SAND2008-1538P

Solid Nanowires Pulled from an Ionic Crystal

Project Overview

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Surface and Interface Sciences

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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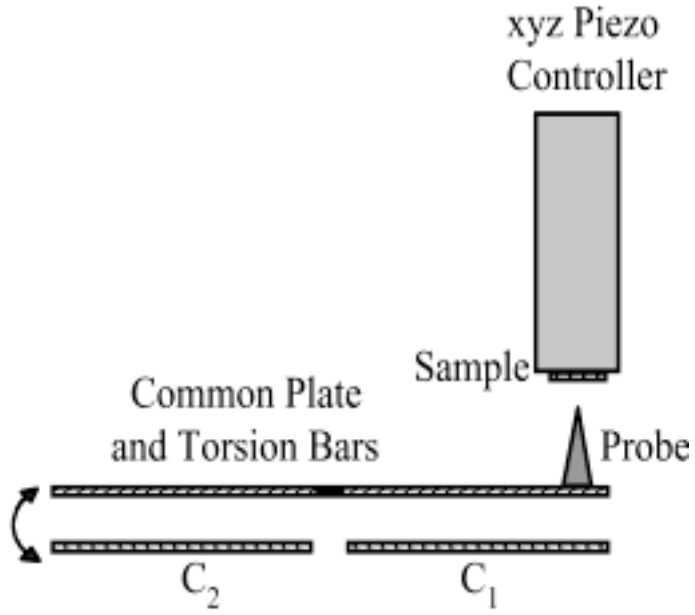
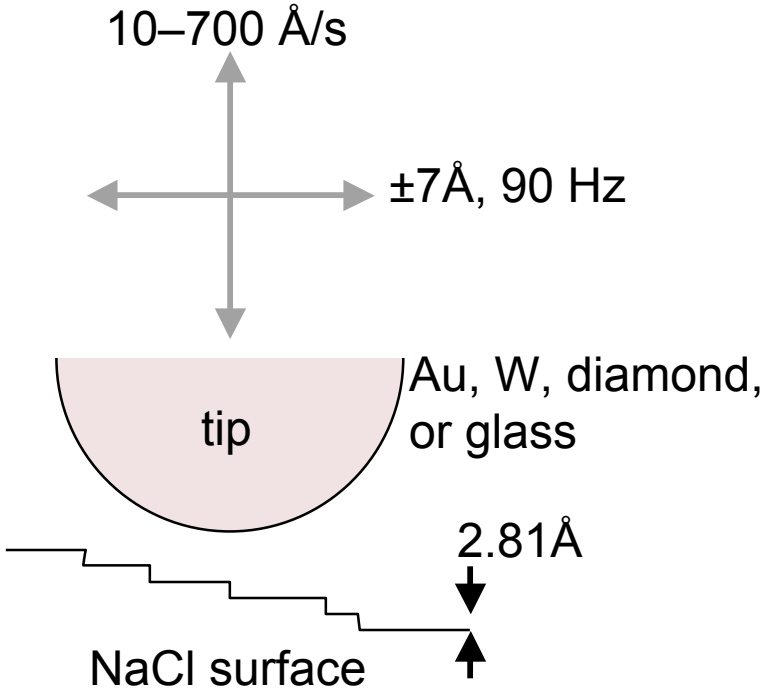
Interfacial Force Microscope (IFM)



Houston and Kim, Acc. Chem. Res. 35, 745 (2002)



