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Polymeric Protection of Navy Fighter Jet Towlines

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An Introduction to Towlines: Towed decoys are used to protect military fighter and transport aircraft against radar-guided air-to-air and surface-to-air missiles (Fig. 1). A towed decoy provides an aircraft-like target that draws an oncoming missile away from the aircraft that is being protected. The towline in general consists of a set of conducting and communication members, which is ensheathed by a structurally protective envelope (strength member) made of a high-performance organic fiber. A towline can "burn through" when exposed to a fighter jet's afterburner plume, resulting in the loss of the decoy. This "burn through" is a result of the initial thermo-oxidative degradation of the protective sheath and the subsequent breakdown of the conducting and communication members. The Naval Research Laboratory is part of an undertaking of the U.S. Navy Integrated Defensive Electronic Countermeasures (IDECM) and Radio Frequency Countermeasures (RFC) programs, who share a central objective, which is the development of advanced towline systems that can function at high temperatures and for longer durations. The developmental effort is a collaborative venture that includes teams of chemists, physicists, engineers, and military personnel.

Protective Polymers: Siloxane polymers that contain carborane clusters, developed simultaneously by Olin Laboratories and Union Carbide in the 1960s, have exceptional thermal stability in air. The thermal stability stems from the synergistic electron-withdrawing effect of the carborane clusters that strengthen the Si-O bonds in these polymers more than in siloxane polymers. Research at NRL has furthered the chemistry of these thermo-oxidatively stable polymers by incorporating crosslinkable diacetylene units.[1] The improved polymers, collectively known as poly(carborane-siloxane-acetylene)s or PCSAs (Fig. 2), produce extended network structures through the

FIGURE 1
Photograph of a misdirected missile heading towards a decoy attached to a towline behind a military fighter aircraft.

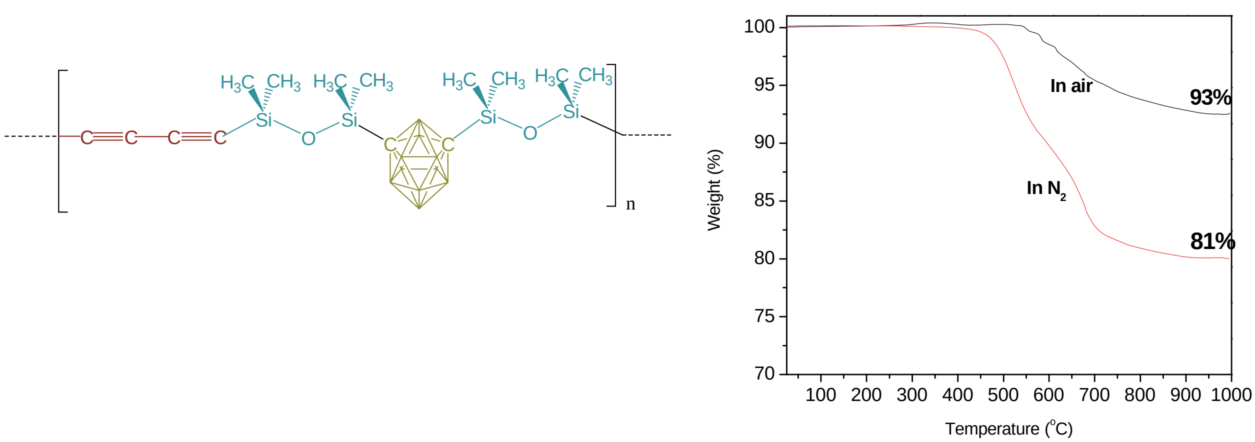

FIGURE 2
Schematic representation of a PCSA polymer (left) and TGA thermograms of its stabilities in air and in N_2 to 1000 °C (right).

thermally initiated crosslinking reactions of the diacetylene groups. The manipulation of the concentration of the diacetylene crosslinking units in the PCSAs allows improvement in their processability and enhancement of their elastic properties.[2] These highly processable PCSAs are ideally suited to protect high-performance organic fiber strength members used in the Navy fighter jet towlines against oxidation.

Protection of High Performance Organic Fibers: The common strength members used in the Navy fighter jet towlines made of materials such as Kevlar, Zylon, and carbon fibers suffer catastrophic thermo-oxidative degradation in the 400° to 700 °C temperature range (Fig. 3). This limits the use of the towlines to temperatures below this range and to very short durations (on the order of seconds). A possible means to extend the operational temperature and the duration of deployment of the towed decoy is to inhibit the oxidative degradation of the towline strength member. Ongoing research at NRL on various organic strength members (Kevlar, Zylon, and carbon fibers) that were coated with PCSAs has demonstrated that the time to degradation, and hence, to failure, of the strength members can be improved by almost 100% under oxidative conditions at high temperatures. The improvement is a direct consequence of the formation of an oxidatively protective sheath on the *strength* member by the PCSAs. Studies have also indicated that a towline *conducting* member can be protected when it possesses a coat of the PCSAs as a protective barrier. This can result in the improvement of the conducting member's insulative properties, thereby enhancing its breakdown voltage and temperature. The protection of the organic fibers by the PCSAs can also have significant impact on the stability of the fibers used in armored vests and in other applications that use high-performance organic fibers.

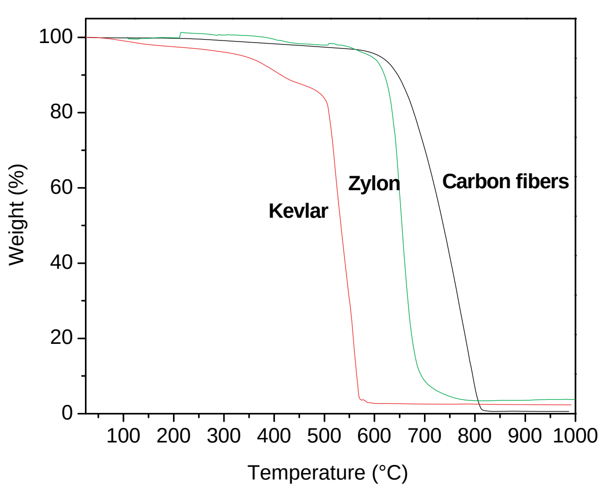

FIGURE 3
TGA thermograms of common towline strength members in air.

Summary and Acknowledgments: Ongoing research at NRL indicates that thermo-oxidative protection of the organic strength member is a viable means of developing improved towlines for use in Navy fighter jets. The benefits of such a protection may be translatable to the case of towline conducting members, which could vastly enhance the utility of this approach. These encouraging findings have led to the initiation of improved towline fabrication for actual flight test simulations. Towards this end, the transitioning of the PCSA technology to industry has been achieved, thereby facilitating the production of PCSAs in bulk quantities. Industrial facilities have also been tasked with applying PCSA coating on strength and conducting members and then assembling improved towlines. The new towline, an example of NRL research for tomorrow's Navy, is slated to be completed in FY2007. The time-to-failure studies and the insulative breakdown studies have been performed at the Materials Science and Technology Division and at the Tactical Electronic Warfare Division, respectively.

[Sponsored by ONR].

References

[1] L.J. Henderson and T.M. Keller, "Synthesis and Characterization of Poly(carborane-siloxane-acetylene)," *Macromolecules* **27**(6), 1660-1661 (1994).
[2] M.K. Kolel-Veetil, H.B. Beckham, and T.M. Keller, "Dependence of Thermal Properties on the Copolymer Sequence in Diacetylene-containing Polycarboranylenesiloxanes," *Chem. Mater*. **16**(16), 3162-3167 (2004).