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TESTING PROTOCOL PROPOSAL TO IDENTIFY AND EVALUATE CANDIDATE MATERIALS TO SUBSTITUTE FOR SILVERIZED TEFLON IN THERMAL CONTROL APPLICATIONS.

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Introduction:

Electrostatic discharge (ESD) has been shown to be the primary cause of several glitches in spacecraft operations [NASA RP1375]. It appears that charged particles encountered in the natural environment in certain orbits can collect on the outer surfaces of a spacecraft, building up a charge of several thousand volts. If the potential exceeds the breakdown voltage of the charged material, then an ESD will occur. ESD events involving relatively low voltages, on the order of 100 V, have been shown to damage electronic components. [Matisoff] When ESD occurs, electronic and electrical components can be damaged, computer instructions can be garbled, and ablation of material from the spacecraft may occur; degrading both the performance of the thermal control blankets, and the cleanliness of any surfaces on which the detritus becomes deposited.

There appear to be six ways to prevent or mitigate the effects of ESD. 1) Choose an orbit where charging is not a problem. 2) Carry extra electromagnetic shielding. 3) Provide redundancy in components and programming. 4) Provide for active dissipation of the charge, by generating a plasma with which to bathe susceptible surfaces. 5) Provide for passive dissipation from a plasma contactors on the susceptible surfaces. 6) Provide thermal control blankets that do not hold a charge, i.e., that are conductive enough to bleed a charge off harmlessly. These six options are discussed in detail in Losure (1996). Of these six options, number 1 is not always practical, given other requirements of the mission; 2,3,4 and 5 will require that extra mass in the form of shielding, etc., be carried by the spacecraft. The most attractive option from a mass and energy point of view seems to be that of finding a material which matches the other performance characteristics of the current thermal control blankets without their tendency to build up an electrostatic charge. The goal of this paper is to describe and justify a testing program which will lead to the approval of materials of this kind.

Preselection of candidate materials

The testing program outlined below is directed toward identifying candidate materials for thermal control blankets. As such, only polymers which can be fabricated as thin, transparent film, will be considered. However, other plastic and rubber parts on spacecraft are also known culprits in ESD events, and it may become desirable to seek replacement materials for gaskets, fasteners, cable ties etc. This testing program should also serve to identify and qualify candidates for these applications, with due consideration of the desirable mechanical properties of thick section parts like gaskets.

Thermal control blankets (TCB) are assembled of multiple layers of (usually) silverized Teflon film, with some polyester netting interlayers. TCB have two main functions: to reflect as much solar energy as possible, in order to keep the spacecraft as a whole from thermal cycling, and to absorb the impact of small orbital debris. The successful candidate will possess a balance of thermal, physical and chemical properties that will allow the easy fabrication and installation of thermal control blankets, the thermal and physical protection of the spacecraft, and a long service life under the conditions of the natural space environment. The properties considered important are discussed below, and summarized in Table 1.

The mechanical properties of the TCB's should allow easy fabrication, installation and deployment; so the film should be light weight, tough, flexible, non-blocking and puncture resistant. The tensile strength of the film is not important, above a minimum level sufficient for handling of the film. The tensile strength of Teflon is given in Table 1 as 14 MPa. Teflon is known as a low-strength plastic, and this value should be considered a minimum acceptable value for candidates. Teflon is also a polymer with a high impact strength, which is one of its main advantages. Any serious candidate should have at least 2 Nm/cm impact strength. Teflon also has a high specific gravity, at 2.1 g/cm^3. This is almost double any other polymer, and should be considered a maximum acceptable value. Teflon film is quite flexible at very low temperatures, and this is a desirable for TCB applications, along with a fairly high distortion or melting temperature. Teflon is known as having a very high melting temperature among thermoplastics. Other polymers may not need to meet this high a value to be successful, and careful consideration should be given to specifying a maximum operating temperature for the TCB.

