Fracture and Fatigue of a Self-Healing Polymer Composite Material

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theoretical and applied mechanics

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MOTOROLA LABS

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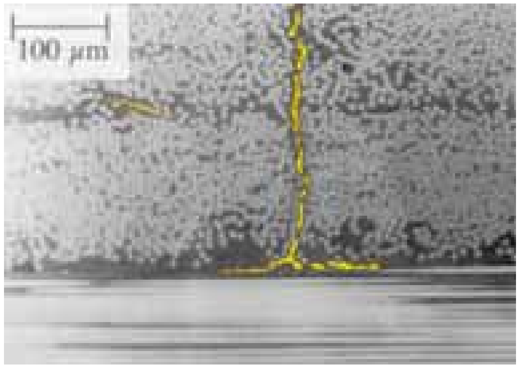
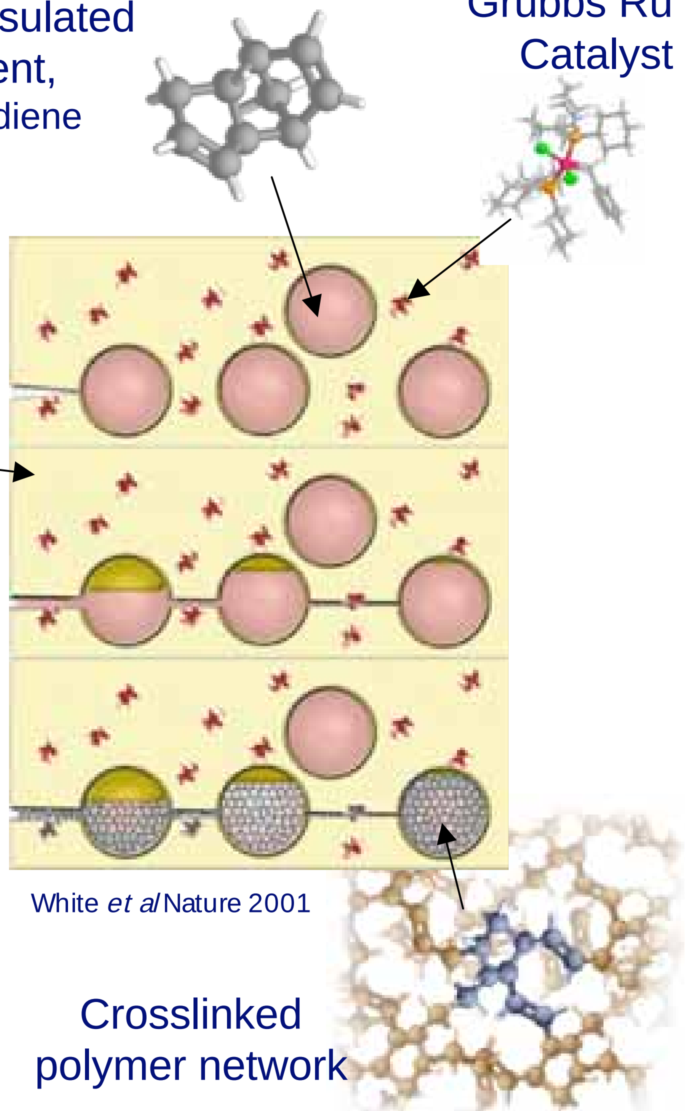
Motivation and Concept

- Thermosetting polymers are used in a wide range of applications, but are susceptible to damage in the form of cracking
- Cracks are often deep in a structure where detection is costly and difficult
- Repair of cracks by external intervention is often impossible

