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Article

On the Representativeness of Proton Radiation Resistance Tests on Optical Coatings for Interplanetary Missions

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Abstract: Optical instrumentation used in space normally employs optical coatings. Future interplanetary space missions will be characterized by ever longer stays in environmental conditions where low energy protons represent one of the main types of radiation impacting the coating longevity and performance. To ensure the reliability of coated optics, environmental resistance tests should be accurately planned to be representative for a mission. To this end, the existing standards for coating tests and the test results interpretation have been constantly improved. In this study, we analyze the relevant standards of the European Space Agency (ESA) and of the Chinese Space Agency (CSA) for testing coated optics for interplanetary missions, and in particular for the missions at the Lagrange points. We focus in particular on the applicability of these standards and hence on their possible refinement when specifically implemented to the optical thin films and coatings. We proceed with the development of a methodology for reliable interpretation of the proton irradiation tests for the optical coatings for interplanetary missions, first briefly overviewing the existing tools which allow for space environment simulation and hence deriving the test conditions for the Lagrange points. Furthermore, we apply the approach to testing of aluminum oxide optical coatings for applications in the visible spectral range, concluding on the representativeness of the proposed approach and on possible refinement of the existing standards for coating tests when they are specifically developed for optical applications.

Keywords: optical coatings; space environment; ground simulation test; space test standards; proton irradiation; proton-induced damage; optical instruments; interplanetary missions; Lagrange points; aluminum oxide

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1. Introduction

Space exploration is of fundamental economic and social importance. CubeSat [1,2] and SmallSat missions [3] paved the way to lower the costs of scientific space programs and to the commercial exploitation of space, with a perspective of ever-deeper space missions. Nowadays, the two world major alliances for the peaceful exploration of space, which are the Artemis Accords [4] led by the USA and the ILRS [5] led by China, are working on a series of lunar and deep space missions. The countries invest in exploration of the solar system aiming for the colonization of nearby space and exploitation of the resources other planets and asteroids may make available.

Every space mission requires a dedicated study for modeling the conditions for the environment a spacecraft will work in or fly through. Challenging conditions for coated surfaces in interplanetary environment are represented mainly by corpuscular radiation, by intense electromagnetic radiation (cosmic and gamma rays), and by cryogenic temperatures.