INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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SMR/390 - 3

WORKING PARTY ON "FRACTURE PHYSICS"
(29 May - 16 June 1989)

OVERVIEW
FUNDAMENTALS OF FRACTURE

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Overview

Fundamentals of Fracture.

Economic Implications

Polarity of Mechanical Response

Dislocations + Cracks.

Elastic Aspects

Atomic Aspects

Qm Force Laws.

Mechanical Failure

Structural materials

Economic value / loss.

Bridge failures
Aircraft failures H: Tech
Gas + oil pipelines
Nuclear pressure vessels H: Tech
Space Appls. H: Tech
El. Devices

High Tech :

Tradeoff of performance / Risk

Requires precise assessment.

Practice

1. Initial design requirements - Matl nominal prop.
2. Processing Quality Control Flaw control (NDE)
3. In-use Monitoring (NDE)

Engineering Practice

NDE

1. Flaw Detection + characterization
   Flaw size / shape (crack/void)
   critical size : 1 μm – ½ m.
2. Must know characteristics of flaw growth.
   Critical size/stress
   Chemical environment
   Growth under cyclic Stress

FRACTURE MECHANICS

Specification of matls in terms of critical toughness tests
J-integral / CoD / K_{Ic}

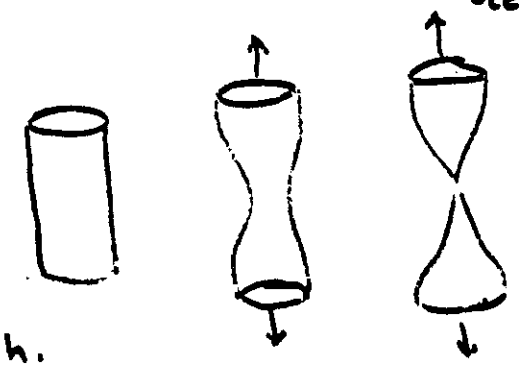
What Role for Fundamental Knowledge?

NEW { What makes matls tough?
Role of external chem. Environ.
Ultimate Limits –

MECHANICAL POLARITY

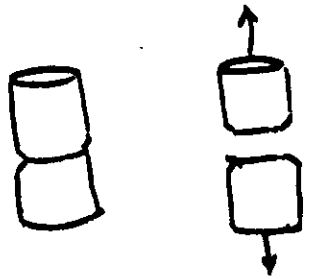
See SSP

Fully Ductile
Au, Ag, Cu, Al ...



1. Low strength.
2. High energy absorbtion to failure (High toughness)
3. Pure deformation : dislocations
   No cracks.

Fully Brittle
C, Si, Mica,
SiO_2 ...



1. Hi Strength (near theoretical bond strength)
2. ≃0 toughness ≃ No energy to fail.
3. Pure crack propagation –
   No deformation.

