Proc. of SPIE Vol. 2864, Optical System Contamination V, and Stray Light and System Optimization, ed. A M Glassford, R P Breault, S M Pompea (Nov 1996) Copyright SPIE

A black and white surfaces and materials database

Susan H. C. P. McCall
Stellar Optics Research International Corporation (SORIC)
78 Normark Drive, Thornhill, Ontario, Canada L3T 3R1
(soric@csr.ists.ca)

Robert P. Breault
Breault Research Organization, Inc. (B.R.O., Inc.)
6400 East Grant Road, Suite 350, Tucson, Arizona, USA 85715-3862
(breault@primenet.com)

Alice E. Piotrowski, John W. Rodney, Lorraine A. Piotrowski
Stellar Optics Research International Corporation (SORIC)

ABSTRACT

Stellar Optics Research International Corporation (SORIC) has compiled one of the world's largest resources of spectral reflectance and Bidirectional Reflectance Distribution Function (BRDF) data for black, white and reflective surfaces and materials. Most of the data has come from formerly proprietary, private sources in the U.S.A., Canada, and the former U.S.S.R., as well as from international, publicly accessible, and private research papers and reports. From this databank, SORIC is creating a series of full-featured, interactive database products available for use with PCs. The first data module that will be released is for BRDF data and the properties of black and white surfaces and materials commonly employed within or viewed by ground-based and space-based instrument applications. The surfaces and materials serve the functions of: (1) stray light control, (2) thermal control, (3) calibration, and (4) visual target cues. The associated BRDF data module can be used with stray light analysis packages, or in conjunction with the black and white surfaces and materials data module. This paper presents an update on the overall database project, and its data modules.

Keywords: black, white, BRDF, BSDF, BTDF, scattering, database, stray light, reflective, absorptive

1. INTRODUCTION

A previous paper[1] outlined the need for a comprehensive database for the properties of black and white surfaces and materials, and Bidirectional Reflectance Distribution Function (BRDF) data, as well as a request for community assistance. This paper outlines the status of the project and summarizes the data donations from the optics community.

Scientists and engineers faced with the task of selecting a black or white surface for a particular application often begin with a set of surface requirements[1,2]: optical requirements of reflectance, emissivity, and/or BRDF; inexpensive; low-risk; durable; easy to apply; and commercially available. For many applications the surface may also have to satisfy special requirements dictated by the end use as well as other parameters such as thermal conduction, adhesion, electrical conduction, outgassing, particulate contamination, particulate generation and resistance to sunlight, humidity and temperature extremes. Space-based applications have many additional requirements, particularly if the surface is to be placed in low earth orbit[3]. These issues can be particularly important in the case of baffles, where black surfaces are used for stray light reduction, since the black surface is often the largest optical surface in the instrument, and a determining factor in system performance. For space-based instrumentation in particular, the performance of space telescopes, space instruments, and space radiator systems depends critically upon the selection of appropriate black, white and reflective surfaces and materials. Many space-based programs have suffered performance limitations and schedule setbacks, and in one case required an expenditure of hundreds of thousands of dollars in damage control because of a lack of readily accessible, accurate data on the properties of black surfaces.

The following are some practical problems that presently confront and often frustrate the individual who must select a black or white surface from commercially available options[1,2]:

• Some of the most appropriate surfaces which were long considered standards are no longer available.

• Data pertaining to the properties of the surfaces and materials are often difficult to find, the manufacturer's data are generally insufficient, and published scientific data are scarce.
• Over the years the names and formulae of the surface preparations, particularly the paints, have changed, causing confusion when one is trying to compare the published or printed data with the presently commercially-available product.
• It can be cumbersome and time consuming to identify the source of existing data. Although it is generally easy to acquire the data once the source has been identified, the process of creating an in-house database can generally take more time than the designer has to select the surface in the first place.
• There are inaccuracies in the published data which the designer may not be aware of.

