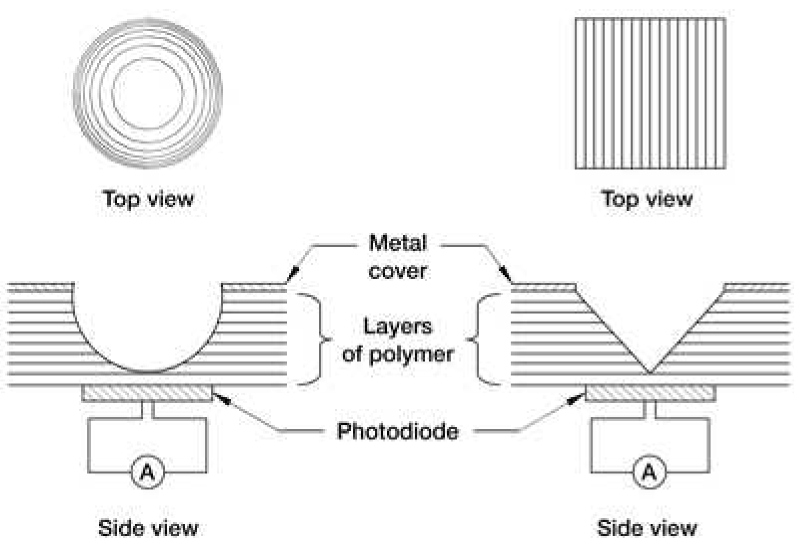
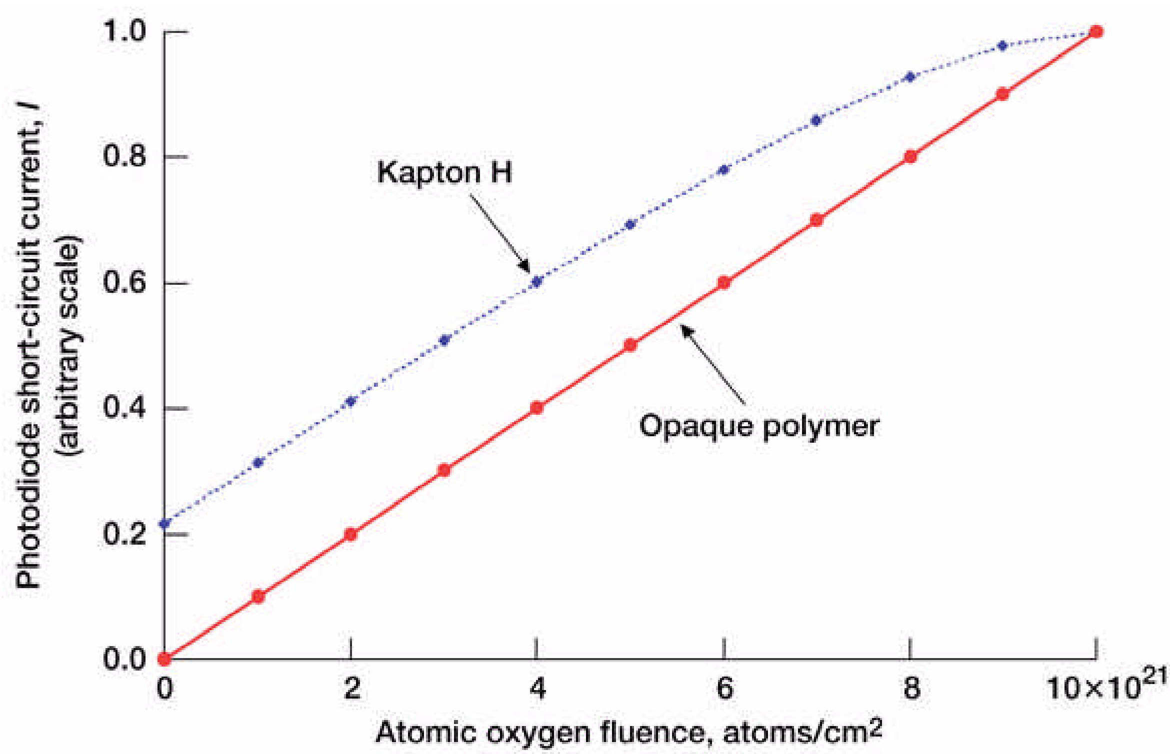
New Active Optical Technique Developed for Measuring Low-Earth-Orbit Atomic Oxygen Erosion of Polymers

