The 10th Asian Workshop on Micro/Nano Forming Technology (AWMFT2017)

POSCO International Center, Pohang, South Korea,
October 15-17, 2017

Conference Program

Organized by Korean Society for Technology of Plasticity (KSTP),
JSTP (Japan Society for Technology of Plasticity),
CSTP (China Society for Technology of Plasticity),
TSTP (Taiwan Society for Technology of Plasticity)
## Contents

Welcome message from the conference Chair 1
Organizing committee 2

Part I

Campus Map 6
Program Overview 7

Part II

Technical Program Schedule 10
Titles and Abstracts (Keynotes and generals) 14
Welcome message from the Conference Chair

The Asian Workshop on Micro/Nano Forming technology (AWMFT) is a part of an exchange program organized by JSTP (Japan Society for Technology of Plasticity), CSTP (China Society for Technology of Plasticity), KSTP (Korean Society for Technology of Plasticity), and TSTP (Taiwan Society for Technology of Plasticity). The workshop focused on the various aspects of micro/nano forming technology and provides a chance for academics, researchers, and engineers to meet and exchange information on all aspects of micro/nano forming technology. The 1st workshop was held simultaneously with the 57th Japanese Joint Conference for the Technology of Plasticity in Hokkaido, Japan. The 2nd workshop was held simultaneously with the 11th Chinese Annual Conference for the Technology of Plasticity, which is one of the biggest domestic conferences on technology of plasticity and metal forming in China. The 3rd workshop was held simultaneously with the KSTP. And then the conference was held in Japan, China, and Korea in turn annually. In 2014, the 7th AWMFT was first time organized by TSTP at Taipei city. In 2015, the 8th AWMFT was held in Suwa, Japan. In 2016, the 9th AWMFT was held in Jinan, China. This year KSTP organizes the 10th workshop in Pohang city in the best season of the year. Pohang is the most active and industry-oriented city with nice natural environments with POSTECH the best university in Korea and POSCO the world leading steel company. The workshop aims to provide an opportunity to discuss and exchange ideas on new applications for micro/nano forming as well as new technology developments. We assure that you will find your participation a rewarding experience for broadening your academic knowledge and for serving your personal needs. Several awards are planned for Young Scientists. Pohang is also a very nice place for tourism in the UNESCO heritage city, Gyeongju which is the oldest Korean Sylla dynasty capital. I would like to represent the organizing committee to welcome all of you to attend the conference and visit Pohang and Gyeongju.

Prof. Hyoung Seop Kim
Conference Chair of the 10th AWMFT
ORGANIZING COMMITTEE

International Steering Committee
Prof. Hyoung Seop Kim, POSTECH (Korea)
Prof. Debin Shan, Harbin Institute of Technology (China)
Prof. Ming Yang, Tokyo Metropolitan University (Japan)
Prof. Yeong-Maw Hwang, National Sun Yat-sen University (Taiwan)

Conference Chairman
Prof. Hyoung Seop Kim, POSHECH (Korea)
Prof. Young Hoon Moon, Pusan National University (Korea)

Organizing Committee
Chinese members of organizing committee
De-Bin Shan (HIT)
Kai-Feng Zhang (HIT)
Xin Lu (BRIMET)
Shi-Hong Zhang (CAS-IMR)
Bing Guo (HIT)
Xue-Ping Reng (USTB)
Jian-Jun Li (HUST)
Xiang-Huai Dong (SJTU)
Ke-Fu Yao (Tsinghua Univ.)
Pan Zeng (Tsinghua Univ.)
Ming Wang Fu (Hong Kong Polytechnic Univ.)
Yue-Peng Song (SDAU)
Le-Hua Qi(NWPU)
Guang-Chun Wang (SDU)
Chun-Ju Wang (HIT)

Japanese members of organizing committee
Yasunori Saotome (Tohoku Univ.)
Naoto Ohtake(Tokyo Inst. Tech.)
Shigekazu Tanaka (Shizuoka Univ.)
Ming Yang (Tokyo Metropolitan Univ.)
Zhigang Wang (Gifu Univ.)
Kazuhiro Kitamura (Nagoya Inst. Tech.)
Jun Yanagimoto (Tokyo Univ.)
Hiroshi Utsunomiya (Osaka Univ.)
Takashi Kuboki (The University of Electro-Communications)
Soo-Hyun Joo (Tohoku Univ.)