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Technological matls intermediate.
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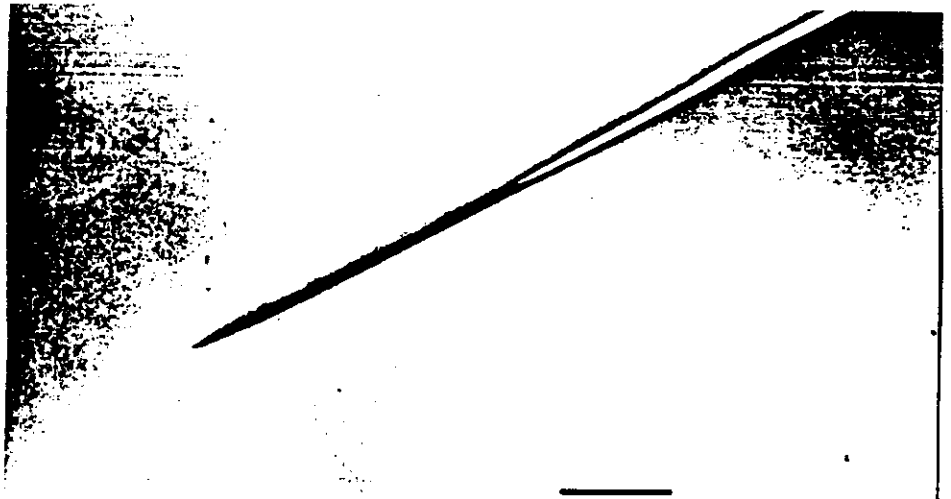
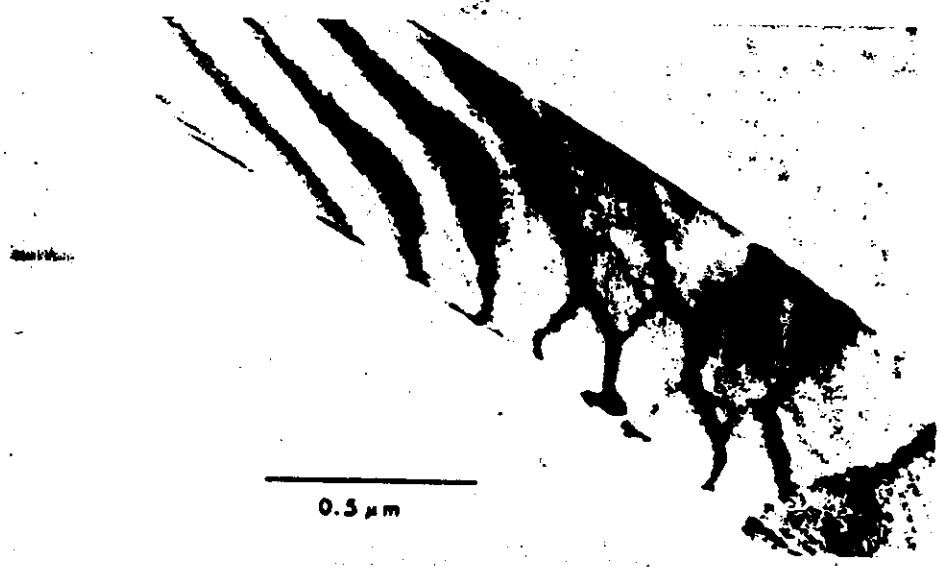
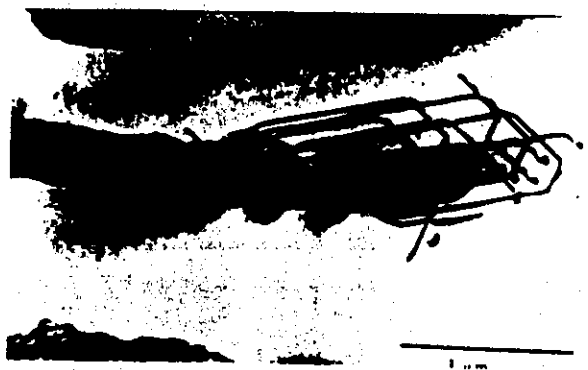
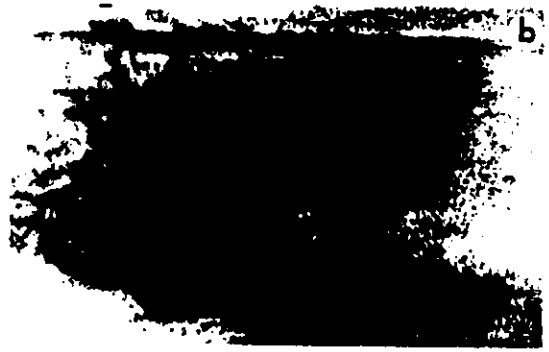


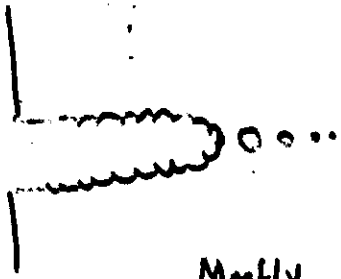




Chia + Clarke (Acta Met)

