

Developing Flexible, High Performance Polymers with Self-Healing Capabilities

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Keywords: Self-healing, High Performance Polymers, Microencapsulation

ABSTRACT

Flexible, high performance polymers such as polyimides are often employed in aerospace applications. They typically find uses in areas where improved physical characteristics such as fire resistance, long term thermal stability, and solvent resistance are required. It is anticipated that such polymers could find uses in future long duration exploration missions as well. Their use would be even more advantageous if self-healing capability or mechanisms could be incorporated into these polymers. Such innovative approaches are currently being studied at the NASA Kennedy Space Center for use in high performance wiring systems or inflatable and habitation structures. Self-healing or self-sealing capability would significantly reduce maintenance requirements, and increase the safety and reliability performance of the systems into which these polymers would be incorporated. Many unique challenges need to be overcome in order to incorporate a self-healing mechanism into flexible, high performance polymers.

Significant research into the incorporation of a self-healing mechanism into structural composites has been carried out over the past decade by a number of groups, notable among them being the University of Illinois [1]. Various mechanisms for the introduction of self-healing have been investigated. Examples of these are:

- Microcapsule-based healant delivery
- Vascular network delivery
- Damage induced triggering of latent substrate properties

Successful self-healing has been demonstrated in structural epoxy systems with almost complete re-establishment of composite strength being achieved through the use of microencapsulation technology. However, the incorporation of a self-healing mechanism into a system in which the material is flexible, or a thin film, is much more challenging. In the case of using microencapsulation, healant core content must be small enough to reside in films less than 0.1 millimeters thick, and must overcome significant capillary and surface tension forces to flow, mix and react to achieve healing. Vascular networks small enough to fit into such films must also overcome these same flow limitations. Self-healing has also been demonstrated in ionomeric substrates such as Surlyn®, wherein the heat generated by a projectile impact triggers the latent ability of this substrate to flow back to its original shape. Recent work using Diels-Alder reactions have shown promise in bringing about actual reforming of broken chemical bonds to achieve self-healing [2]. All self-healing mechanisms that rely on the use of inherent latent substrate properties require some degree of polymer chain flow to achieve any significant level of healing.

For use in aerospace applications, a self-healing capability must satisfy the following:

1. Provide excellent self-healing in thin films as well as in thicker substrates
2. Capable of being incorporated into existing high performance substrates, such as polyimides or fluoropolymers
3. Capable of self-healing in defined timeframe

Some early studies into the development of self-healing processes for wiring using microencapsulation were performed at the Kennedy Space Center, and patented [3]. Further consideration of the

challenges associated with development of high performance, flexible, self-healing systems indicate that a combination of self-healing mechanisms may be necessary and the delivery of a microcapsulated healant alone will not suffice. Preliminary work on the development of a high performance polymer matrix with self-healing capability with flowable, sealable properties has shown promise. Figure 1 indicates the ability of such a polymer to begin to heal and fill in voids of a small cut observed over a 45 minutes period of time. Other formulations have indicated self healing ability in less than 30 seconds. Work continues in utilizing the promising concept of such matrices, together with other substrates, blends and/or laminate systems to develop robust, high performance self-healing materials systems.

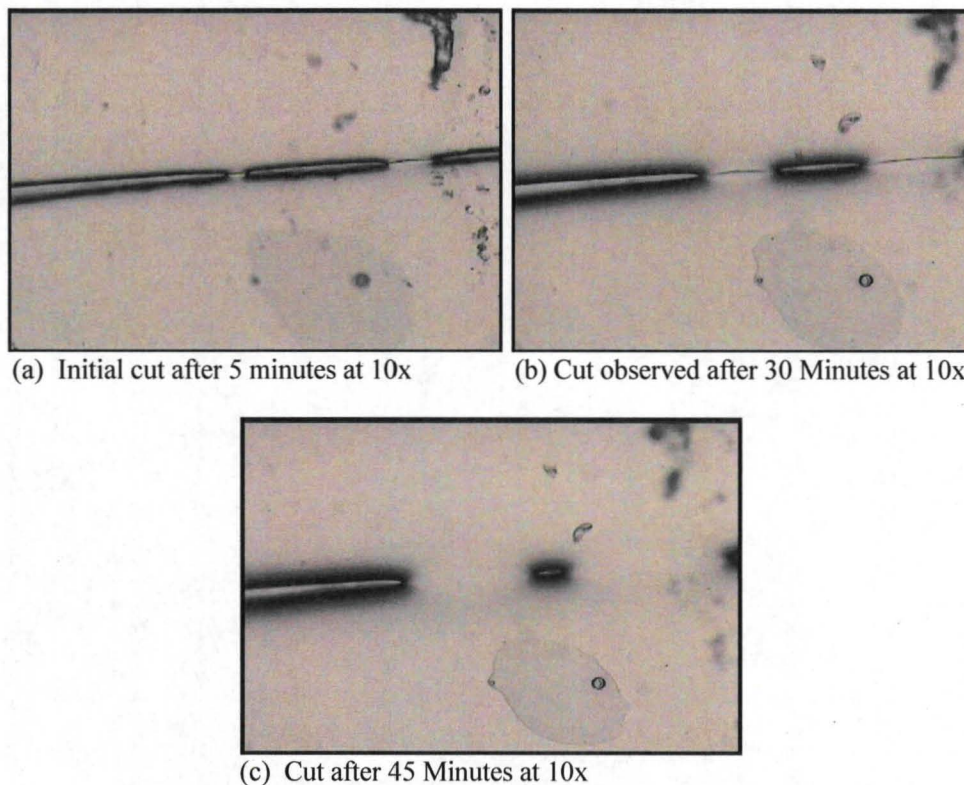


Figure 1. Self-healing progress of a cut made in a high performance polymer film matrix after 5 (a), 30 (b), and 45 (c) minutes

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