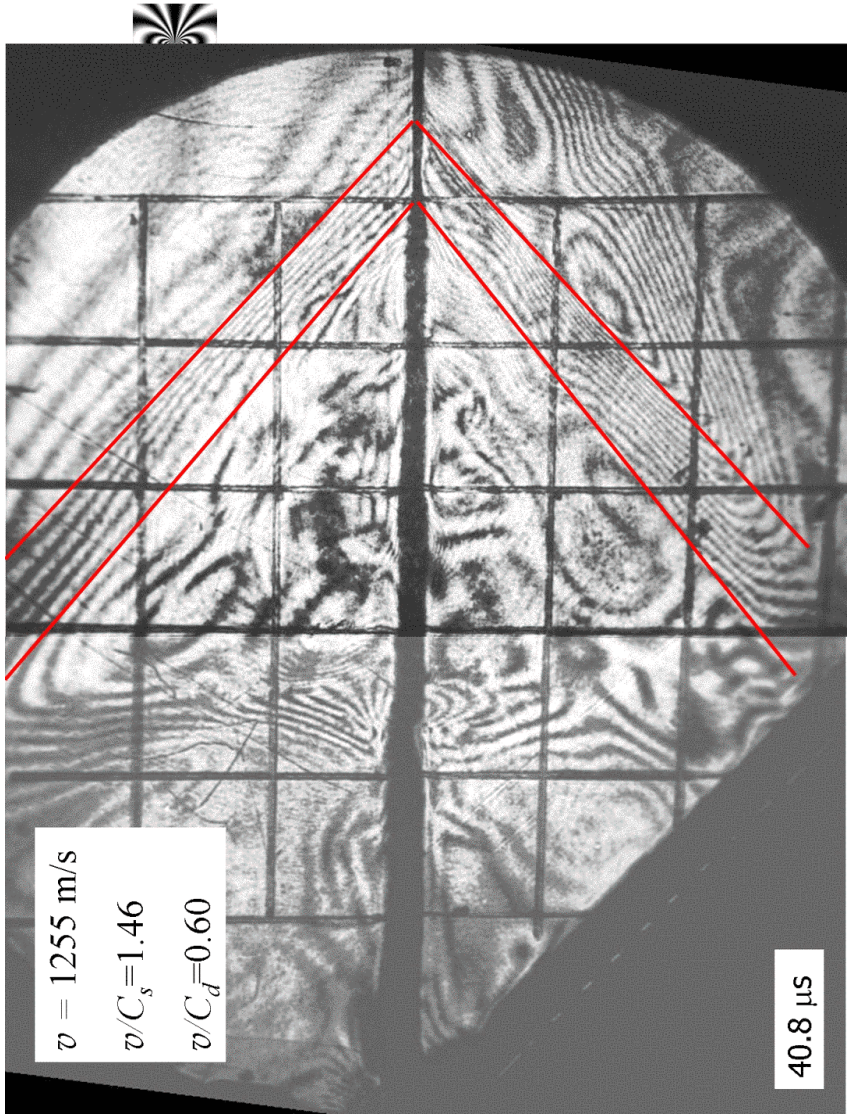


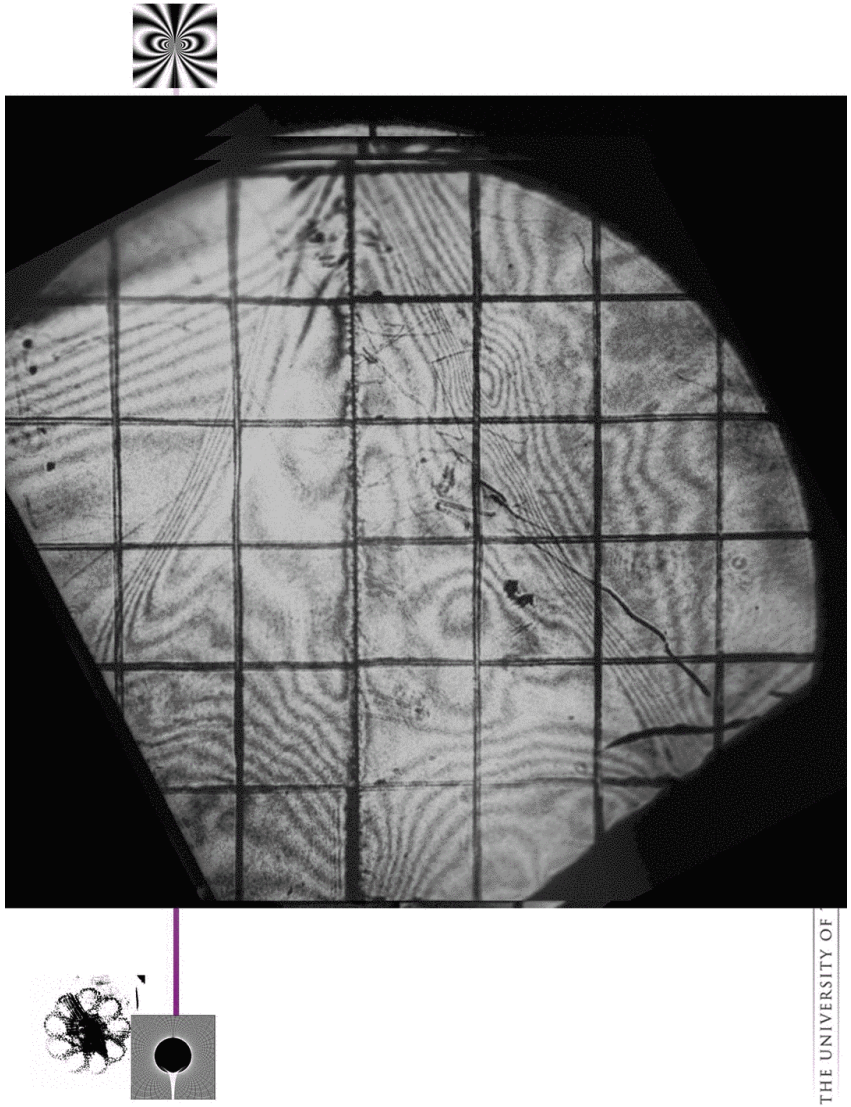

6.8 μs

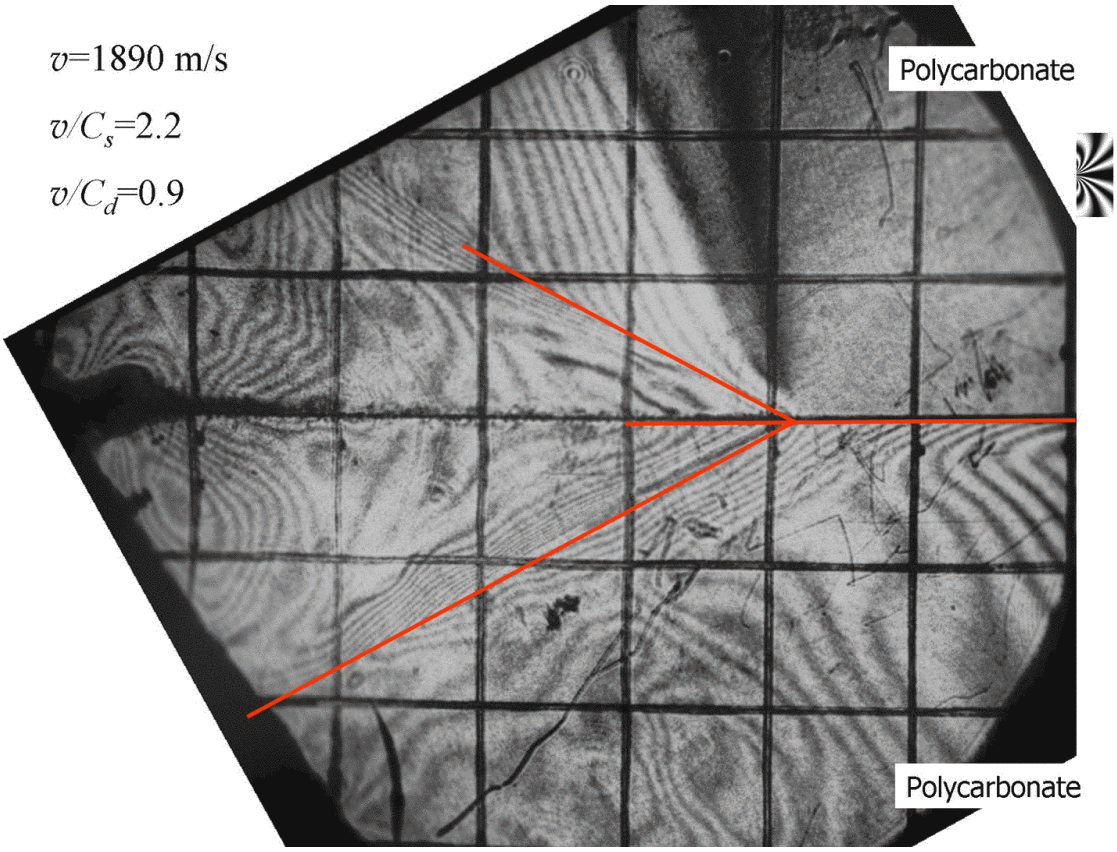

