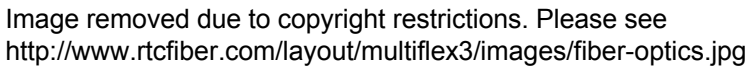
3.22 Mechanical Properties of Materials
Spring 2008

Water-ageing of silica optical fibers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http://www.rtcfiber.com/layout/multiflex3/images/fiber-optics.jpg

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Big Picture

- Macroscopic mechanism : stress-corrosion cracking
  - Subcritical crack growth in silica in the presence of water or water vapor
  - Stress-enhanced corrosion reaction

➔ Decrease in fiber resistance from 4.1 GPa to 2.9 GPa over 4 weeks at 85°C and 85% humidity[1]

$$\sigma_F \, c^{1/2} \propto K_C$$

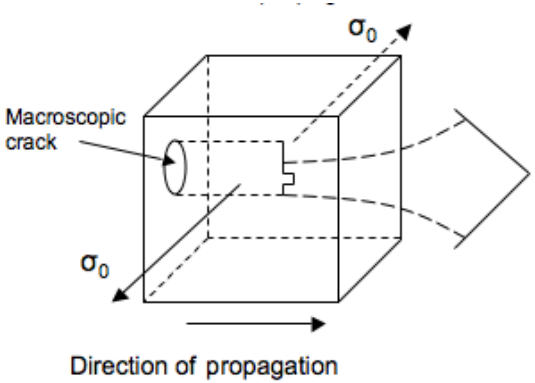
σ_F – crack propagation stress
c – crack length
Kc – material fracture toughness

- Applications :
  - Telecommunications
  - Medical imaging

[1] Mauro do Nascimento, E., and Lepienski, C.M. “Mechanical Properties of optical glass fibers damaged by nanoindentation and water ageing.” *Journal of Non-Crystalline Solids* 352 (2006): 3556-3560.

Microscopic mechanism

Slow fracture model by Michalske and Bunker



Source : [2]

- Microscopic advancement of this crack cannot occur by simultaneous bond cleavage.
- Kinked front allows for localized bond rupture process. Kink can spread laterally to advance the crack front.

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Please see Fig. 6a and 7 in [2].

- Atomic site becomes reactive in step 4, where the Si are forced to give up their tetrahedral molecular orbital configuration.

Source : [2]

To optimize mechanical properties we need to minimize flaw size and control exposure to water.

[2] Michalske, T. A., and B. C. Bunker. "Slow fracture model based on silicate fracture models." *Journal of Applied Physics* 56 (15 November 1984): 2686-2693.

Prediction & Optimization

- Prediction :

$$K_I = f\sigma\sqrt{\pi c} \approx \sigma\sqrt{\pi c}$$

orders of magnitude ≠ between H_20 and N_2

σ = 100MPa, c = 150 nm

→ v = 5 nm/s

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Please see Fig. 2 in [2].

Source : [2]

- Optimization :
  - Careful handling
  - Hermetic coating
    - Diffusion of H^+ and OH^- ions into fiber → cracks & attenuation
    - Cu tubes, water-repellant jelly, water-absorbing powder
    - Coating depends on environment : indoor, under water…

[3] Kurkjian, C.R., Krause, J.T., and Matthewson, M.J. "Strength and Fatigue of Silica Optical Fibers." *Journal of Lightwave Technology* 7 (1989): 1360-1370.