What is the ground state?

Energy of stretched state
\[ E = \varepsilon \frac{\Delta L}{L} \]

Fracture energy 20L²

\[ \Rightarrow \text{Breaks in two (in equilibrium)} \]

\[ \text{if } \varepsilon^2 \geq 40 / Y_L \]

Pretend every bond has energy 1eV
\[ E = 3 \text{eV} / a^2 \quad 3 \text{bonds/atom} \]

Every atom has 2 - 12 bonds, break at \( E = 1 \)
\[ Y = 6 \text{eV/Å} \]

\[ \varepsilon^2 \geq \frac{a}{Y} \Rightarrow \varepsilon \geq \sqrt{\frac{10^{-10}}{1 \text{m}}} \sim 10^{-5} \]

1m rod breaks when stretched (0.01mm²)
Hard to believe?

- **Solids are hard to stretch.**
  
  \[ \gamma = 200 \text{ GPa steel} \]
  
  \[ = 90-90 \text{ GPa glass} \]
  
  \[ \gamma E = \frac{12eV}{(3A)^3} \approx 100 \text{ GPa estimate} \]
  
  \[ \gamma E = r = 10^6 \text{ N/m}^2 \text{ compare to } Mg = \frac{(P_L^3)}{L^2} \]
  
  \[ = \frac{(10 \text{ kg})(10^3 \text{ L})(10)}{L^2} = 10^5 \text{ N/m}^2 \]

- **Brittle solids are easy to break**

  \[ \sigma = 0.8 \text{ J/m}^2 \text{ steel} \]
  
  \[ = 0.4 \text{ J/m}^2 \text{ glass} \]
  
  \[ = \frac{3eV}{(3A)^2} = 4.8 \text{ J/m}^2 \text{ estimate} \]

Are solids really so weak?

Intuition: 1 m glass rod, cracked halfway: How hard would you need to pull to crack it? 10x its own weight?
**Why don't steel rods break easily?**

- Steel is ductile: oozes when stressed.
  - Brittle glass: sharp tip, stress concentrates.
  - Ductile steel: plastic tip, blunts crack.
- Blunts crack or damaged surface layer creates many bonds.

\[
\sigma_{\text{effective}} \gg \sigma_{\text{equilibrium}}
\]
How will this crystal respond to shear?  
Plastic deformation?

Actually, both questions are the same.

\[ \text{Rotate by 45°: Shear } \Leftrightarrow \text{ Stretch.} \]

So a material could be

Brittle under shear

or

Ductile under stretch

or

Nanopillars under compression