17.8 μs


28.8 μs

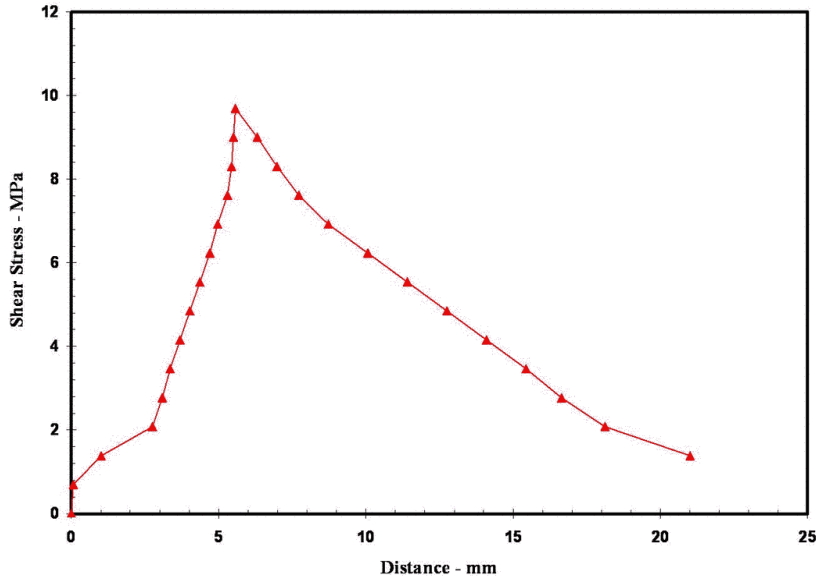

39.8 μs


v = 1255 m/s
v/C_s=1.46
v/C_d=0.60
40.8 μs