Korean members of organizing committee
Young Hoon Moon (Pusan National Univ.)
Won Jong Nam (Kookmin Univ.)
Sin Ill Kang (Yonsei Univ.)
Young-Seon Lee (KIMS)
Yong Nam Kwon (KIMS)
Myoung-Gyu Lee (Korea Univ.)
Seong-Hoon Kang (KIMS)
Kwang Seok Lee (KIMS)
S. Praveen (POSTECH)
Young-Sang Na (KIMS)
Hyoung Seop Kim (POSTECH)
Byoungchul Hwang (SNUT)
Jae-II Jang (Hanyang Univ.)
Jong Bae Jeon (KITECH)

Taiwanese members of organizing committee
Jong-Ning Aoh (National Chung Cheng University)
Fuh-Kuo Chen (National Taiwan University)
Yeong-Maw Hwang (National Sun Yat-Sen University)
Cho-Pei Jiang (National Formosa University)
Rong-Shean Lee (National Cheng Kung University)
Jinn-Jong Sheu (National Kaohsiung University of Applied Sciences)
Li-Wei Chen (National Formosa Univ.)
The 10th Asian Workshop on Micro/Nano Forming Technology

**General Secretariat**

Dr. Kwang Seok Lee (ksl1784@kims.re.kr)

Conference Secretariat: hskim@postech.ac.kr
Website: [http://awmft2017.postech.ac.kr](http://awmft2017.postech.ac.kr) / E-mail: awmft-2017@postech.ac.kr
PART I

Campus Map
Program Overview
## Program Overview

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Agenda</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sunday</strong></td>
<td>15/10/2017</td>
<td><strong>18:00-20:00</strong> Welcome Snack&lt;br&gt;&lt;i&gt;Place: 2&lt;sup&gt;nd&lt;/sup&gt; floor of Engineering Bldg. 1 in POSTECH**</td>
</tr>
<tr>
<td></td>
<td>08:00-08:30</td>
<td><strong>Registration&lt;br&gt;&lt;i&gt;Place: 2&lt;sup&gt;nd&lt;/sup&gt; floor of POSCO International Center</strong></td>
</tr>
<tr>
<td></td>
<td>08:30-08:40</td>
<td><strong>Opening Ceremony&lt;br&gt;&lt;i&gt;Prof. Hyoung Seop Kim (Pohang University of Science and Technology, South Korea)&lt;br&gt;AWMFT2017 Conference Chair</strong></td>
</tr>
<tr>
<td><strong>Monday</strong></td>
<td>16/10/2017</td>
<td><strong>Keynote Speech Session I (Chairman: Prof. Hyoung Seop Kim)</strong></td>
</tr>
<tr>
<td></td>
<td>08:40-09:05</td>
<td><strong>Keynote Speech I&lt;br&gt;Prof. Yeong-Maw Hwang</strong></td>
</tr>
<tr>
<td></td>
<td>09:05-09:30</td>
<td><strong>Keynote Speech II&lt;br&gt;Prof. Ming Yang</strong></td>
</tr>
<tr>
<td></td>
<td>09:30-09:55</td>
<td><strong>Keynote Speech III&lt;br&gt;Prof. Jae-il Jang</strong></td>
</tr>
<tr>
<td></td>
<td>09:55-10:10</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td></td>
<td>10:10-12:05</td>
<td><strong>R1 Session I: Micro/nano forming processing and application&lt;br&gt;&lt;i&gt;Chairman: Prof. Myoung-Gyu Lee</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>R2 Session II: Micro/nano forming equipment and simulation&lt;br&gt;&lt;i&gt;Chairman: Prof. Jae-il Jang</strong></td>
</tr>
<tr>
<td></td>
<td>12:05-13:30</td>
<td><strong>Lunch</strong></td>
</tr>
<tr>
<td></td>
<td>13:30-13:55</td>
<td><strong>Keynote Speech IV&lt;br&gt;Prof. Tatsuhiko Aizawa</strong></td>
</tr>
<tr>
<td></td>
<td>13:55-14:20</td>
<td><strong>Keynote Speech V&lt;br&gt;Prof. Cho-Pei Jiang</strong></td>
</tr>
<tr>
<td></td>
<td>14:20-14:45</td>
<td><strong>Keynote Speech VI&lt;br&gt;Prof. Myoung-Gyu Lee</strong></td>
</tr>
<tr>
<td></td>
<td>14:45-15:00</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td></td>
<td>15:00-16:05</td>
<td><strong>R1 Session III: Preparation and properties of micro/nano materials&lt;br&gt;&lt;i&gt;Chairman: Prof. Debin Shan</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>R2 Session IV: Measuring and controlling of micro/nano forming, and Nanocrystallization and nanomechanics&lt;br&gt;&lt;i&gt;Chairman: Prof. Cho-Pei Jiang</strong></td>
</tr>
<tr>
<td></td>
<td>16:05-16:20</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td></td>
<td>16:20-16:45</td>
<td><strong>Keynote Speech VII&lt;br&gt;Prof. Tae-Sung Jun</strong></td>
</tr>
<tr>
<td></td>
<td>16:45-17:10</td>
<td><strong>Keynote Speech VIII&lt;br&gt;Prof. Tianfeng Zhou</strong></td>
</tr>
<tr>
<td></td>
<td>18:00-20:00</td>
<td><strong>Dinner</strong></td>
</tr>
<tr>
<td><strong>Tuesday</strong></td>
<td>17/10/2017</td>
<td><strong>09:00-16:00</strong> Post-Conference Tour (Gyeongju)**</td>
</tr>
</tbody>
</table>
PART II