Over the past several years SORIC has attempted to overcome these problems by compiling a large databank of information, and turning it into a user-friendly, easily-accessible database with the assistance of the donor community (see §3)[1,2,3,4,5]. Although a full database library containing all the compiled data will take many years to complete, a series of smaller database products will be released starting within the next year, the first one of which is for the properties of black and white surfaces and materials and their associated BRDF data. With the help of these database products, it is hoped that the user can overcome the above mentioned problems and thus:
• substantially improve the ultimate system performance;
• minimize the risk of system failure and thus the cost of damage control;
• substantially reduce the costs, time, and scope of a measurement program and/or pre-selection process since much time and money is being unnecessarily wasted by industry and government in the remeasurement of existing data, simply because the designers don't know where to find it.

The utility of the SORIC database has already been successfully used in the selection of black and white surfaces and materials for: target materials for the Space-Station positioning targets and visual cues used to support Space Station robotics operations; space-flight hardware thermal control surfaces for spacecraft radiators and thermoelectric cooler plates; and black baffles and white flat fielding screen calibration surfaces for ground and space-based astronomical telescope projects.

2. DATABASE SCOPE AND FORMAT

2.1 Overall database project

In addition to thousands of spectral reflectance curves, the SORIC databank contains over 60,000 Bidirectional Reflectance Distribution Function (BRDF) data curves. To date, 20 GigaBytes of information has been collected from the donors. SORIC stores it in compressed format on magneto-optical disc. In addition to the digitally formatted data SORIC compiled over 4,000 published and unpublished research papers and reports mostly on the subject of BRDF data and black and white surfaces and materials. The data covers the spectral region extending from the far ultraviolet to the far infrared. SORIC has over 300 in-house samples of black, white, & reflective substances. The database for the properties of black and white surfaces and materials described below is a subset of this larger database project.

2.2 The black and white surfaces and materials data module

Black and white surfaces and materials are employed in almost every optical instrument. SORIC's black and white surfaces and materials database pertains those commonly employed within or viewed by ground-based and space-based instrument applications, serving the functions of:

• stray light control;
• thermal control;
• calibration, and
• visual target cues.

The data module contains data for over three hundred commercially-available black and white surfaces and materials for both ground and space-based instrument applications. It includes numerous specific data fields for the following overall categories of properties:

• optical properties (from the far ultraviolet to the far infrared spectral regions);
• thermal properties;
• mechanical and physical properties;
• electrical properties;

• chemical properties;
• the effects of space-based and ground-based environments on the above properties; and
• manufacturer and vendor information for the commercially available surfaces and materials.

The software for this relational database is being written in Microsoft Access for PCs. The construction types and manufacturing processes of the black and white surfaces and materials represented in the database, include:

• paints and their primers, lacquers and varnishes;
• bulk materials (e.g. glasses, metals, polymers, ceramics, glass ceramics, composites);
• films, foils, tapes and meshes;
• fibers, textiles and fabrics;
• papers and meshes;
• dyes, inks and marking materials;
• anodization processes;
• electrodeposition processes;
• plasma spray deposition processes;
• chemical vapor deposition surfaces;
• vacuum deposition processes, and
• proprietary processes.

The types of applications that the database specifically addresses are:

Database BLACK surfaces & materials applications:

- Apertures
- Calibration Screens
- Choppers
- Cold shields
- Detectors
- Dewars
- Instrument Enclosures
- Laser Beam Terminators
- Lens Edges
- Optical Mounts
- Optical References
- Radiators
- Radiometers
- Room Enclosures & Curtains
- Solar Collector Absorbers
- Standards of Reflectance
- Targets and Visual Cues
- Telescope Vanes & Baffles

Database WHITE surfaces & applications:

- Calibration Screens
- Diffusion Screens
- Integrating Sphere Enclosure Surfaces
- Projection Screens
- Room and Telescope Enclosures & Curtains
- Standards of Reflectance
- Targets & Visual Cues
- Telescope Dome Surfaces

Database REFLECTIVE surfaces & materials applications (for a future database release):

- Planar Mirrors
- Solar Collector Concentrating Reflectors
- Telescope Dome Enclosures
- Telescope Mirrors
- Thermal Blankets