TCB's should have bright mirrored or dazzling white surfaces, so as to reflect as much sunlight as possible. That is, the solar absorbtivity should be as low as possible. On the other hand, the thermal emissivity must be as high as possible, and this is generally promoted by a dark or rough surface. These seemingly mutually exclusive properties are achieved in silverized Teflon and a few other materials, as discussed in Losure (1996). These properties should not deteriorate during the expected life of the spacecraft, due to the orbital environment. Standard tests exist in the literature for these properties at the beginning of life (BOL) of a material. Properties at the end of life (EOL) require the material to subjected the space environment, either in actuality or in simulation.

The materials of TCB's should also be able to stand up to the physical and chemical effects of vacuum, atomic oxygen, and ultraviolet (and other kinds) radiation from the sun, without changing thermal properties, outgassing, or throwing off other kinds of debris. There is no standardized test for these properties, but the literature contains descriptions of testing done under simulated space conditions, which can be adopted. Of course, these earth-bound tests may need to be supplemented by flight testing.

Various kinds of TCB, mainly silverized Teflon, have satisfied the requirements listed above, with the exception of discouraging ESD. Silverized Teflon does not have satisfactory anti-static properties, as it has a surface resistivity of about 10^{18} ohm-cm. A successful TCB candidate should have the lowest possible resistivity, with 10^{12} ohm-cm being the practical maximum. Surface resistivity, bulk resistivity, breakdown voltage, and other electrical properties can be evaluated by means of standardized tests, as described below.

Sources of material properties data.

Materials properties data has been compiled into a number of handbooks and computerized data-bases. In general, values are available for a wide variety of materials and properties, but seldom is any particular material thoroughly treated in any of the resources discussed below. Therefore, though it seems reasonable to use published property values as a guideline to nominate candidate materials, there are enough gaps in the literature to make thorough testing of any candidate material absolutely necessary before qualifying it for flight. Indeed, some of the newer polymer formulations have not even been tested with a space environment in mind, so that no suitable published data may exist. What follows is a discussion of the various sources of property data available to the author.

MATDAT.XLS

This database was compiled during the summer of 1995. It contains values gleaned from the literature for 43 properties of 118 materials. The database is only 21% complete, due to the lack of literature values for very many of the properties or materials of interest. In particular, there is no data in the open literature for silverized Teflon film, or for thermal control blankets. Such data as were gleaned for these entries came from internal NASA sources. Thus, there is a deep lack of readily available data on many materials of interest to the space program. Perhaps data that are available only in laboratory notebooks should be compiled and published to help alleviate this lack, and to avoid duplication of effort.

MAPTIS

MAPTIS is a database of material properties created and administered at MSFC. It concentrates on engineering properties of very specific materials, often identified by manufacturer's trade name. As such, it is useful to spacecraft designers debating the use of one alloy in favor of another. However, the database seems to be very weak in coverage of polymer materials in general, and TCB materials in particular. Indeed, the only values available in MAPTIS for MLI (Multi-layered Insulation, a relative of TCB) was the results of flammability testing. As far as could be determined, there are no values for solar absorbtivity nor infra-red emissivity stored in MAPTIS. Therefore, MAPTIS is not useful for the choice of candidate materials for TCB. Indeed, the results of any testing program should be forwarded to MAPTIS, for inclusion in the database.

NASCAP

NASCAP is a computer program that calculates the charging potential of spacecraft surfaces, given the nature of the surface, and the nature of the space environment. It contains a small database of a dozen or so materials that are currently in use for spacecraft surfaces. The property values included in this data are all related to spacecraft charging; no tensile, thermal or environmental properties are compiled. In addition, some properties like the radiation induced conductive power, are peculiar to NASCAP, and appear nowhere else in the literature. When TCB candidates are identified, these properties peculiar to NASCAP will have to be evaluated, so that they can be incorporated in the spacecraft charging model.

Manufacturer's Literature

For materials that already exist in commercial grades, the manufacturer's literature on material properties can be very helpful. However, it is usually restricted to reporting those values that are of particular interest to the potential customer. Most manufacturers have neither tested nor reported material properties with an eye to the special requirements of the space program. Therefore, it is likely that the manufacturer's literature can be used as a guide for candidate screening, but not as a substitute for in-house testing.

In-House testing.