Polymers such as polyimide Kapton (DuPont) and Teflon FEP (DuPont, fluorinated ethylene propylene) are commonly used spacecraft materials because of desirable properties such as flexibility, low density, and in the case of FEP, a low solar absorptance and high thermal emittance. Polymers on the exterior of spacecraft in the low-Earth-orbit (LEO) environment are exposed to energetic atomic oxygen. Atomic oxygen reaction with polymers causes erosion, which is a threat to spacecraft performance and durability. It is, therefore, important to understand the atomic oxygen erosion yield *E* (the volume loss per incident oxygen atom) of polymers being considered in spacecraft design. The most common technique for determining *E* is a passive technique based on mass-loss measurements of samples exposed to LEO atomic oxygen during a space flight experiment. There are certain disadvantages to this technique. First, because it is passive, data are not obtained until after the flight is completed. Also, obtaining the preflight and postflight mass measurements is complicated by the fact that many polymers absorb water and, therefore, the mass change due to water absorption can affect the *E* data. This is particularly true for experiments that receive low atomic oxygen exposures or for samples that have a very low *E*. An active atomic oxygen erosion technique based on optical measurements has been developed that has certain advantages over the mass-loss technique. This in situ technique can simultaneously provide the erosion yield data on-orbit and the atomic oxygen exposure fluence, which is needed for erosion yield determination.



Optical atomic oxygen erosion measurement technique. Left: Circular-parabolic-shaped well polymer layer. Right: Rectangular V-shaped well polymer layer.

In the optical technique, either sunlight or artificial light can be used to measure the erosion of semitransparent or opaque polymers as a result of atomic oxygen attack. The technique is simple and adaptable to a rather wide range of polymers, providing that they have a sufficiently high optical absorption coefficient. If one covers a photodiode with a uniformly thick sheet of semitransparent polymer such as Kapton H polyimide, then as atomic oxygen erodes the polymer, the short-circuit current from the photodiode will increase in an exponential manner with fluence. This nonlinear response with fluence results in a lack of sensitivity for measuring low atomic oxygen fluences. However, if one uses a variable-thickness polymer or carbon sample, which is configured as shown in the preceding figure, then a linear response can be achieved for opaque materials using a parabolic well for a circular geometry detector (see the drawing on the left) or a V-shaped well for a rectangular-geometry detector (see the drawing on the right). Variable-thickness samples can be fabricated using many thin polymer layers. For semitransparent polymers such as Kapton H polyimide, there is an initial short-circuit current that is greater than zero. This current has a slightly nonlinear dependence on atomic oxygen fluence in comparison to opaque materials such as black Kapton as shown in the following graph. For this graph figure, the total thickness of Kapton H was assumed to be 0.03 cm. The photodiode short-circuit current shown in the graph was generated on the basis of preliminary measurements-a total reflectance ρ of 0.0424 and an optical absorption coefficient a of 146.5 cm^{-1}.



Short-circuit current as a function of atomic oxygen fluence for the optical atomic oxygen erosion measurement techniques shown in the preceding drawings.

In addition to obtaining on-orbit data, the advantage of this active erosion and erosion yield measurement technique is its simplicity and reliance upon well-characterized fluence witness materials as well as a nearly linear photodiode short-circuit current dependence upon atomic oxygen fluence. The optical technique is useful for measuring either atomic oxygen fluence or erosion, depending on the information desired. To measure the atomic oxygen erosion yield of a test material, one would need to have two photodiode sensors, one for the test material and one that uses a known erosion yield material (such as Kapton) to measure the atomic oxygen fluence.

Find out more about the research of Glenn's Electro-Physics Branch -- http://www.grc.nasa.gov/WWW/epbranch/

Glenn contacts: Bruce A. Banks, 216-433-2308, Bruce.A.Banks@nasa.gov; and Kim K. de Groh, 216-433-2297, Kim.K.deGroh@nasa.gov
Authors: Bruce A. Banks, Kim K. de Groh, and Rikako Demko
Headquarters program office: OAT
Programs/Projects: ISS, EOS, DOD, Future LEO spacecraft