# TABLE OF CONTENTS

## Arc Interruption I
Chair: P. Slade  
Co-Chair: G. Horn

1.1 Low-Voltage Arc Simulation with Out-Gassing Polymers ................................................................. 1  
Christian Rümpler, Hartwig Stammberger and Albert Zacharias

1.2 Experimental Investigation of the Interaction of Interrupting Arcs and Gassing Polymer Walls.......... 9  
D. Gonzalez, H. Pursch and F. Berger

1.3 Influence of Voltage and Current on Arc Duration and Energy of DC Electromagnetic Contactor ....... 17  
Kiyoshi Yoshida, Koichiro Sawa, Kenji Suzuki, Masaaki Watanabe and Hideki Daijima

## Young Investigator Award
Chair: E. Smith  
Co-Chair: R. Martens

2.1 A Preliminary Investigation of Graphite, Graphene and Carbon Nanotubes (CNT's) as Solid State  
Lubricants ...................................................................................................................................................... 22  
Andrew Loyd, Jessica Hemond and Rod Martens

2.2 Contact Resistance with Dissimilar Materials: Bulk Contacts and Thin Film Contacts ..................... 31  

2.3 Arc Fault Model of Conductance. Application to the UL1699 Tests Modeling ............................................... 37  
Jonathan Andrea, Patrick Schweitzer and Jean-Mary Martel

2.4 High Current Arc Erosion on Copper Electrodes in Air ........................................................................ 43  
Thomas Øyvang, Elin Fjeld, Wilhelm Rondeel and Svein Thore Hagen

2.5 Whisker Growth under Controlled Humidity Exposure ........................................................................ 49  
E. R. Crandall, G. T. Flowers, P. Lall and M. J. Bozack

## Fundamentals
Chair: R. Timsit  
Co-Chair: Z.K. Chen

3.1 The Effects of Current Density Variations in Power Contact Interfaces ..................................................... 55  
Robert D. Malucci

3.2 Direct Observation of Current Density Distribution in Contact Area by Using Light Emission Diode  
Wafer ......................................................................................................................................................... 62  
Shigeki Tsukiji, Shigeru Sawada, Terutaka Tamai, Yasuhiro Hattori and Kazuo Iida
### 3.3 Effect of Contact Parameters on Current Density Distribution in a Contact Interface

M. Myers, M. Leidner and H. Schmidt

#### Fretting

Chair: B. Malucci  
Co-Chair: B. Rickett

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Fretting Behavior of Nickel Coatings for Electrical Contact Applications</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>S. Noël, D. Alamarguy, S. Correia and P. Laurat</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Research on Fretting Resistance and Fretting Wear Property of Ni-Au Contact Pair</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>Xue-Yan Lin, Liang-Jun Xu, Yan-Chao Shao, Guo-Ping Luo and Hong-Xue Zhang</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Measurement of Contact Resistance Distribution in Fretting Corrosion Track for the Tin Plated Contacts</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Soushi Masui, Shigeru Sawada, Terutaka Tamai, Yasuhiro Hattori and Kazuo Iida</td>
<td></td>
</tr>
</tbody>
</table>

### Relays / Arcing

Chair: C. Leung  
Co-Chair: D. Moore

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Contact Resistance Characteristics of Relays Operated in Silicone-Vapor-Containing and Non-Silicone Atmospheres with Different Electrical Load Conditions</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Makoto Hasegawa, Nanae Kobayashi and Yoshiyuki Kohno</td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Evaluation of Contact Surface Damages with an Optical Cross-Section Method</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Makoto Hasegawa and Keisuke Takahashi</td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>The Effect of Mechanical Parameters of Switch-Type Contact on Relay Operation Characteristics</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Wanbin Ren, Songjun Ma, Guofu Zhai and Huadong Xu</td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>Development of Contact Material Solutions for Low-Voltage Circuit Breaker Applications (2)</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>Timo Mützel and Ralf Niederreuther</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>Transient Phenomena from Melting to Electric Discharge during Making and Breaking Operations of Electric Contacts</td>
<td>123</td>
</tr>
<tr>
<td></td>
<td>Takayuki Kudo, Noboru Wakatsuki and Nobuo Takatsu</td>
<td></td>
</tr>
</tbody>
</table>

### Arc Fault / Electrical Safety

Chair: T. Schoepf  
Co-Chair: H. Czajkowski

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>RF Current Produced from Electrical Arcing</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>John J. Shea and Jason B. Carrodus</td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td>Method to Design Arc Fault Detection Algorithm Using FPGA</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>Michäel Rabla, Patrick Schweitzer and Etienne Tisserand</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td>Influence of Capacitive and Inductive Loads on the Detectability of Arc Faults</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>Peter Müller, Stefan Tenbohlen, Reinhard Maier and Michael Anheuser</td>
<td></td>
</tr>
<tr>
<td>6.4</td>
<td>Characteristics of Overheated Electrical Joints Due to Loose Connection</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>Xin Zhou and Thomas J. Schoepf</td>
<td></td>
</tr>
</tbody>
</table>
Modelling
Chair: X. Zhou
Co-Chair: R. Jackson

7.1 Numerical Study of Asperity Distribution in an Electrical Contact .......................................................... 156
Per Lindholm

7.2 Computational Modeling and Analysis of a Contact Pair for the Prediction of Fretting Dependent Electrical Contact Resistance ................................................................................................. 161
Keiji Mashimo and Yasuyuki Ishimaru

7.3 Discrete Analysis of Gold Surface Asperities Deformation under Spherical Nano-Indentation Towards Electrical Contact Resistance Calculation ..................................................................................... 167
Brice Arrazat, Pierre-Yves Duvivier, Vincent Mandrillon and Karim Inal