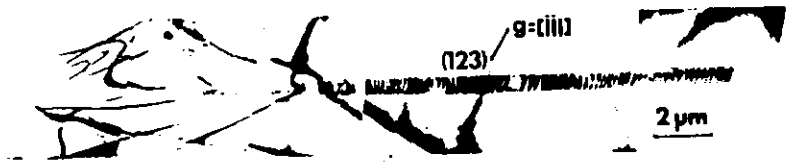


"Fracture" of a Techn. Matl. (F_e)

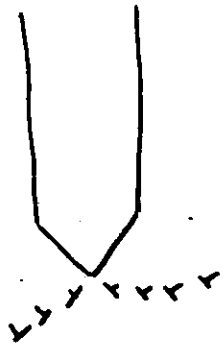


Mostly a ductile process.

1. Initiation of holes / voids
2. Growth of voids by pure deformation shear processes. (shear bands, shear cracks ???)



a 100μm



100μm

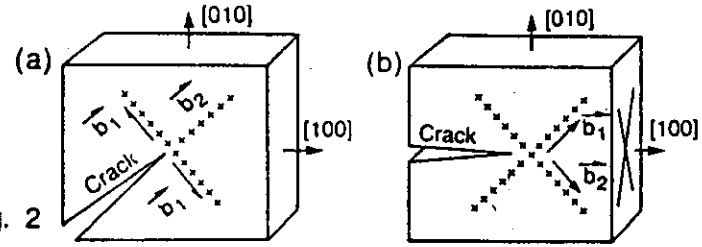


Fig. 2

Figure 2. A schematic representation of (a) $(\bar{1}10)$ plane crack with (110) and $(\bar{1}\bar{1}0)$ plane edge dislocations. (b) (010) plane crack with (110) and $(\bar{1}\bar{1}0)$ plane edge dislocations. The more common screw dislocations are lightly shown on the (100) face.

Figure 3. A photomicrograph of crack tip deformation in 2(b). The horizontal line is the crack. The cross are edge dislocations, some screw dislocations are also seen parallel to the crack.

also Fu·
Zn
$k_e^{II} \ll$ T
k_e is k^I
Ohr
$k_e \approx$ T

Burns, Scripta Met. 20 489 (1986)

Very small k_e based on measured shielding (?) (dipoles ?)

Pugh, See NATO
Atomistics of Fracture

"Pure" cases exist, but as a rule,

Cracks AND dislocations coexist + interact

Relative toughness depends on crack/dislocation interactions

Direct dislocation/crack interact.

Crack as Source of Disl.

External Chemicals modify crack/disl. interact.

Tools

Elasticity (plasticity?) (ties to macroscopic)

Atomic scale theories / ideas

Bonding of Defective Solids (force laws)

Microstructural characterization

cl. Microscopy.

exp.er. study of crack structure Difficult

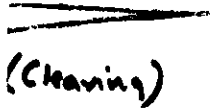
Disciplines

fract. Mech., Matls. Science, Physics Chemistry

A Hint

Classification Scheme for Cracks

Atomic Crack



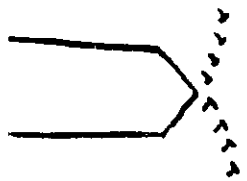
(Cleaving)

{ hi mobility
Lo resistance

$\sigma \propto \frac{K}{\sqrt{r}}$ f. K^2

Shielded by disl. $K = K + K^D$

Emitting Crack



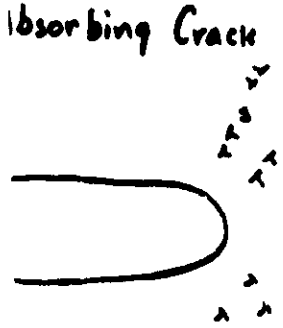
"Zero" mobility

Zero force

moves only by emission

$\sigma \propto \frac{1}{r^p}$ $p > \frac{1}{2}$

Absorbing Crack



"Zero" mobility

Zero force

moves by Plastic opening

σ not singular (but stress concentration)

Again No pure cases — understand how one relates to another.