Controlled humidity
and temperature

1400 permuted conditions

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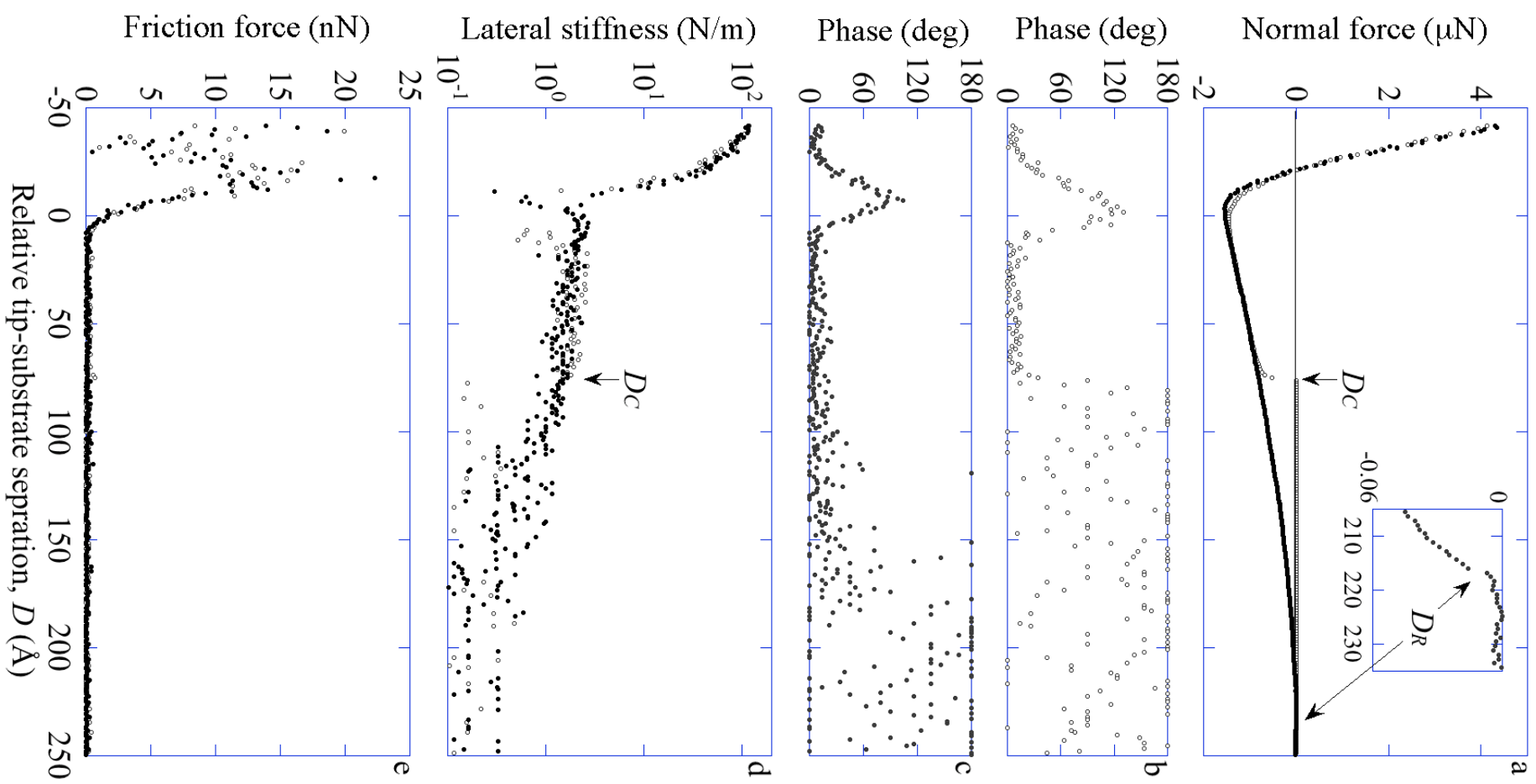
Mechanical response of NaCl Interface



Diamond tip, 25ºC, 20% RH

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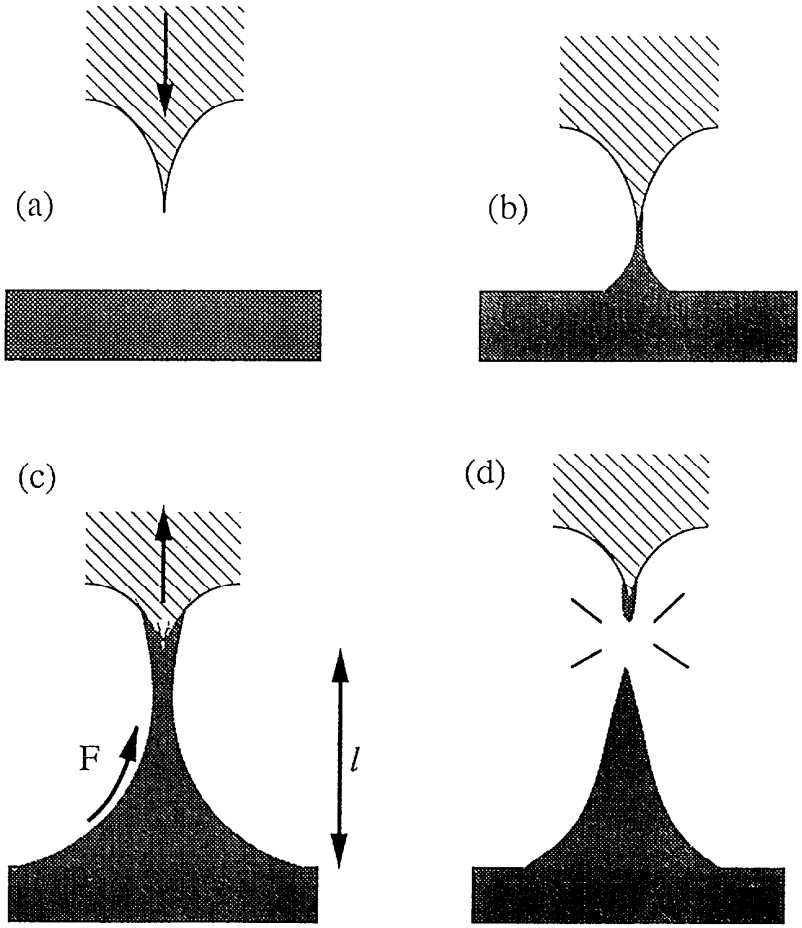
Diffusion-limited model of nanowire growth