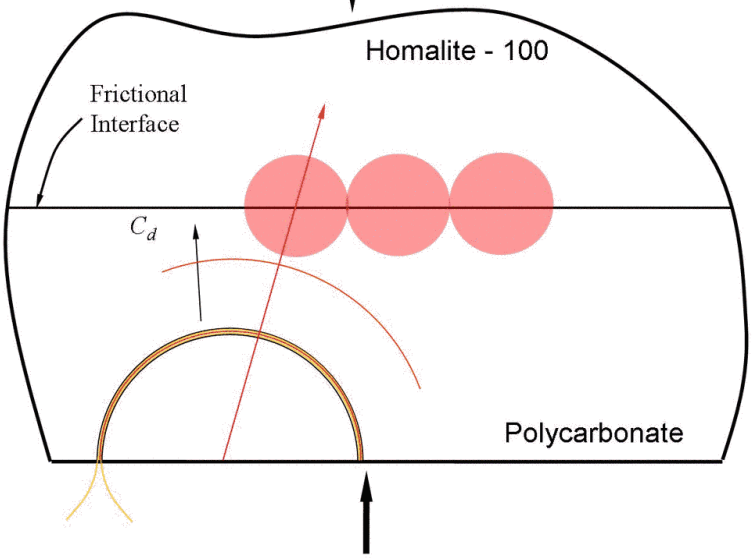


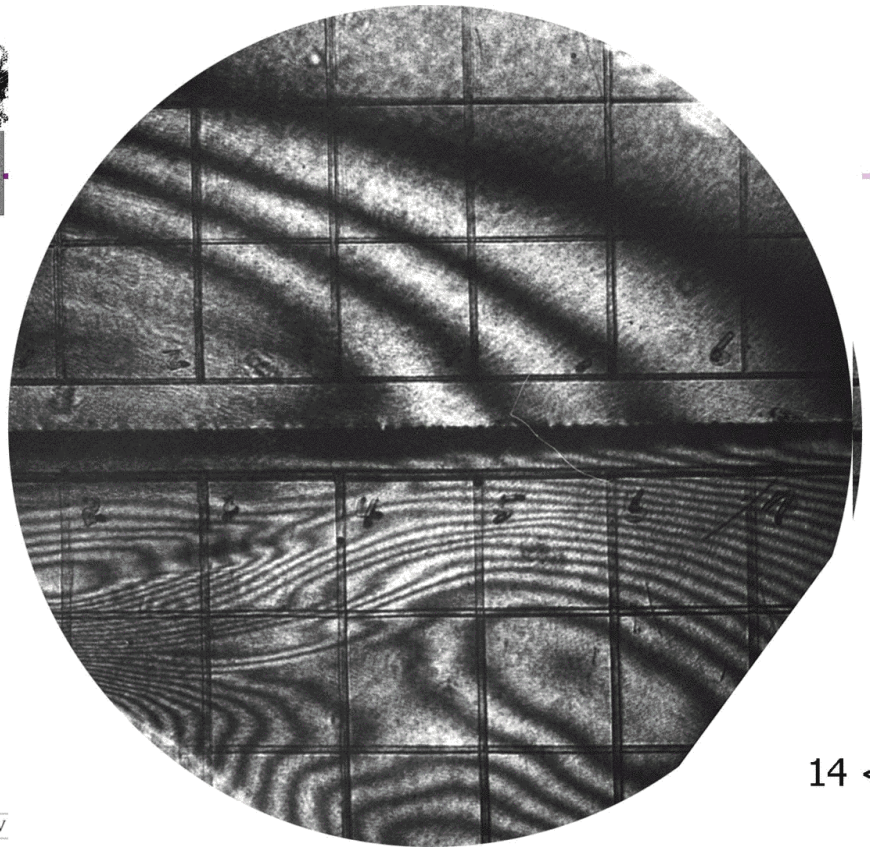


Shear stress variation along interface