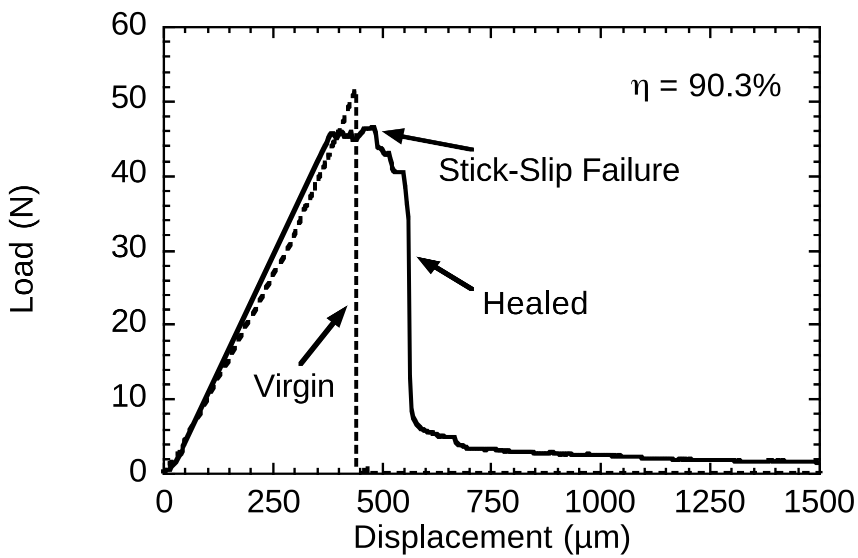


Cracking in cross-ply laminate Jennings (1990)

