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Hypervelocity impact tests on coated thermoplastic films at cryogenic and elevated temperatures

B.K. Wells*

Space Research Institute, 231 Leach Science Center, Auburn University, AL 36849, USA

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Abstract

The hypervelocity impact facility at Space Research Institute (SRI), Auburn University has recently completed a series of tests on coated thermoplastic films at cryogenic (40 K) and elevated temperatures (420 K). With a 1-in gap, two films were mounted in a frame that applied biaxial tension to each film. The materials were impacted with 40–100 μm soda lime spheres utilizing a plasma drag gun to accelerate the particles to velocities between 5 and 12 km/s. The facility diagnostics allow for the determination each particle's, size, velocity and impact location along with micrographs of the nature of the impact damage. This summary of the test includes a general overview of the nature of damage on the films along with representative impact micrographs of the impact sites.
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Keywords: Hypervelocity; Kapton; Cryogenic

1. Introduction

The current effort developed from a need to verify the viability of the coated thin film sunshield design for the James Webb Space Telescope (JWST). The JWST, shown in Fig. 1, is an infrared-optimized space telescope to be deployed in August 2011 to a Lissajous orbit on the far side of the moon. Initial NASA and industry design concepts for the project incorporate a sunshield to provide passive cooling of the telescope's infrared sensors. Designs for the sunshield include a series of low emissive films spaced in a support frame. The films are expected to experience operational temperatures from 400 K for sun facing films to sub-100 K for films nearest to the detectors. The principal concern regarding the feasibility of the sunshield design is degradation of the sunshield reflective and emissive properties due to cumulative effects of surface penetrations by meteors over the 10-years mission lifetime. [1] The effect of impacts on the integrity of the coatings and extent of delamination and/or crazing needs to be evaluated to develop a suitable design. Additionally, debris generated from the break up of an impacting particle and the material ejected from the impact site can contaminate the telescopic optics. The effect of hypervelocity impacts upon thin film-coated membranes at cryogenic and elevated temperatures has not been previously examined. A limited number of studies has been conducted to assess the effect of target temperature upon impact dynamics and damage

*Tel.: +334 844 5894.
E-mail address: wellsbk@auburn.edu.

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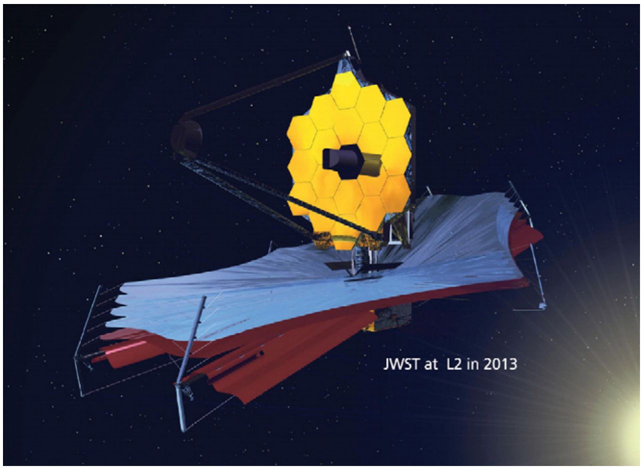

Fig. 1. James Webb Space Telescope (JWST).

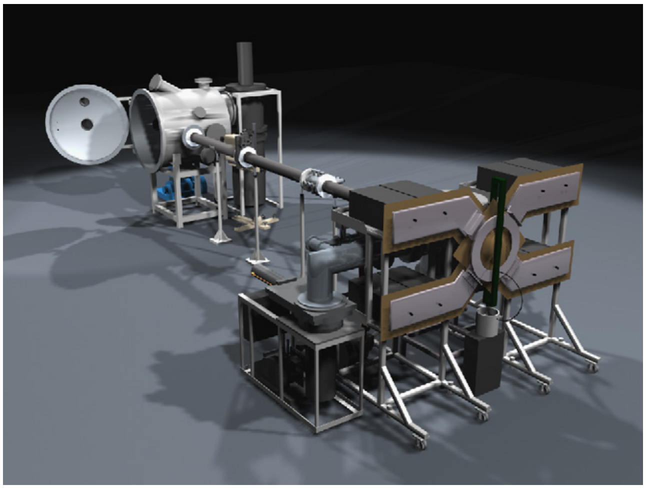

Fig. 2. Auburn hypervelocity impact facility.

estimation for metallic targets [2]. The principal objective of the current work is to summarize the morphology of the impact damage to coated thin film membranes from the preliminary screening tests of the JWST sunshield material. Possible mechanisms for the differences between characteristics observed at cryogenic versus elevated temperature conditions are also proposed.

2. Facility overview

The hypervelocity impact facility at Space Research Institute, shown in Fig. 2, operates a plasma drag gun to simulate the impacts of space debris and micrometeorite materials that occur in the extraterrestrial environment [3]. The facility is capable of accelerating 40–100 μm particles at velocities between 5 and 12 km/s. For each test 5–50 particles impact the sample target in a shot pattern 15 cm in diameter. The diagnostic capabilities of the facility allow the speed, size and impact location for each particle to be determined. During operation the target chamber is evacuated to $\sim 10^{-5}$ Torr and the sample temperatures between 40 and 450 K have been achieved. Within the gun chamber, a 10^6-A arc is discharged from a 40 kV capacitor bank through an exploding foil to generate an expanding plasma. As the plasma moves down the gun barrel, it exchanges momentum with particles suspended within the gun chamber assembly. To reduce gun debris generated by