Technical Program Schedule
Titles and Abstracts (Keynotes and Generals)
## Technical Program Schedule

**Monday, October 16, 2017**  
*Place: The 2nd floor of POSCO International Center*

### Opening Ceremony and Keynote Speech Session Ⅰ (*Room 1, R1*)
*Chairman: Prof. Hyoung Seop Kim*

<table>
<thead>
<tr>
<th>Time</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 08:30-08:40| **Opening Ceremony**  
*Prof. Hyoung Seop Kim (Pohang University of Science and Technology, South Korea)*  
AWMFT2017 Conference Chair |
| 08:40-09:05| **Keynote Speech Ⅰ**  
*Effects of configurations of copper embedded substrates on warpage behavior during packaging process*  
*Prof. Yeong-Maw Hwang (National Sun Yat-sen University, Taiwan)* |
| 09:05-09:30| **Keynote Speech Ⅱ**  
*Development of a novel resistance heating system for micro-forming by modifying die surface*  
*Prof. Ming Yang (Tokyo Metropolitan University, Japan)* |
| 09:30-09:55| **Keynote Speech Ⅲ**  
*What can we additionally estimate through nanoindentation?*  
*Prof. Jae-il Jang (Hanyang University, South Korea)* |
| 09:55-10:10| **Coffee Break** |

### Session Ⅰ: Micro/nano forming processing and application (*Room 1, R1*)
*Chairman: Prof. Myoung-Gyu Lee*

<table>
<thead>
<tr>
<th>Time</th>
<th>Paper ID</th>
<th>Title, Authors</th>
</tr>
</thead>
</table>
| 10:10-10:30| A1(Invited)| **Micro-embossing properties of a metallic glass/aluminum clad sheet**  
*Kwang Seok Lee* |
| 10:30-10:50| A2(Invited)| **Research on uniaxial tensile mechanical properties of TA2 pure titanium foil under ultrasonic vibration**  
*Chunjie Wang, Yang Liu, Bin Guo, Debin Shan, Manman Zhang* |
| 10:50-11:05| A3        | **Deformation behavior of sheath material of superconducting MgB2 wires**  
*Young-Seok Oh, Ho Won Lee, Seon-Myung Park, Duck-Young Hwang, Seong-Hoon Kang* |
| 11:05-11:20| A4        | **Development of warm microforming method utilizing pulsed-current**  
*Ichsan Indhiarto, Tetsuhide Shimizu, Ming Yang* |
### Session II: Micro/nano forming equipment and simulation (Room 2, R2)