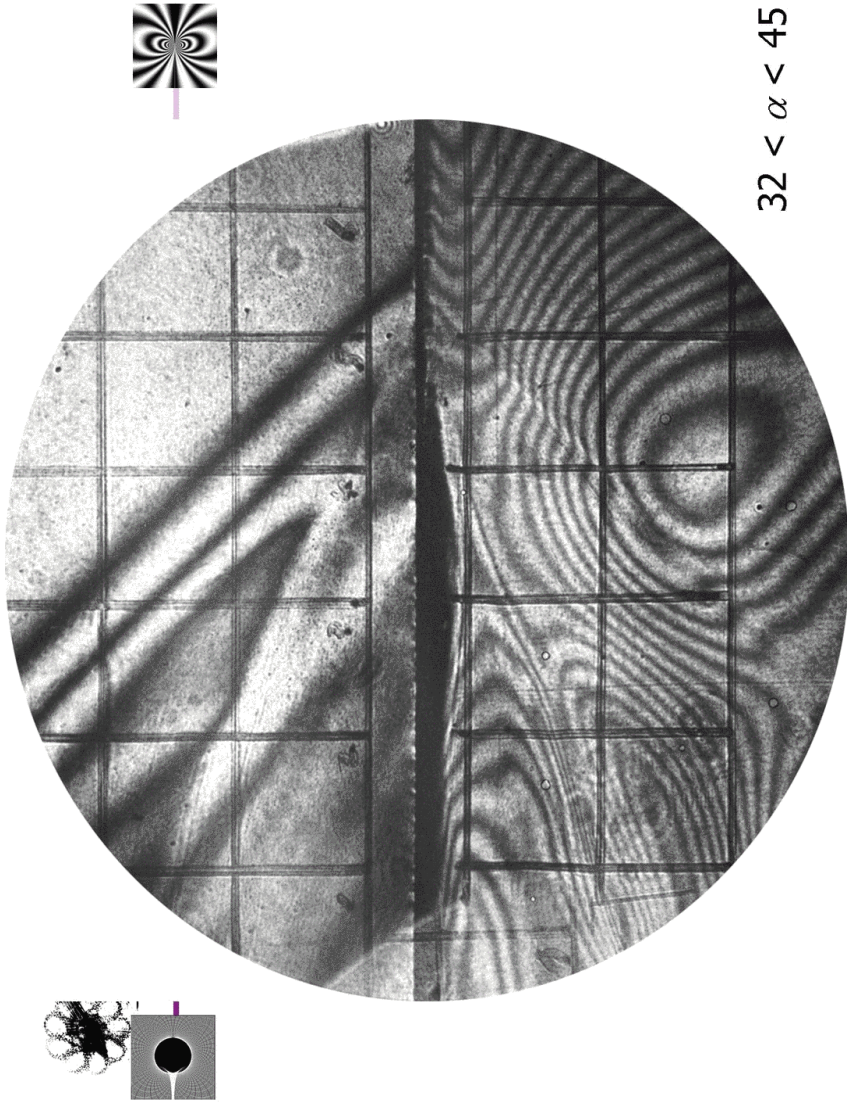


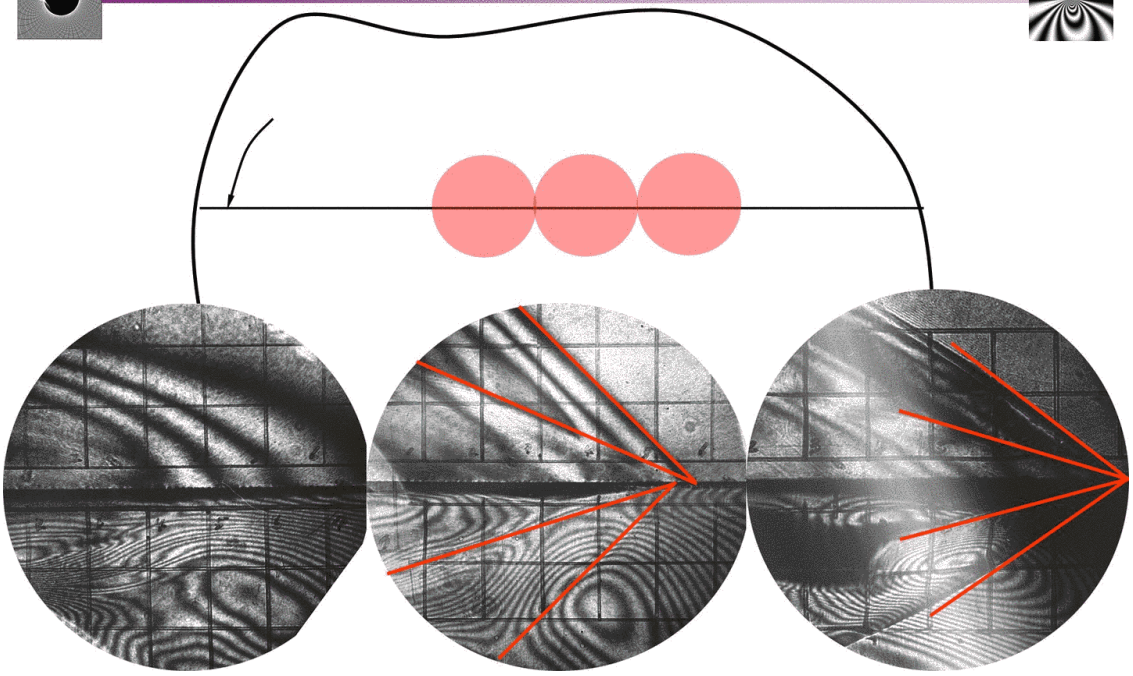
Experimental arrangement - 2