7.4 The Effect of Coil on Combined Three-Subsection Permanent Magnet in Close Magnetic Circuit Model ................................................................................................................................. 175
You Jiaxin, Liang Huimin, Ye Xuerong and Zhai Guofu

MEMS/Micro-Contact
Chair: K. Sawa
Co-Chair: R. Coutu

8.1 Gold Coated Carbon-Nanotube Surfaces as Low Force Electrical Contacts for MEMS Devices: Part II, Fine Transfer Mechanisms ........................................................................................................... 179
J. W. McBride, S. M. Spearing, L. Jiang and C. Chianrabutra

8.2 A Nano-Scale Investigation of Material Transfer Phenomena at Make in a MEMS Switch ....................... 185
Christophe Poulain, Alexis Peschot, Maxime Vincent and Nelly Bonifaci

8.3 Compliant Carbon Nanotube-Metal Contact Structures ............................................................................. 192
Onnik Yaglioglu, Rod Martens, Anyuan Cao and A. H. Slocum

Connector Degradation I
Chair: J. McBride
Co-Chair: M. Myers

9.1 A Summary Report on the Mechanism of Electric Contact Failure Due to Particle Contamination ...... 197
Ji Gao Zhang

9.2 Correlation of Intrinsic Thin Film Stress Evolution and IMC Growth with Whisker Growth ............ 205
C. L Rodekohr, G. T. Flowers, M. J. Bozack, R. Jackson, R. Martens, Z. Zhao, E. R. Crandall, V. Starman,
T. Bitner and J. Street

9.3 A Study on Mobile Communication Device Structure Design Resisting Dust Particles Ingress .......... 212
Na Lu, L.J. Xu, Huang Feng and Y.S. Li

Arc Interruption II
Chair: J. Shea
Co-Chair: G. Haupt

10.1 A Study of Arc Duration on Supple Carbon Contacts in the Automotive Field .................................... 220
10.2 Effects of Rotational Motion of Break Arcs on Arc Duration and Contact Erosion .................................. 226
Junya Sekikawa and Takayoshi Kubono

10.3 AC Electrical Arcs with Graphite Electrodes ..................................................................................... 232
E. Carvou, J. B. A. Mitchell, N. Ben Jemaa, S. Tian and Z. Belhaja

High Power Sliding/Contact Resistance
Chair: S. Cole
Co-Chair: D. Gagnon

11.1 Effect of Lubricant on Degradation Process of Au-Plated Slip-Ring and Ag-Pd Brush System for Small Electric Power ........................................................................................................ 238
Koichiro Sawa, Yasunori Suzuki, Noboru Morita, Takahiro Ueno and Kaoru Endo

11.2 Pantograph Arc's Energy Characters under Various Load ...................................................................... 244
Bo Wang, Guangning Wu, Lijun Zhou, Guoqiang Gao, Wangang Wang, Donglai Liu, Dajian Li and Tianzhi Li

11.3 Pantograph Arcing's Impact on Locomotive Equipments ..................................................................... 249
Tianzhi Li, Guangning Wu, Lijun Zhou, Guoqiang Gao, Wangang Wang, Bo Wang, Donglai Liu and Dajian Li

11.4 An Experimental Study to Show the Behavior of Electrical Contact Resistance and Coefficient of Friction at Low Current Sliding Electrical Interfaces ................................................................. 254
V. Siddeswara Prasad, Prashant Misra and J. Nagaraju

Sliding
Chair: Ben Jemaa
Co-Chair: G. Flowers

12.1 There is Tin and there is Tin – Characterisation of Tribological and Electrical Properties of Electroplated Tin Surfaces ........................................................................................................ 261
F. Ostendorf, T. Wielsch and M. Reiniger

12.2 Study on Characterization of Electrical Contact between Pantograph and Catenary ......................... 269
Wangang Wang, Anping Dong, Guangning Wu, Guoqiang Gao, Lijun Zhou, Bo Wang, Yi Cui, Donglai Liu, Dajian Li and Tianzhi Li

12.3 The Effect of Various Atmospheric Temperature on the Contact Resistance of Sliding Contact on Silver Coating Slip Ring and Silver Graphite Brush ................................................................................... 275
Emad Barnawi, Koichiro Sawa, Noboru Morita and Takahiro Ueno

Connectors/Contact Resistance
Chair: J.G. Zhang
Co-Chair: M. Myers

13.1 Peculiar Phenomenon in Friction Coefficient of Tin Plated Connector Contacts with Application of Lubricant .................................................................................................................. 283
Terutaka Tamai, Shigeru Sawada and Yasuhiro Hattori

13.2 Stress Analysis of Dust Particle on the Electrical Contact Surface.......................................................... 290
Yang Lv and Liangjun Xu
13.3 Stress-Strain Response of Copper-Based Spring Materials under Forward and Reverse Deformations and Its Mathematical Description................................................................. 298
Yasuhiro Hattori, Kingo Furukawa and Fusahito Yoshida

Connector Degradation II
Chair: B. Rickett
Co-Chair: R. Martens

14.1 Growth of Sn Whiskers under Net Compressive and Tensile Stress States.............................................. 304
E. R. Crandall, G. T. Flowers, R. Jackson, P. Lall and M. J. Bozack

14.2 Degradation Phenomena of Electrical Contacts Using Hammering Oscillating Mechanism and Micro-Sliding Mechanism- Contact Resistance and Its Model .................................................. 309
Shin-ichi Wada and Koichiro Sawa

14.3 The Influence of the Organic Compounds on the Contaminated Electrical Contacts ......................... 317
Yilin Zhou, Yang Lv and Hao Wang

14.4 Selected Aspects of the Electrical Behavior in Sliding Electrical Contacts........................................... 325
C. Holzapfel

Author Index