Equipment and procedures exist in-house at MSFC for performing tests on candidate materials. No comprehensive program to test candidate materials has been undertaken, and the results of other testing performed over the years exist as fragments in memos, short reports and laboratory notebooks. This spot-testing program no doubt was timely and useful when questions of the suitability of a particular material came up, but the fragmentary reporting is a bar to getting the full benefits or the testing that has already been done.

Long Duration Exposure Facility

The Long Duration Exposure Facility (L-DEF) flew with samples of various TCB materials, but no candidates for future TCB applications were flown. In fact, the only polymer films besides Teflon were some samples of Polyethylene film being evaluated for weather balloon applications. The film was destroyed by the orbital environment during the extended stay of the L-DEF on orbit. Thus, there is no data from the L-DEF that seems applicable to the search for new TCB materials, aside from estimation of orbital debris impact rate and energy.

Justification for a testing program for selection of new TCB materials.

It has been shown above, and in other reports (see Losure 1995) that the existing literature on materials properties for currently qualified TCB materials is fragmentary and scattered. Other materials which may be good candidates also suffer from a lack of reporting. Indeed, some of the materials that may be the best candidates are not fully characterized or reported in the literature because they have been commercially available only a short time. In order to solve the spacecraft charging problem by replacing silverized Teflon with a material possessing equivalent or superior physical properties, comprehensive testing must be carried out by NASA, or its contractor. The literature is not reliable except on the level of screening candidates. Material suppliers are not equipped to do the space environmental testing needed.

Therefore, a project to screen, select, and evaluate candidate materials for silver/Teflon replacement is proposed. The work is to be carried out by a Mississippi State graduate student under the supervision of the PI, who holds a faculty position at MSU. Testing will be carried out at both MSU and MSFC, to make the best use of existing facilities. As shown in Table 1, MSU is well equipped to carry on the testing of physical properties, while MSFC is equipped to do the thermal and space environmental testing.

Electrostatic discharges are a constant threat to the operation of spacecraft. Identifying and qualifying TCB materials that will eliminate ESD will greatly increase spacecraft reliability, and decrease overall mission costs due to provision of back-up systems and repair missions. This project will provide a means to approach the goal of zero ESD-related failures in future space operations.

References

Leach, R.D.; and M.B. Alexander, Eds. Failures and Anomalies Attributed to Spacecraft Charging. NASA Reference Publication 1375. August, 1995.

Losure, N.S.; and M.B. McCollum, The ESD Prevention Primer, in progress, August 1996.

Matisoff, Bernard S.; Handbook of Electrostatic Discharge Controls (ESD): Facilities Design and Manufacturing Procedures. Van Nostrand Reinhold Co., New York NY. 1986.

Table 2: Materials Testing Program.

Property	Standard	Sample size & number	Time	Facility	Notes
Tensile strength and modulus	ASTM D-882	10 x 60 mm 5 ea.	24 hr cond.	MSU	This test to be performed on both as-received and SSE samples.
Puncture resistance	FTMS 101C #2031	10 x 4 in	24 hr cond.	MSU	
Flexibility: bending fatigue		film + coating, 3cm wide strips	24 hour con.	MSU	
Density	ASTM D-792	1 - 5 gram	< 1 hr	MSU	
Hardness, Shore		1 in dia.	24 hr cond.	MSU	
Absorbtivity	MSFC internal	film + coating		MSFC	MSU can acquire the necessary equipment for this test.
Emissivity	MSFC internal	film + coating		MSFC	MSU can acquire the necessary equipment for this test.
Color				MSFC	
Surface and bulk resistivity	ASTM D-257 MIL-B-82646	2 x 2 in, 3 ea. 10 x 10 in, 1 ea.	24 hr cond.	MSFC	MSU can acquire the necessary equipment for this test.
ES Decay	EIA-541 Apx. F	3 x 5 in, 5 ea.	48 hr. cond.	MSFC	MSU can acquire the necessary equipment for this test.
Total Mass Loss	ASTM E-595	1 g powder or pellets, 3 ea.	24 hr cond.	MSFC	MSU can use thermogravimetric analysis for this test.
Environmental resistance	ASTM E-512	film,	52 days	MSFC	
LEO environmental resistance	No standard	film		MSFC/shuttle	