2.3 The BRDF data module

For decades, leaders in the optical stray light community have advocated that a databank and retrieval system should be set up for Bidirectional Reflectance Distribution Function (BRDF) and Bidirectional Transmittance Distribution Function (BTDF) data. Some of the problems and solutions in organizing BRDF data were outlined by Klicker et. al.[6] With the assistance of Dr. R. P. Breault of Breault Research Organization, Inc. (B.R.O. Inc., Tucson, AZ, USA) SORIC is co-developing this data module in conjunction with the black and white data module. The BRDF data module will be used in two ways: (1) as a standalone module in conjunction with light scattering software such as APART (from B.R.O., Inc.) and GUERAP (from Lambda Research Corp.), and (2) in conjunction with the black and white data module, and future specialty data modules. SORIC is grateful to an Expert Advisory Panel of 18 BRDF experts, from industry, university and government, who assisted in giving advice for the BRDF data module (see §5). Given the large number of BRDF curves SORIC now has, the BRDF curves first being entered into the BRDF module correspond to the surfaces and materials being entered into the specialty modules (i.e. the black and white module). All BRDF data is being stored in the ASTM reporting format for scattering data[7].

3. KEY PARTICIPANTS AND DONORS

The key institutions that donated funding, labor and data to SORIC's database project will now be outlined. The Canadian Space Agency (Optics Technology Section) funded the Feasibility Study, and provided the seed funding the data acquisition phase of the project. The National Research Council of Canada's Industrial Research Assistance Program also provided seed funding for the data acquisition phase. The remainder of the data acquisition phase, and the software development phase is funded by SORIC. All labor of those involved in the database creation is on a volunteer basis (i.e. from members of SORIC, the Expert Advisors, and the data donors).

The Major Donors to the database project are those who have donated some or all of: (1) thousands, and in some cases tens of thousands of digital data curves and/or paper documents, (2) funding (cash and in-kind), (3) significant key software, and (4) hundreds, and in SORIC's case thousands of hours of labor. The following are the Major Donor institutions and the individuals who participated in the data transfer and/or approval process:

- Breault Research Organization, Inc. (Tucson, AZ, USA) - Robert P. Breault*, Michael Gauvin, Raymond Castonguay, Wayne Hall, Wally Davidson
- Canadian Space Agency (Saint-Hubert, Quebec, Canada) - Fernand Rheault, Lorne Schmidt
- Jet Propulsion Laboratory (Pasadena, CA, USA) - Paul Willis
- Labsphere, Inc. (North Sutton, NH, USA) - Arthur Springsteen**
- Oak Ridge National Laboratories (re: the Optical Materials Information Service) (Oak Ridge, TN, USA) - Marty Marchbanks, Brigham Thomas, Raymond Miller
- Stellar Optics Research International Corporation (SORIC) (Thornhill, Ontario, Canada) - Susan McCall, Alice Piotrowski, Lorraine Piotrowski, John Rodney, Robert Breault
- Toomay Mathis and Associates (Bozeman, MT, USA) - John Stover, Kelly Kirchner, Marvin Bernt
- University of Arizona, Optical Sciences Center (Tucson, AZ, USA) - W. Wolfe, J. Palmer

* Key Advisor to the BRDF and black surfaces aspects of the database

**Key Advisor to the white surfaces aspects of the database

The following donors have also sent data, reference papers and/or reports to update SORIC on their research which is of pertinence to the database project:

- Leon Begrambekov (LIDASA Ltd. - Moscow, Russia)
- S-K. Chang (Spar Aerospace Ltd. - Brampton, Ontario, Canada)
- Robert Harned (Hughes Danbury Optical Systems, Inc. - Danbury, CT, USA)
- Thomas Leonard (Leonard Research Corportion - Dayton, OH, USA)
- Donald Shepard (Martin Marietta - Denver, CO, USA)
- Sheldon Smith (NASA Ames - Moffett Field, CA, USA)
- Timothy Wise (Opto-Mech Interface Organization - Boulder, CO, USA)
- Hundreds of manufacturers of black and white surfaces and materials, who have given SORIC unpublished research data and product information about their products.

4. CONCLUSION

With the assistance of the hundreds of data donors and the expert advisors, SORIC has compiled one of the world's largest information resources for the properties of black and white surfaces and materials and BRDF data. User-friendly, database modules are being written in Microsoft Access for PCs, to enable end users to overcome many of the difficulties presently encountered with finding and using BRDF data and data for black and white surfaces and materials which are serving the functions of: (1) stray light control, (2) thermal control, (3) calibration, and (4) visual target cues.