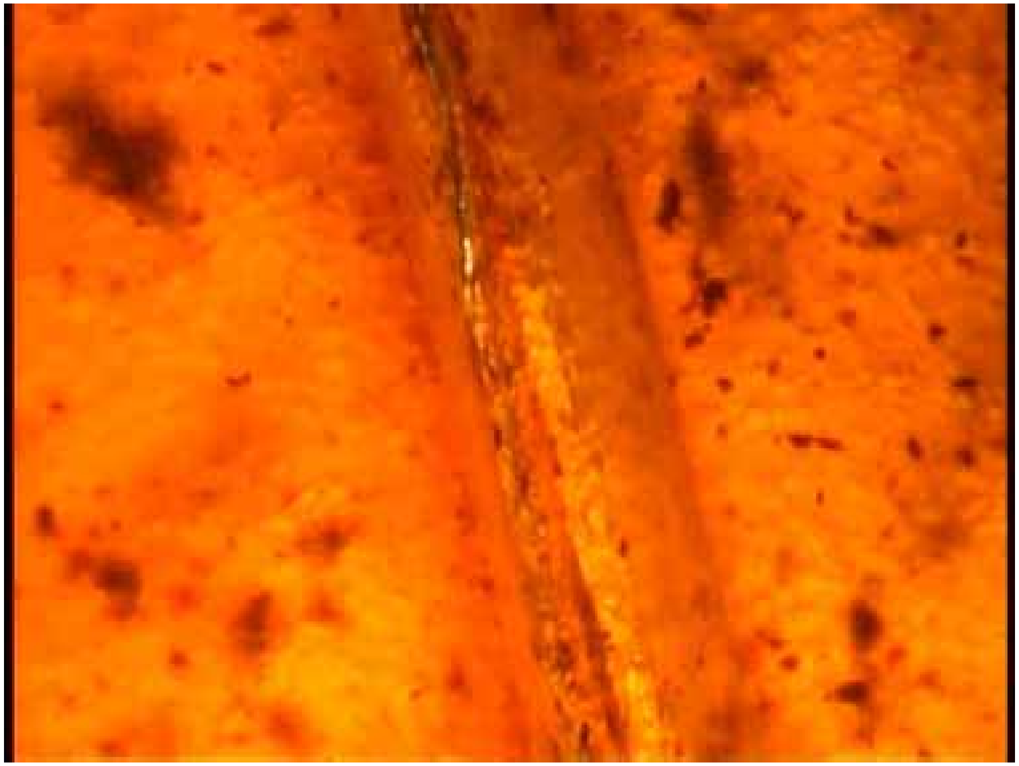


White *et al* Nature 2001

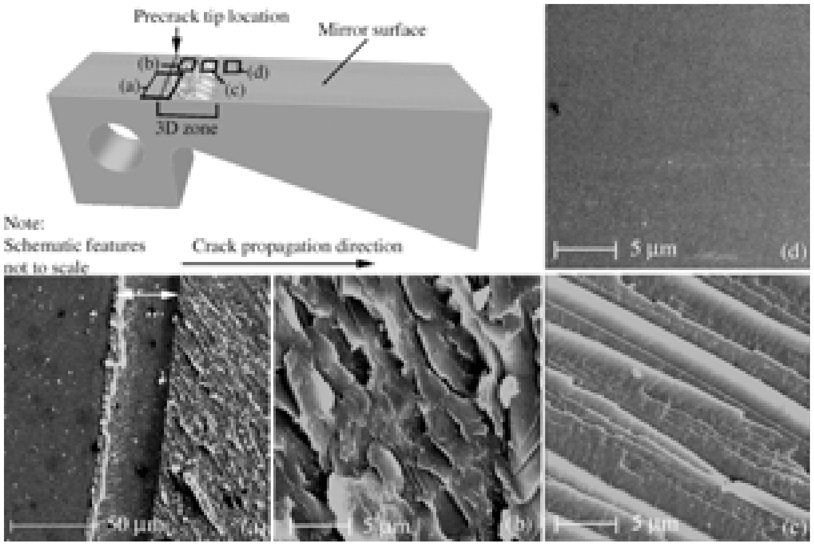
TDCB Load -Displacement Data



Brown *et al* Experimental Mechanics 2002



Fracture Mechanism of Neat Epoxy

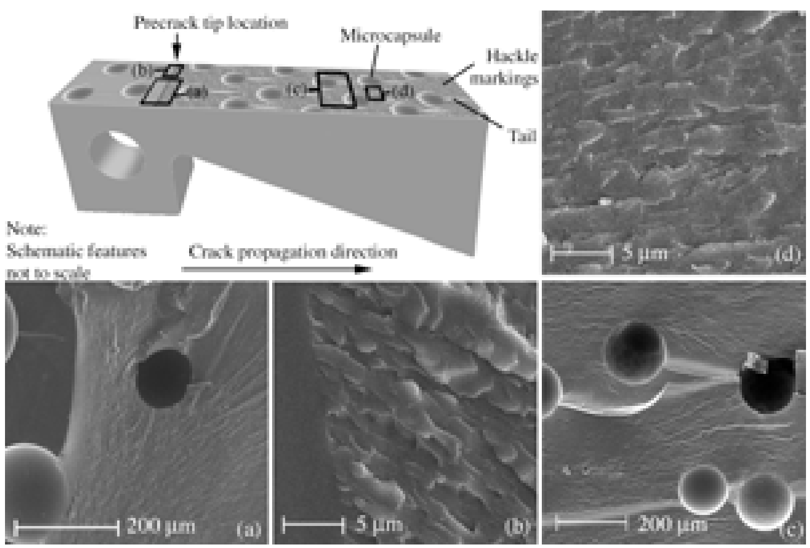


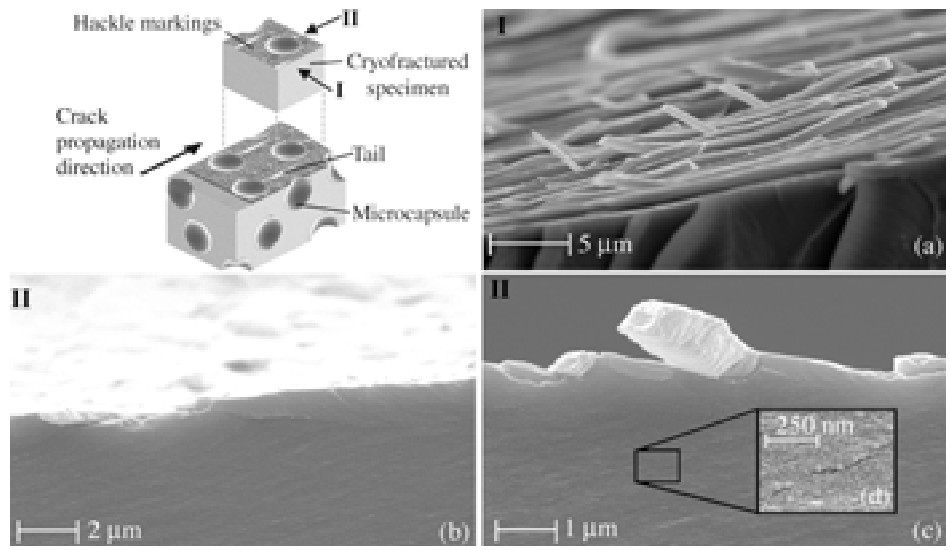
Brown *et al* Journal of Materials Science 2004

Plastic Zone Size:

