evaluation of any new simplified approaches that may emerge in the future.

Many topics discussed in this book remain the subject of ongoing research, and better models and methodologies will undoubtedly follow.

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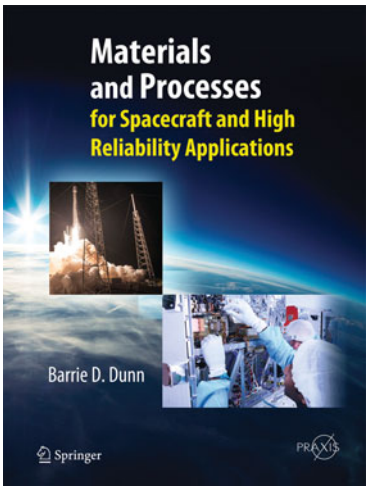

Materials and Processes for Spacecraft and High Reliability Applications

B. D. Dunn

Springer. 2016. 667pp. Illustrated. £126.50. ISBN 978-3-319-23361-1.

This very substantial reference book is an expanded and updated version of the author's previous text *Metallurgical Assessment of Spacecraft Parts, Materials and Processes* (John Wiley & Sons Limited, 1997). As such, it is no longer confined to metallurgy but now covers organic and ceramic materials, together with the processes for applying them within spacecraft equipment and structures. The stated aims of the book are to provide a balance between general background and in-depth technical information, to a target audience spanning engineers, scientists, and technicians: those who need to select suitable materials and processes for a given (usually but not necessarily space-based) application.

As with any good piece of engineering, following the introduction, the book starts by addressing requirements. This includes the general issues and constraints coming from the space environment, but also covers particular requirements for different applications and the issues that may arise through the whole space project lifecycle. This chapter also identifies some novel materials that have potential to meet challenging requirements; those discussed include carbon nanotubes, shape memory polymers and even, fascinatingly, material found in the teeth of limpets.

The focus then moves on to quality, reliability and safety, which forms a major part of the book. Chapter 3 addresses the programmatic aspects of managing materials selection, procurement, and processing. This includes topical issues such as 'greener spacecraft' and increasing restrictions on the use of hazardous materials; chromate primers being one well-known example. The reliability theme is continued in the very extensive Chapter 4, where a range of sources of failure including hydrogen embrittlement, corrosion and stress-corrosion are discussed. Approaches for failure prevention are explored across different applications and

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processes, such as printed circuit boards, a wide range of composites, welding techniques and coatings.

Chapters 5 and 6 address failures: failures and degradation in particular components or equipment (fasteners, thrusters, thermal control surfaces, mechanisms, electrical harnesses, etc.). This material covers what can go wrong, how and why it occurs, how to detect issues and how to mitigate them. Topics covered range from galvanic corrosion in fasteners, through micro-cracking in detector window foils, to cold-welding in mechanisms. A huge number of real-world failure examples are presented, which make for very interesting, if cautionary, reading. Process control, and verification and inspection approaches are discussed, again with examples given. There are extensive figures, data tables, and references provided throughout.

A specific chapter is dedicated to the phenomenon of whisker growth. This again provides examples of failures, and discusses the growth mechanisms and properties of tin whiskers, together with recommended precautions and mitigation practices.

The final chapter presents the information obtained via assessment of materials that have been exposed to the space environment, either operationally or as experimental coupons. There is some interesting discussion of the further lessons learned and process improvements that have resulted from analysis of post-flight items, particularly in the improved understanding of contamination control. There are again some very interesting figures, especially those from returned HST solar arrays.

Multiple appendices are provided to support the main textbook. These include material properties, very comprehensive lists of metal alloy composition data and an extensive glossary of terms. A nice addition is an outline management plan for materials, processes and mechanical parts, which would be suitable for use as a guideline for a small university cubesat project or similar. This includes a flowchart to summarise the key considerations and activities.

Overall, this book provides an immense reference resource. It can be a little daunting to look through as it contains such a huge amount of information. However, it can provide interesting and informative reading for a general materials researcher, as well as specific information for addressing a more targeted enquiry. A very useful book to have available when developing and testing spacecraft equipment.

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