Effect of Microstructure on the Performance of Carbon Fiber Solar Sail Spacecraft

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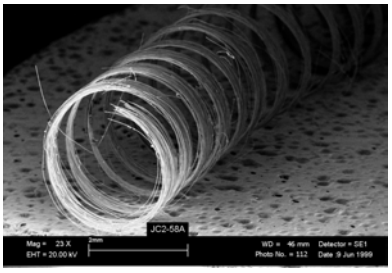
Abstract

Solar sails are spacecraft that use photons for some, or all, of their propulsion and/or attitude control. This propulsion can be provided by the sun, lasers or beamed microwaves. Given the small force typically provided by electromagnetic sources, these spacecraft must be very lightweight. A number of agencies are currently interested in such craft. For example, Geostorms is a mission currently under development by NASA (JPL), NOAA and the USAF to monitor solar wind activity using a 67-m square sail deployed roughly 1.5 Mkm from Earth and maintained in a sub-L1 position using photon pressure [1]. A launch year of 2002 to 2003 is expected. Such a sail will provide two to three times greater warning time of an impeding solar storm on Earth than is currently available.

In this paper, we will focus on the electromagnetic force and toque computations for solar sails formed from carbon fibers. Such sails will provide a number of advantages over conventional materials (such as Mylar and Kapton) including high temperature resistance, immunity to UV degradation and the ability to be elastically self-deployed from rolled stowage.

There are two primary topics of this paper. The first is the computation of the induced electromagnetic force and torque for fibrous sails [2,3]. The second is the effects of sail microstructure on the macroscopic response of the sail to various illuminations. Anisotropy and/or chirality are two types of microstructure that could potentially provide additional degrees of control for these craft. At ESLI, thin carbon fibers (10 μm diameter) have been formed into long helices as shown in the figure. With chirality built into a sail, we will show that it is possible to extract torque from uniform plane wave illumination with randomly changing polarization. Consequently, it is likely that torque can be induced on a chiral sail from unpolarized illumination, such as that provided by incoherent sources. Such motion could provide motional stability and turning capabilities for sailcraft.



References

[1] See <http://www.osd.noaa.gov/sats/geostorms.htm>.

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[3] K. W. Whites and T. R. Knowles, *IEEE Antennas Propagat. Soc. Int. Symp. Dig.*, Boston, MA, pp. 326-329, July 8-13, 2001.