- Measured plastic zone size ~ 37 µm
- Theoretical plastic zone size = 39µm

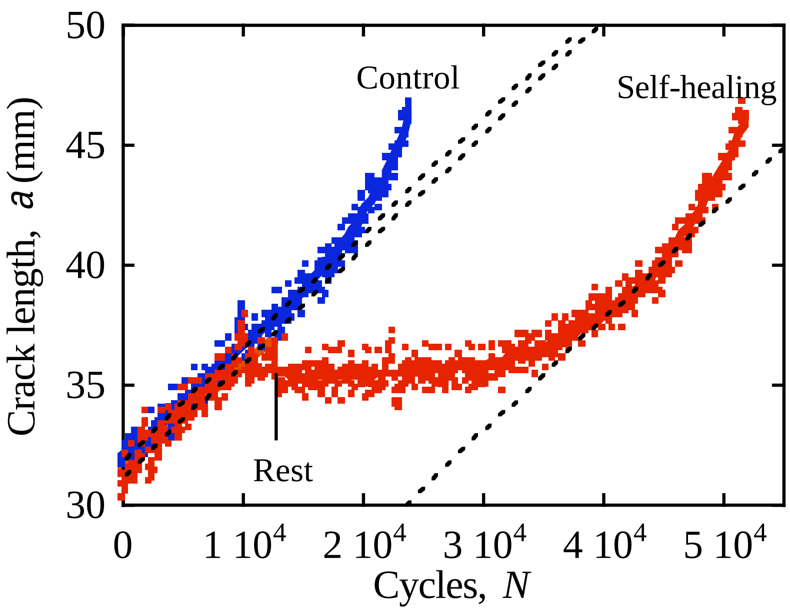
$$r_y = \frac{1}{2\pi}\left(\frac{K_{Ic}}{\sigma_{ys}}\right)^2 = \frac{1}{2\pi}\left(\frac{0.55\,MPa\sqrt{m}}{35\,MPa}\right)^2$$

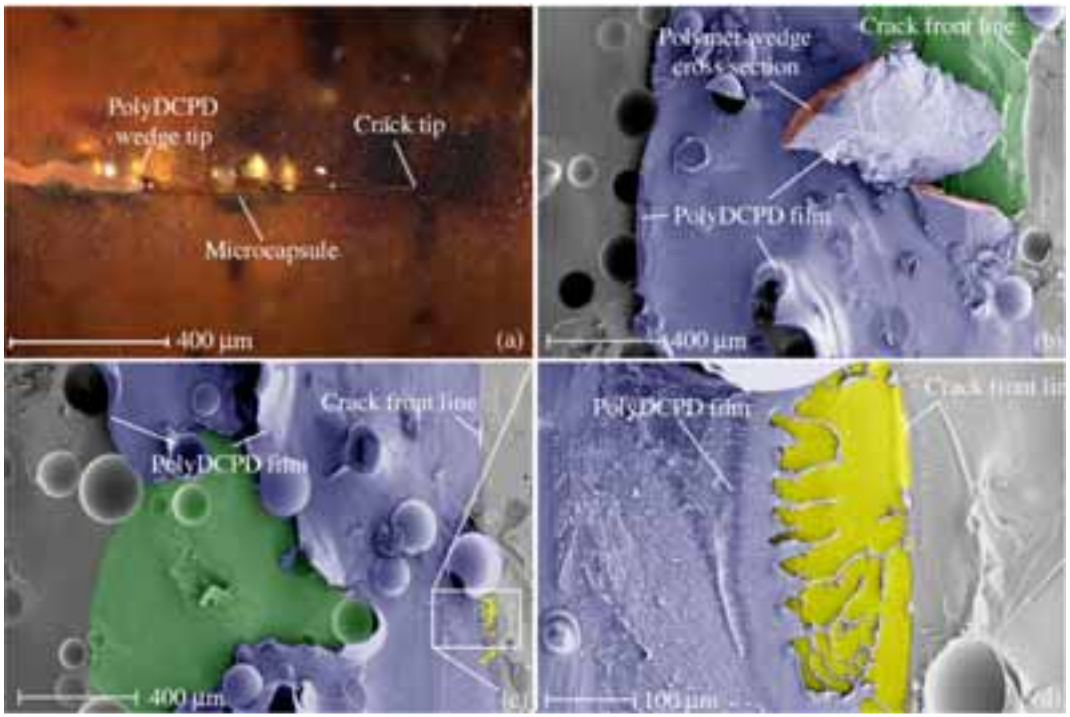




Low-Cycle In Situ Healing

Healed *in situ* with rest period under K_{max} loading





λ = 118%

ΔK_I = 0.405 MPa m$^{1/2}$, K_{max} = 0.450 MPa m$^{1/2}$, K_{min} = 0.045 MPa m$^{1/2}$, R = 0.1, and f = 5 Hz

Conclusions

- **Recover over 90% of virgin fracture toughness**

- **Addition of microcapsules significantly toughens the epoxy**

- ***In situ* healing while under constant load provides crack tip shielding that retards or completely arrests fatigue crack growth**

- **………the introduction of smart materials with autonomic functionality enables a paradigm shift in how we design for material failure**