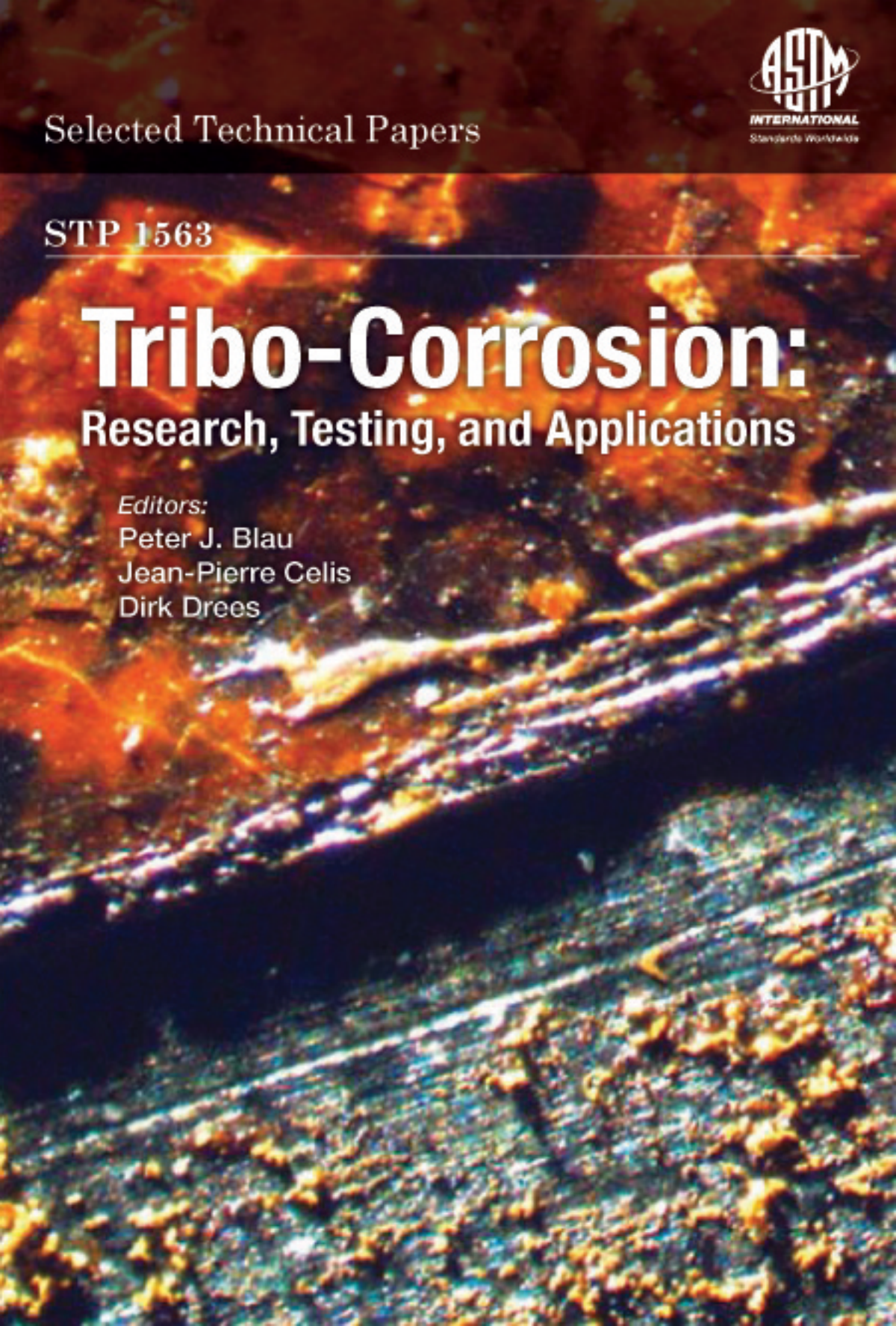
Selected Technical Papers

STP 1563

Tribo-Corrosion:
Research, Testing, and Applications

Editors:
Peter J. Blau
Jean-Pierre Celis
Dirk Drees



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Foreword

THIS COMPILATION OF *Selected Technical Papers,* STP1563, on *Tribo-Corrosion: Research, Testing, and Applications*, contains peer-reviewed papers that were presented at a symposium held April 19–20, 2012 in Atlanta, GA. The symposium was sponsored by ASTM International Committee G02 on Wear and Erosion and Subcommittee G02.40 on Non-Abrasive Wear.

The Symposium Co-Chairpersons were Dr. Peter J. Blau, Oak Ridge National Laboratory, Oak Ridge, TN, USA and Dr. Friedrich Franek, AC2T Research GmbH, Wiener Neustadt, Austria. The STP Editors are Dr. Peter J. Blau, Professor Jean-Pierre Celis, and Dr. Dirk Drees.

