3.22 Mechanical Properties of Materials
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Plasticity and fracture of microelectronic thin films (SOI - Silicon on Insulator)

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http://www.electronicsweekly.com/blogs/electronics-weekly-blog/14jun05IBM_SOI.JPG

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Big Picture

- Fabrication of SOI (Smart-cut^{TM} process[1])
  H^+ implantation → wafer bonding → forming blisters → splitting
- Mechanical issues related to the process
  Need homogenous blisters forming and flat fracture surface

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Please see Fig. 10 in [1]

[1] Celler, G.K., et al. "Frontiers of silicon-on-insulator." *Journal of Applied Physics* 93 (1 May 2003): 4955-4978.

Microscopic mechanism

- Stress and strain state at the location of blister[2]

$$\sigma_{ij} = \begin{pmatrix} \sigma & 0 & 0 \\ 0 & \sigma & 0 \\ 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} \frac{PR}{2d} & 0 & 0 \\ 0 & \frac{PR}{2d} & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\varepsilon_{ij} = \begin{pmatrix} \varepsilon & 0 & 0 \\ 0 & \varepsilon & 0 \\ 0 & 0 & -2\frac{\upsilon\sigma}{E} \end{pmatrix} = \begin{pmatrix} \frac{a^2+h^2}{2ah}\sin^{-1}\left(\frac{2ah}{a^2+h^2}\right)-1 & 0 & 0 \\ 0 & \frac{a^2+h^2}{2ah}\sin^{-1}\left(\frac{2ah}{a^2+h^2}\right)-1 & 0 \\ 0 & 0 & -\frac{\upsilon PR}{Et} \end{pmatrix}$$

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[2] Raman, A., et al. "Effect of stress state and polymer morphology on environmental stress cracking in polycarbonate." Journal of Applied Polymer Science 88 (2003): 550-564.

Prediction & Optimization

- Fracture at interface (Griffith's theory)

$$\Delta U_{total} = \Delta U_{surf} + \Delta U_{el} = 4at\gamma_{surf}^{Si} - \pi a^2 t\sigma^2 \frac{1}{E_{Si}}$$

$$\frac{\partial \Delta U_{total}}{\partial a} = 0 \Rightarrow \sigma_f = \sqrt{\frac{2E_{Si}\gamma_{surf}^{Si}}{\pi a}}$$

$$Estimate: \sigma_f = 420MPa$$

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- Optimization[1]
  - Implant other ions (He, etc)
  - Temperature
  - Use other Modes (Mode III)

[1] Celler, G.K., et al. "Frontiers of silicon-on-insulator." *Journal of Applied Physics* 93 (1 May 2003): 4955-4978.