Assumes:

1. growth is diffusion-limited
2. nanowire breaks when retract speed = “growth” speed

Developed for Pb necking *

Known necking materials:

Au, Pb, Pt, Ir, Na

* Kuipers & Frenken, Phys. Rev. Lett. 70, 3907 (1993)

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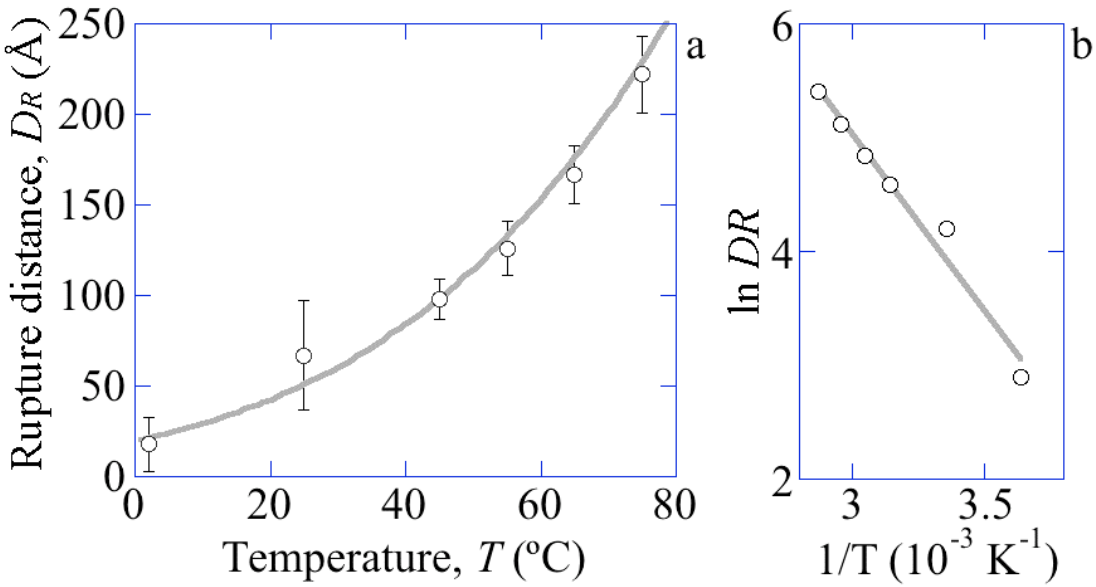
Nanowire rupture: temperature dependence



Au tip, 25ºC, 0% RH

Diffusion-limited model of nanowire growth: $D_R \propto e^{-(E/3)/kT}$ *

E = activation energy for ion pair diffusion

0.8±0.2 eV measured

0.3–0.6 eV in literature

* Kuipers & Frenken, Phys. Rev. Lett. 70, 3907 (1993)