Contents

Overview

Tribo-corrosion (alternately spelled "tribocorrosion") is an unfamiliar term to most individuals despite the prevalence of the phenomena that it concerns. The combined costs of wear and corrosion are difficult to determine, but estimates in the hundreds of billions of dollars per year in the United States are not unreasonable. In academic and engineering circles, wear and corrosion are often studied separately, but as the papers in this STP demonstrate, there are many practical situations in which the two processes are inextricably linked. It has only been within the two years preceding this symposium that ASTM Standard G40 "Terminology Relating to Wear and Erosion" was revised to include the following definition:

tribocorrosion, n. – a form of solid surface alteration that involves the joint action of relatively moving mechanical contact with chemical reaction in which the result may be different in effect than either process acting separately. Synonym: *wear-corrosion synergism*.

Once the meaning of tribo-corrosion is understood, numerous important examples become apparent. They range from the interaction of corrosive liquids with processes like erosion and abrasion in chemical plants, mining, petroleum exploration, and agriculture to the elevated temperature oxidation of jet engine bearings and abradable seals. An important subfield of tribocorrosion is concerned with medical and dental implants that rub together in the presence of synovial fluid or saliva. In fact, the last article in this volume proposes a new definition for the term "bio-tribocorrosion" to address this situation.

The papers in this collection begin with tutorial-style discussions of how the chemistry of the surrounding environment can interact with mechanical contact to cause a rapid increase in material loss. A graphical representation of these interactions is described in the second article. The interdisciplinary nature of tribocorrosion is partly the reason why it is not taught at the undergraduate level in universities. It involves a grounding in chemistry, mechanics, and materials that is rarely acquired until at least the post-graduate level. Rare is the university department that offers a course in tribo-corrosion. For that reason, review papers like the first two in this volume will be useful not only to students but to scientists, engineers, and medical practitioners as well.

The papers following the first two describe the role of tribo-corrosion in erosive situations. Examples of implant-related tribocorrosion are then discussed. The next papers address tribo-corrosion in machinery. In two cases, they involve the challenging problem of ensuring reliability of nuclear power plants, and in a third example, how an ASTM test method was adapted to develop materials for engine exhaust valves where wear plus oxidation is a concern.

The paper following that is a historical perspective and case study of the work at a British university that has led to a deeper understanding of tribo-corrosion mechanisms and its applications. The next to last contribution provides a snapshot of on-going collaborations between European professional organizations in the area of corrosion and tribo-corrosion; and the final paper summarizes a concluding discussion held at the symposium. It supplements the results of a written survey of symposium attendees with the comments of a panel of symposium keynote speakers. The need for improvement of ASTM G119 "Standard Guide for Determining Synergism between Wear and Corrosion" is addressed.

The field of tribo-corrosion is at an early stage and greater public awareness and development of diagnostic methods will be required to address future tribo-corrosion needs in medicine, off-shore wind energy, petroleum exploration, nuclear energy, wave energy, propulsion systems, and many more important technical challenges. Basic education in the field is also needed to equip future engineers with the understanding and research methods needed to solve tribo-corrosion problems.

The symposium was the third in a series that was developed under the auspices of the Tribo-Corrosion Network, a voluntary collaboration between research scientists and engineers founded at the University of Strathclyde, Glasgow, UK. The first symposium in the series was held in December 2006 in Hyderabad, India, and the second was held in March 2009 in Wiener Neustadt, Austria. Tribo-Corrosion 2012 was the first international symposium on this subject to be held in the United States and testifies to a growing recognition of the practical importance of wear in the presence of corrosive environments.

More than forty-one scheduled presentations included keynote addresses by international experts in tribo-corrosion. A poster session and a tour of the Manufacturing Research Center (MARC) at Georgia Tech completed the program. The technical papers in this volume highlight the rich diversity of fundamental and applied topics that were presented in Atlanta. The two-day event concluded with a discussion of current needs in tribo-corrosion research that, along with a survey of participants, is summarized in the concluding article of this collection. ASTM Committee G2 has an existing standard on wear-corrosion synergism (ASTM G119), and some of the discussions held at Tribo-Corrosion 2012 may advance its future improvement.

In addition to Co-Chairs Blau and Franek, the steering committee included:

Prof. Richard Cowan, Georgia Institute of Technology (USA)
Prof. Margaret M. Stack, University of Strathclyde (UK)
Prof. dr. ir. Jean-Pierre Celis, Katholieke Universiteit Leuven (Belgium)
Prof. Robert J. K. Wood, University of Southampton (UK)
Dr. Irina Hussainova, Tallinn University (Estonia)
Dr. Stefano Mischler, EPFL (Switzerland)
Dr. Pierre Ponthiaux, Ecole Central Paris (France)

Dr. Manish Roy, Defence Metallurgical Research Laboratory (India)
Dr. Jiaren Jiang, NRC Institute for Fuel Cell Innovation (Canada)
Dr. John J. Truhan, Jr, Caterpillar Inc. (USA)

Plans for a Fourth International Symposium on Tribo-Corrosion are under discussion at this writing.