$14 < \alpha < 32$

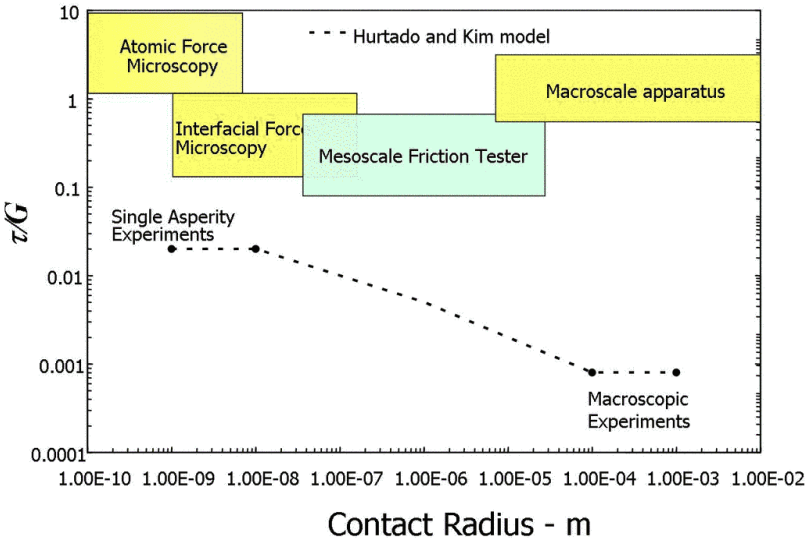




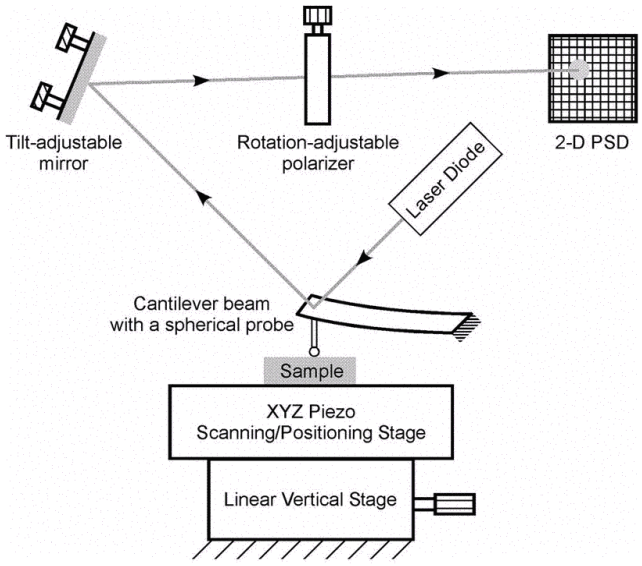
Supersonic slip speeds

	H-100	PC	
C_d	2266	2106	*m/s*
C_s	1189	860	*m/s*
v/C_d	**1.75**	**1.9**	
v/C_s	**3.32**	**4. 6**	
θ	35	32	*deg*
	17.5	12.6	*deg*

