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Preface

by Tim Rost, 2005 IRPS General Chair

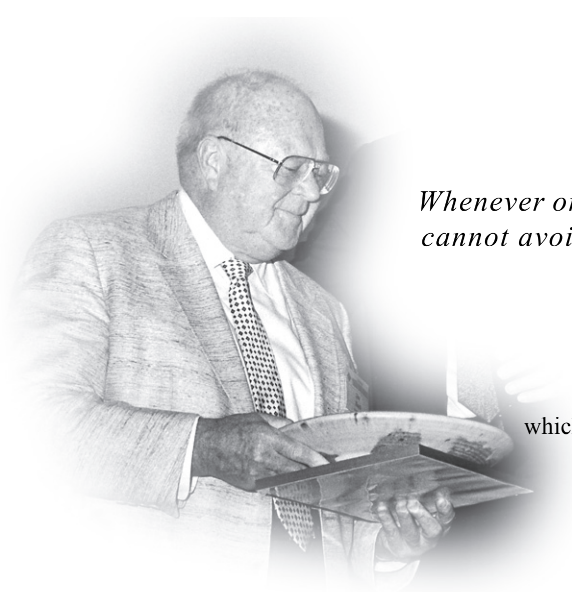
It is truly my pleasure to present the 43rd edition of the IRPS proceedings for your reference. The technical information contained in this volume is the culmination of the efforts of many people, most notably the authors whose work has been selected for publication and is described in detail in the pages that follow. This year we had a record number of submissions, from which a record number of papers were selected. The papers in this volume and their presentation at the Symposium represent the core focus of the IRPS.

These proceedings also represent the efforts of many IRPS technical and management committee members who volunteer their time and energy, along with help from consultants, to help make the IRPS the leading forum for publishing, presenting, and discussing recent understanding in the broad area of microelectronics reliability. To the authors, volunteers, and consultants, I give my thanks for helping make the IRPS an annual success.

This year we have two presentations that I would like to call to your attention. David Yen, from Sun Microsystem's Scalable Systems Group will deliver the Symposium's keynote address. David's presentation is titled "Chip Multithreading Processors Enable Reliable High Throughput Computing" which describes the union of performance and reliability in state of the art microprocessor designs. The other important presentation is a retrospective on Jim Black, presented by Jim Lloyd from IBM. Jim Black was a regular attendee at the IRPS and his foundational work on electromigration has had a profound and long-lasting effect on the semiconductor industry. In his honor, and due to his contributions to the IRPS and the reliability community at large, we are reprinting what is considered to be a foundational paper from the 1967 IRPS titled "*Mass Transport of Aluminum by Momentum Exchange with Conducting Electrons*" that outlines the basics of electromigration physics including the now-familiar Black's Law.

The CDROM companion to the proceedings, which you received as part of your registration package, contains files where color is used which can make viewing data graphs and charts a little easier. Abstracts of the Sunday and Monday tutorials can also be found on the last two pages of these proceedings.

A virtual IRPS 2005 on DVD-ROMs will be available soon after the Symposium (check www.irps.org for availability) that contains video, audio, and presentation material for all of the technical presentations. We hope that you enjoy this Symposium and will consider joining us again at another IRPS.



Jim Black

Whenever one thinks of electromigration failure in integrated circuits, one cannot avoid thinking of "Black's Law"

$$MTF = \frac{1}{A}\frac{1}{j^2}e^{(\phi/kT)}$$

which appeared in *J.R. Black, Proc. 6th Ann. Rel. Phys. Sym., 148 (1967)*

or for those of us who were lucky enough to have known him, of Jim Black himself. His cherubic countenance, sense of humor and modest manner belies the huge effect that his presence and pioneering work had on our community.

Jim didn't discover electromigration, that honor belongs to an otherwise obscure French scientist by the name of Gerardin a century before, nor did he explain the physics of electromigration, an honor shared by a number of scientists over the past few decades. However, Jim did look at the strange and troubling "cracked stripe" failures that had begun to plague the fledgling semiconductor industry and threaten it with extinction before it reached puberty. His pioneering engineering approach to the subject gave us more than Black's Law.

MASS TRANSPORT OF ALUMINUM BY MOMENTUM EXCHANGE WITH CONDUCTING ELECTRONS

James R. Black
Motorola Inc.
Phoenix, Arizona

It is remarkable how many important topics were covered in this initial paper.

1) Effect of step coverage on electromigration lifetime
2) Hillock and whisker formation
3) Effect of texture
4) Grain size effects
5) Temperature dependence
6) Current density dependence

From his analysis, it was determined that electromigration in the wide Al films of the day was via a grain boundary diffusion mechanism. Also that well ordered large grained films are much superior to randomly oriented fine grained films. Most of these findings were rediscovered again and again over the years.

A non-scientific survey of the citation index shows that references to Black's Law have continued unabated since the original publication. If you count references to the three papers by Jim that are usually used to refer to it, we see at least 350 references. This does not count the many times it is mentioned without reference. It has become such an accepted part of our vocabulary that many workers in the field apparently don't see the need to cite the reference. This is not a slight, but an honor.

In 1996 the MRS had a special session honoring 30 years of electromigration research and Jim, of course, was one of the most important contributors to be honored. He had been in retirement a few years and we convinced him to join the other honorees to present a paper. He was actually surprised that anybody remembered what he had done and was a bit taken aback by all the attention that was paid to him. I had the distinct honor and pleasure to be the chair of that session. I was sitting with Jim later during one of the normal sessions and he got to see many references to "Black's Law". He beamed and said "I can't believe it…they're still using that thing." But he was justifiably proud.

All we can do in our lives is to hope that we can have a beneficial effect, that we might have left it a little better for our presence than when we arrived. For all of us who were fortunate to have known him, we know he successfully realized that ambition.

Jim Lloyd

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