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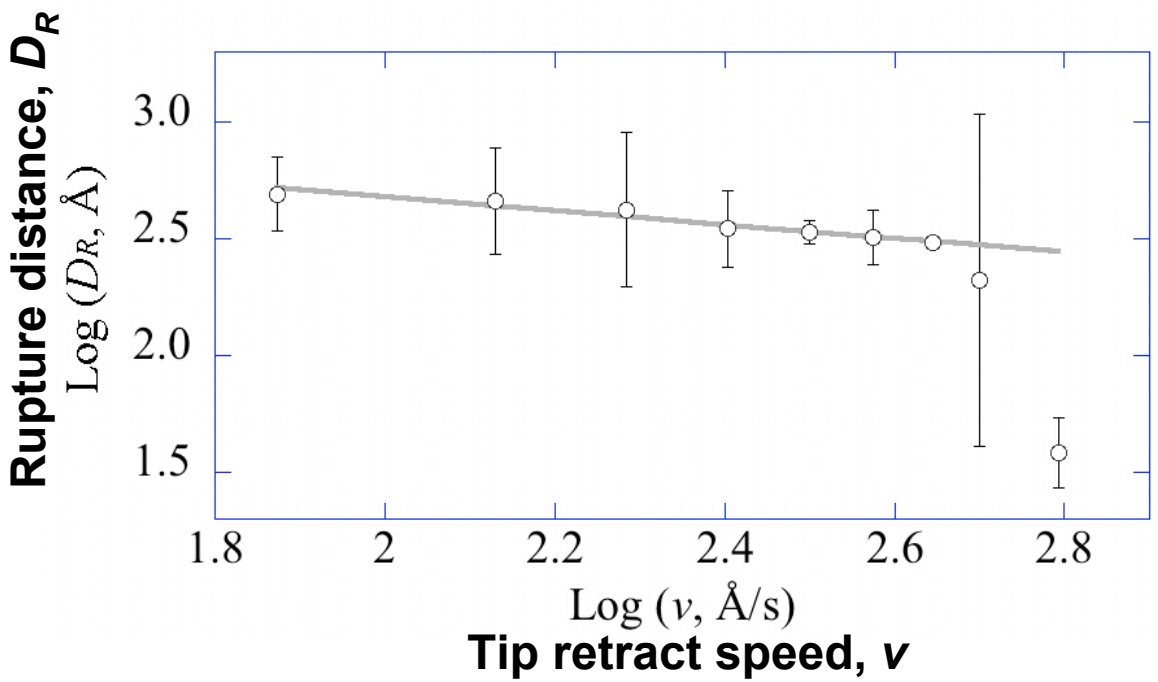
Nanowire rupture: strain rate dependence



Au tip, 25ºC, 0% RH

Diffusion-limited model of nanowire growth: $D_R \propto v^{-1/3}$ *

Measured: $D_R \propto v^{-0.30\pm0.03}$

* Kuipers & Frenken, Phys. Rev. Lett. 70, 3907 (1993)

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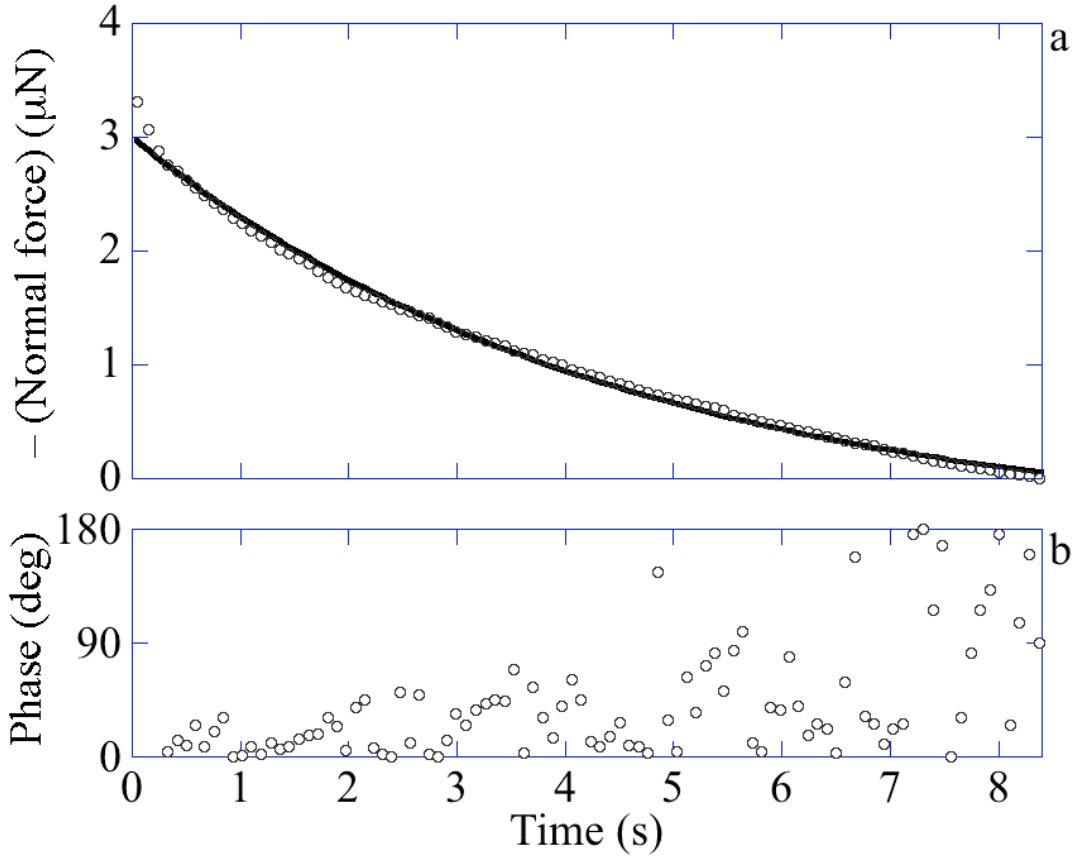
Nanowire relaxation