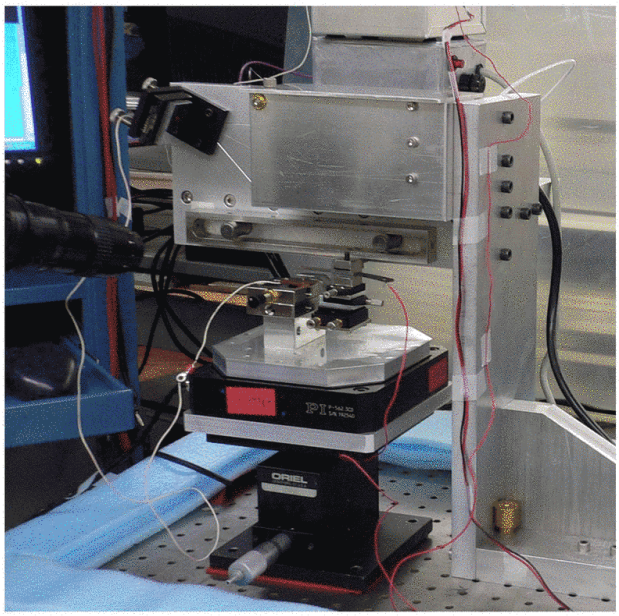
Scale dependence in friction



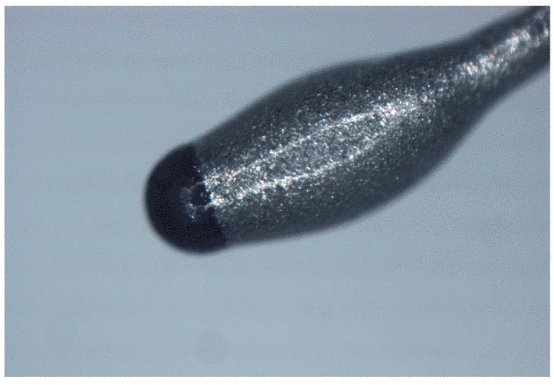
Mesoscale Friction Test Apparatus



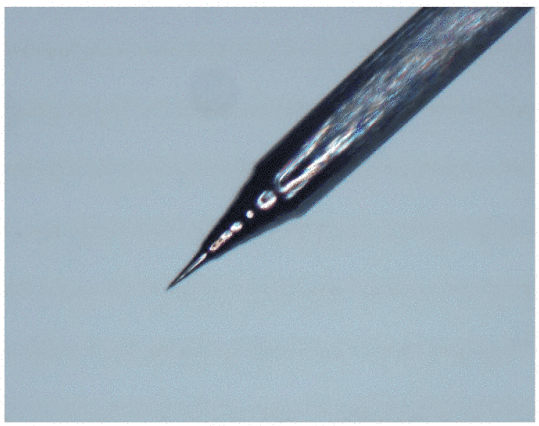
Mesoscale Friction Test Apparatus



Probe Tips



Steel ball bonded to tungsten wire
250 μm tip radius

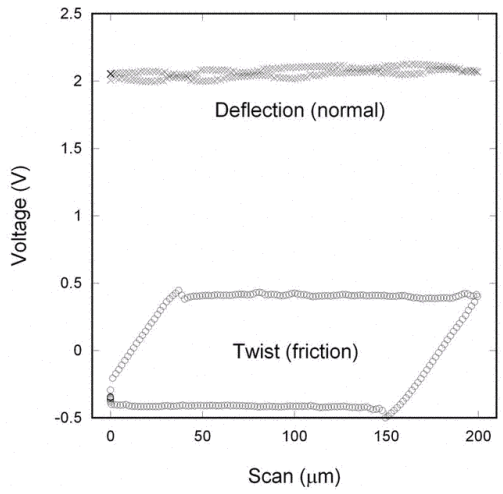


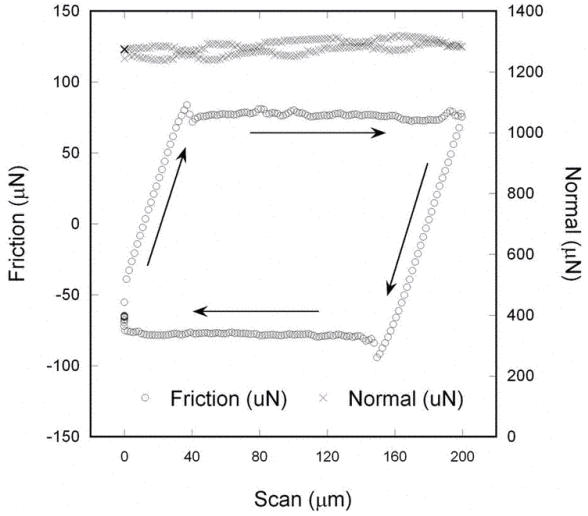
Electrochemically etched tungsten tip
200 nm tip radius