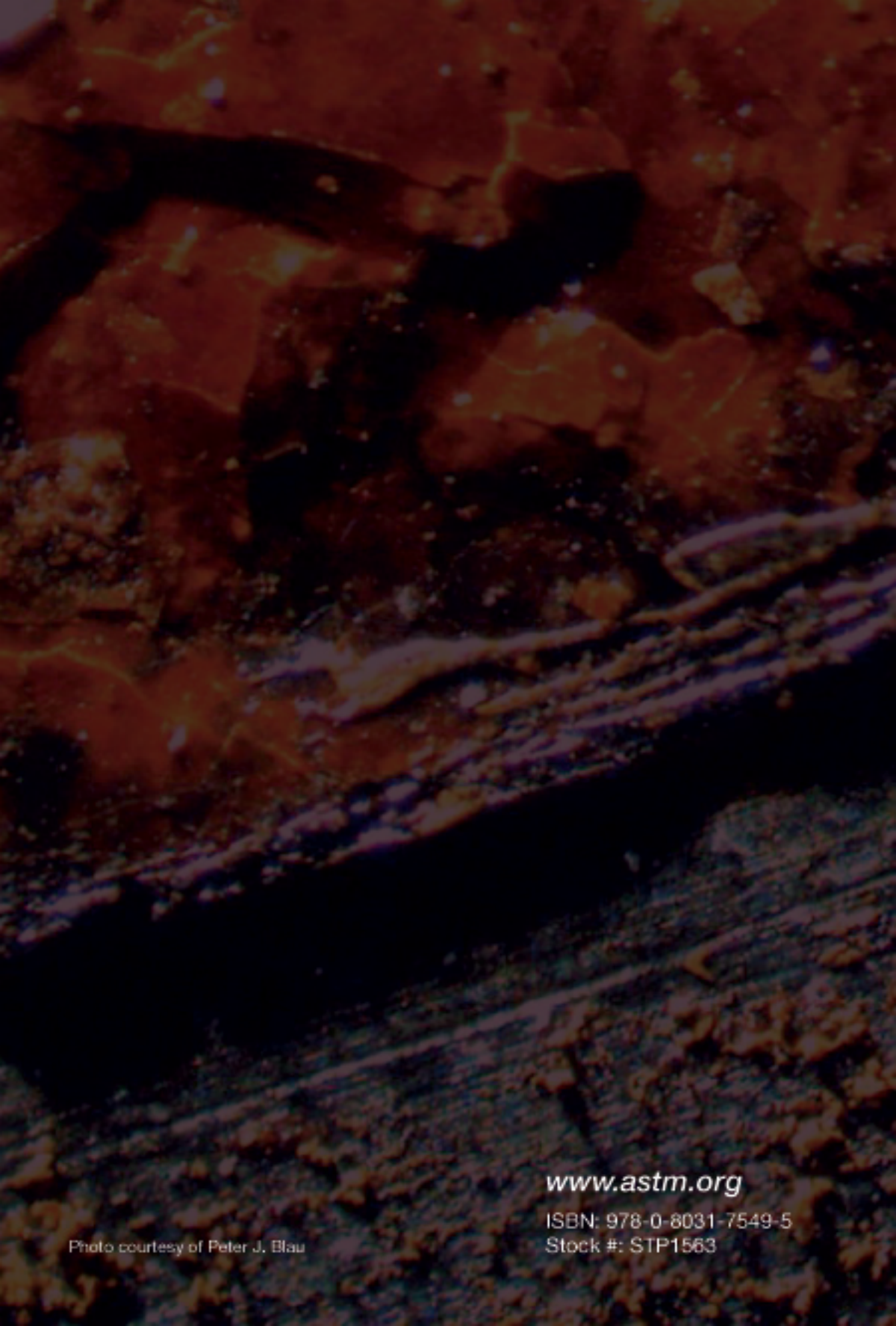
Dr. Peter J. Blau
Materials Science and Technology Division
Oak Ridge National Laboratory (USA)

Acknowledgements

This symposium would not have been possible without the generous support of many people and financial sponsors. In particular, among the steering committee members listed in the Overview, the help of Dr. Rick Cowan, Deputy Director of the Manufacturing Research Center at the Georgia Institute of Technology, was essential in planning local arrangements and securing the facilities. The administrative support of the ASTM International Symposium Manager, Mary Mikolajewski and Meetings Manager, Diane Rehiel was also key to the event's success. Financial support to enable the participation of expert keynote speakers was obtained from the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, and from a grant from Wear of Materials, Inc., a not for profit organization that organizes the bi-annual International Conferences on Wear of Materials.

The organizers wish especially to thank the members of ASTM Committee G2 on Wear and Erosion, Chaired by Prof. Scott Hummel of Lafayette College (USA), for their willingness to support and encourage this event. Lastly, and perhaps most importantly, it is only through the enthusiastic participation of speakers, poster presenters, commercial exhibitors, and attendees that events like this Third International Symposium on Tribo-Corrosion can be successful.

Attendees of TriboCorr 2012 gather in the poster and exhibit area inside Georgia Tech's Manufacturing Research Center (MaRC). First row behind the banner, left to right: R. Cowan, R. J. K. Wood, M. Roy, M. Stack, P. Blau, I. Hussainova, and T. O'Toole (ASTM). Other members of the planning committee included J. Jiang (behind Wood and Roy), E. Badisch (behind Blau and Hussainova), and S. Mischler (behind Hussainova and O'Toole).



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