5. ACKNOWLEDGMENTS

The authors would like to thank Dr. F. Rheault and the Canadian Space Agency (Optics Technology Section) for generously funding of the feasibility study of the database and for providing partial seed funding for the data acquisition phase of the project. Thanks also go to the National Research Council of Canada's Industrial Research Assistance Program for their partial funding as well. The authors also thank those who are named in §3, who generously donated data and/or labor during the data transfer process, without whom this project would not have been possible. Thanks also go to the following panel of expert advisors for advising on various aspects of the BRDF module:

- Asmail, Clara, C. - National Institute of Standards and Technology (Gaithersburg, MD, U.S.A.)
- Bernt, Marvin - Ball Aerospace (Boulder, CO, U.S.A.)
- Breault, Robert, P. - Breault Research Organization, Inc. (Tucson, AZ, U.S.A.)
- Castonguay, Raymond - Breault Research Organization, Inc. (Tucson, AZ, U.S.A.)
- Church, Eugene L. - Private Consultant (Morristown, NJ, U.S.A.)
- Freniere, Edward - Lambda Research Corporation (Littleton, MA, U.S.A.)
- Glassford, Peter A. - Lockheed Missiles & Space Company Inc. (Sunnyvale, CA, U.S.A.)
- Harvey, James, E. - CREOL, University of Central Florida (Orlando, FL, U.S.A.)
- Kirchner, Kelly H. - TMA Technologies, Inc. (Portland, OR, U.S.A.)
- Leonard, Thomas A. - Leonard Research Corporation (Dayton, OH, U.S.A.)
- Pfisterer, Richard N. - Breault Research Organization, Inc. (Tucson, AZ, U.S.A.)
- Pompea, Stephen M. - S. M. Pompea & Associates; Steward Observatory, Univ. of Arizona (Tucson, AZ, U.S.A.)
- Shepard, Donald F. - Lockheed Martin Astronautics Group (Denver, CO, U.S.A.)
- Smith, Sheldon M. - NASA Ames Research Center (Moffett Field, CA, U.S.A.)
- Springsteen, Arthur W. - Labsphere Inc. (North Sutton, NH, U.S.A.)
- Stover, John C. - TMA Technologies, Inc. (Portland, OR, U.S.A.)
- Wise, Timothy D. - Opto-Mech Interface Organization (Boulder, CO, U.S.A.)
- Wolfe, William L. - Optical Sciences Center, University of Arizona, & Infrared Inc. (Tucson, AZ, U.S.A.)

6. REFERENCES:

1. McCall, S., Sinclair, R., Pompea, S., Breault, R., Spectrally Selective Surfaces for Ground and Space-Based Instrumentation: Support for a Resource Base, SPIE Proceedings, 497, Vol 1945, 1993.

2. Pompea, S., and McCall, S., Outline of Selection Processes for Black Baffle Surfaces in Optical Systems, SPIE Proceedings, 92, Vol 1753, 1992.

3. McCall, S., Pierre, J., Mabee, A., Tennyson, R., Morison, D., Kleiman, J., Iskanderova, Z., Gudimenko, J., The Atomic Oxygen Exposure Effects Module of the Database for the Properties of Black, White, Reflective and Transmissive Spectrally Selective Surfaces, SPIE Proceedings, Vol 2260, 1994.

4. McCall, S., Pompea, S., Breault, R., Regens, N., Reviews of Black Surfaces for Space and Ground-Based Optical Systems, SPIE Proceedings, 158, Vol 1753, 1992.

5. McCall, S., Begrambekov, L., Pierre, J., A Review of Black and Reflective Spectrally Selective Surfaces Developed in the Former U.S.S.R., SPIE Proceedings, Vol 2260, 1994.

6. Klicker, Kyle A., Fuhrman, David M., Bjork, Donald R., A BSDF database, SPIE Proceedings, 270, Vol 1331, 1990.

7. ASTM Designation E 1392-90, Standard Practice for Angle Resolved Optical Scatter Measurements no Specular or Diffuse Surfaces, ASTM Vol 06.01, p. 892.