Sensitivity of the probes

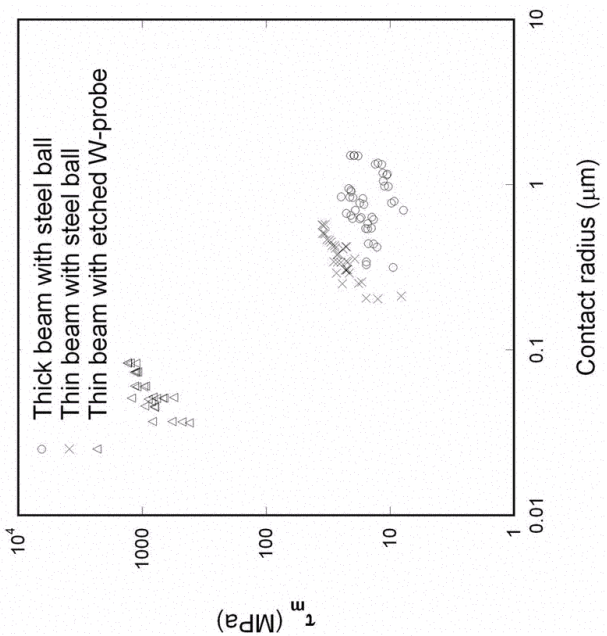
Thickness (μm)	Length (mm)	Normal Froce (μN/V)	Twisting Moment (μN-m/V)	Resolution (μN)
25.4	12.7	28.34	0.399	0.028
	25.4	6.97	0.199	0.007
50.8	12.7	226.75	3.192	0.227
	25.4	55.74	1.596	0.056
63.5	12.7	442.88	6.23	0.443
	25.4	108.88	3.117	0.108
76.2	12.7	765.29	10.77	0.765
	25.4	188.14	5.39	0.188

Normal and sliding forces





Frictional coefficient



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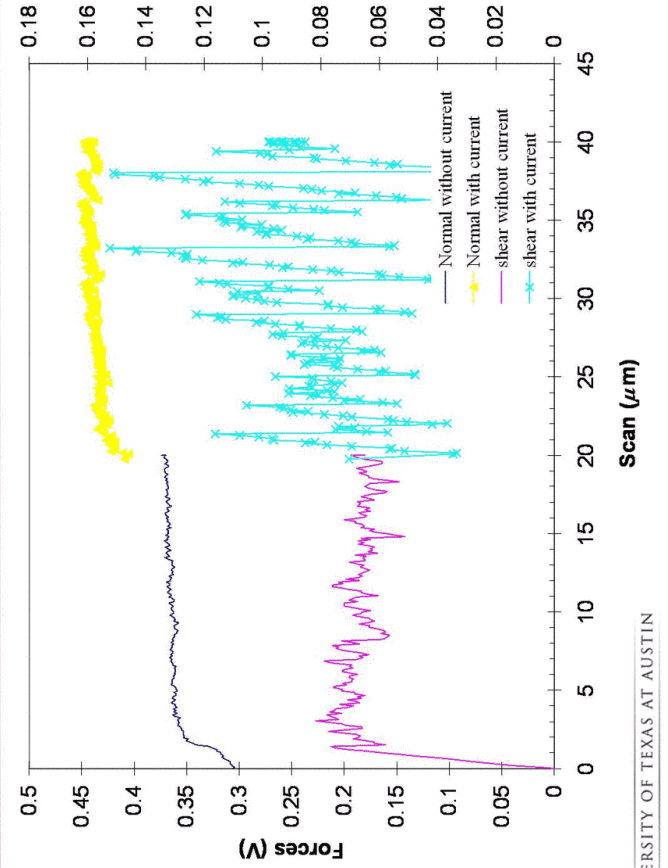
Effect of electrical current



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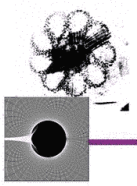

Summary

- Slip pulses are generated from frictional interfaces through interaction with propagating stress waves
- Slip pulses are observed to propagate at a speed controlled by the wave that generates slip
- Mesoscale friction measurements in the presence of electrical currents indicate significant influence of electrical blow-off forces