ON THE THERMAL STABILITY OF POLYIMIDES FOR SPACE APPLICATION

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Abstract

Currently planned missions of ESA (European Space Agency) to the inner part of the solar system will require the use of materials at an extreme radiation/temperature environment. This paper deals with the investigation of the thermal stability of two types of polyimides at a temperature of 350°C. Both materials were assessed by TGA (Thermo Gravimetric Analysis). Further tests were conducted in a high vacuum facility at 350°C. Test data were gathered up to a duration of 2500 hrs. The thermal stability was assessed by mass loss measurements and by UV/VIS/NIR spectrophotometric transmission measurements. Furthermore the degradation behaviour of the thermo-optical properties versus time at this temperature was characterised.

1.0 Introduction

ESA (European Space Agency) is currently planning missions to the inner solar system. The first of such missions named Bepi-Colombo was approved at the end of 2000 as the fifth cornerstone mission of the Horizon 2000 science programme. This mission aims at a comprehensive exploration of the innermost terrestrial planet and aims to find answers about the understanding of planetary formation as well as the evolution in the hottest parts of our solar system [1].

As the environment closer to the sun will be harsher in terms of the impinging solar radiation (particle, UV etc.) such missions set a major challenge to materials and processes (M&P) and will require design solutions that are somewhat different to solutions used for spacecraft (s/c) in Earth orbit applications. The solar irradiance is inverse proportional to the square of the distance from the sun. At the Mercury perihelion for instance at about 0.3 AU it is more than a factor of ten above the averaged earth solar constant of about 1.3 kW/m². Such high solar irradiances will naturally increase the temperature of any s/c in that environment.

For the materials engineer it is therefore important to predict and understand the behaviour of materials at such an environment/temperature. This requires understanding the limits of the available materials, what drives their degradation
mechanisms and whether a material could fulfill its application in a certain environment within the s/c design life. This triggered us to adopt a certain testing & analysis philosophy within the Materials & Processes division. This philosophy is sketched in fig. 1 and has been presented in a previous paper [2].

In this paper results about the thermal stability of two different types of polyimides are presented. Polyimides have been widely characterised in the past and are well known for their thermal stability [3,4,5,6] and their intriguing mechanical properties [7]. Such materials are commonly used on the outside of s/c for thermal control purposes and are good candidates for sunshields [8,9].

The temperatures that such an external layer will reach depend on its solar absorptance ($\alpha$) versus thermal emittance ($\epsilon$) ratio, i.e. the ratio between the amount of the absorbed solar energy and the amount of the thermally emitted radiation. This so-called $\alpha/\epsilon$ ratio can be varied in a wide area with various coatings. For inner solar system missions we want to assess the behaviour of such polymers at extreme temperatures. Figure 2 shows equilibrium temperatures as a function of the $\alpha/\epsilon$ ratio for three different distances. The first would be at 1 Astronomical Unit (AU), the second

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**Figure. 1.** Approach to materials testing & analysis for inner solar system missions