UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

A STUDY OF SEMICONDUCTOR-BASED ATOMIC OXYGEN SENSORS FOR GROUND AND SATELLITE APPLICATIONS

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Near-Earth space is known to be a hazardous environment. For example, operation of satellites in the thermosphere is endangered by atomic oxygen impingement. Oxidative reactions of atomic oxygen erode, or otherwise deteriorate, many of the materials used to fabricate satellites, especially polymers and silver. As a result of these deleterious effects there is a requirement to perform in situ measurements of orbital oxygen atom densities. Review of the literature, coupled with a new quantitative, graphical comparison of the available AO measurement techniques reveals that sensors previously used for these evaluations suffer from several disadvantages, such as large mass and power budgets, and/or limited lifetime of operation. Thus, for these reasons, not one of the methods appears appropriate for regular inclusion on long duration microsatellite missions.

A novel technique has been investigated to create a suitable atomic oxygen detector. The method is based upon the same principles as the increasingly popular semiconductor gas sensor. In this study the semiconductor used is thin film, n-type, zinc oxide, deposited onto an alumina substrate equipped with a heater on the reverse side. Two different designs of sensor have been conceived; the difference between the two models is the method of making electrical contact to the oxide film, which is formed either by thin gold films, or by more robust thick gold interdigitated array.

Laboratory-based experiments have exposed several sensors to hyperthermal atomic oxygen. Upon exposure to this species, the conductance of the semiconductor is observed to decrease. It is found that the sensor response, which is measured by its rate of conductance decrease, is proportional to the magnitude of the flux engendering that change. Moreover, it is discovered that heating the sensor refreshes it, so that the sensor may be employed for further flux measurements - the technique is reusable, unlike many other oxygen atom sensors. Regeneration of the sensor is a complex process; a permanent decrease of conductivity is observed, with no recovery to the pre-exposure value. However, it is found that repeated flux measurements may still be made with the device.

The sensors have also been initialized to determine the axial flux variation in a ground-based atomic oxygen source. The results of this study agree closely with those of another measurement, using a second technique, and with gas dynamic predictions. This research represents the only employment of thin film zinc oxide sensors for the measurement of hyperthermal oxygen atom fluxes. For the first time, a lightweight and low power experiment has been built to demonstrate the application of the devices in Earth orbit on the STRV-1c microsatellite. The design and interface of the experiment is described in detail. Launch of the vehicle is anticipated in spring 2000. Due to the mass and power properties of the unit it is suitable for application to other microsatellite missions.