Nanowire relaxation after imbedding the tip ~20Å below the crystal surface and then retracting 500Å.

Line: exponential fit (time constant = 4.5±0.3s).

Glass tip, 25ºC, 9% RH.

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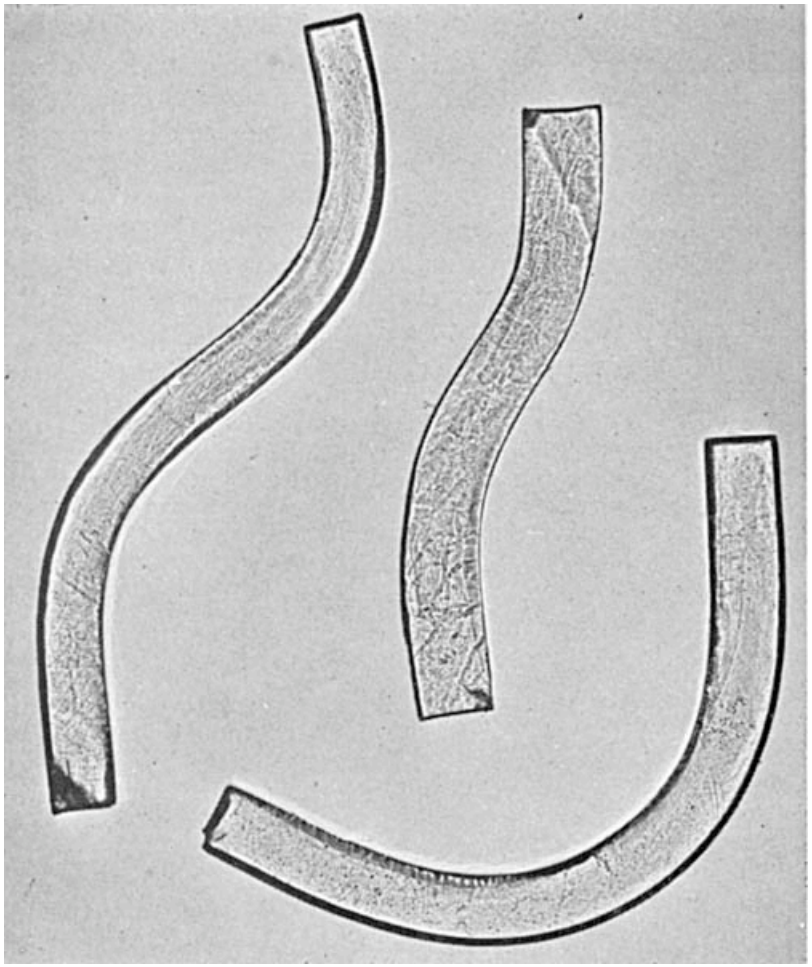
Ionic crystals can be ductile



Gorum, et al., J. Am. Ceram. Soc. 41, 161 (1958)

KCl crystals bent by hand at room temperature

(~1 inch lengths)

Also:

KCl, LiF, MgO

Underground rocksalt (deforms plastically, 150–200ºC)

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Conclusions

- NaCl surface is ductile, even near 0% RH and at room temperature.
- Nanowires pulled from NaCl surface have ~3 nm diameter, up to 120 nm in length.
- Ductility of NaCl surfaces may be important for aerosols in cloud nucleation, smog formation, ozone destruction, triggering asthmatic responses, and for rock salt mining.

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