**Chairman: Prof. Jae-il Jang**

<table>
<thead>
<tr>
<th>Time</th>
<th>Paper ID</th>
<th>Title, Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:20-11:35</td>
<td>A5</td>
<td>Effect of ultrasonic vibration on piercing of fine grain SUS304 sheet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ken Mita, Jun Hu, Tetsuhide Shimizu, Ming Yang</td>
</tr>
<tr>
<td>11:35-11:50</td>
<td>A6</td>
<td>Circumferential sample-rotation during route B equal-channel angular pressing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hak Hyeon Lee, Ki Chae Jung, Jae Kun Lee, Hong Lae Park, Kyung-Tae Park,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyoun Seop Kim</td>
</tr>
<tr>
<td>11:50-12:05</td>
<td>A7</td>
<td>Development of forging process of micro cup-shape internal gear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chang-Cheng Chen, Cho-Pei Jiang, Bo-Shen Chen</td>
</tr>
</tbody>
</table>

**Session III: Micro/nano forming equipment and simulation (Room 2, R2)**

**Chairman: Prof. Jae-il Jang**

<table>
<thead>
<tr>
<th>Time</th>
<th>Paper ID</th>
<th>Title, Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:10-10:30</td>
<td>B1(Invited)</td>
<td>Blow forming of metallic glass foil using a rapid heating system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Young-Sang Na, Ka-Ram Lim, Kwang Seok Lee, Yong-Hak Lee</td>
</tr>
<tr>
<td>10:30-10:50</td>
<td>B2(Invited)</td>
<td>Influence of different deformation routes on the mechanical properties and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>microstructures of micro-ECAP processed pure Mg specimen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hejie Li, Ken-ichi Manabe, Andreas Öchsner, Kazuo Tada, Zhengyi Jiang,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tsuyoshi Furushima</td>
</tr>
<tr>
<td>10:50-11:05</td>
<td>B3</td>
<td>Micro-bulging properties of Ti foils under ultrasonic vibration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shaosong Jiang</td>
</tr>
<tr>
<td>11:05-11:20</td>
<td>B4</td>
<td>Engineering design for super-hydrophobicity via the femto-second laser</td>
</tr>
<tr>
<td></td>
<td></td>
<td>machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tomoki Hasegawa, Tatsuhiko Aizawa, Tadahiko Inohara, Kenji Wasa</td>
</tr>
<tr>
<td>11:20-11:35</td>
<td>B5</td>
<td>Micro-piercing of electromagnetic steel sheets by nitrided punch and die</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with nearly zero clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Etsuro Katsuta, Tatsuhiko Aizawa, Kunio Dohda</td>
</tr>
<tr>
<td>11:35-11:50</td>
<td>B6</td>
<td>Measurement of cyclic behavior of ultra-thin stainless steel sheets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>based on pre-straining and bending</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jun-Yeol Chae, Shun-lai Zang, Yangjin Chung, Ji Hoon Kim</td>
</tr>
</tbody>
</table>

**Lunch**

### Keynote Speech Session II (Room 1, R1)

**Chairman: Prof. Ming Yang**

<table>
<thead>
<tr>
<th>Time</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:30-13:55</td>
<td>Fine micro-texturing into stainless steels via the plasma printing with</td>
</tr>
<tr>
<td></td>
<td>chemical etching</td>
</tr>
<tr>
<td></td>
<td>Prof. Tatsuhiko Aizawa (Shibaura Institute of Technology, Japan)</td>
</tr>
<tr>
<td>13:55-14:20</td>
<td>Recent development of three-dimensional printing for dental restoration</td>
</tr>
<tr>
<td></td>
<td>device fabrication</td>
</tr>
<tr>
<td></td>
<td>Prof. Cho-Pei Jiang (National Formosa University, Taiwan)</td>
</tr>
</tbody>
</table>
The 10th Asian Workshop on Micro/Nano Forming Technology

### Keynote Speech VI

**Linking microstructure level of properties and macroscopic responses in metals using crystal plasticity simulations**

*Prof. Myoung-Gyu Lee (Korea University, South Korea)*

### Coffee Break

#### Session III: Preparation and properties of micro/nano materials *(Room 1, R1)*

*Chairman: Prof. Debin Shan*

<table>
<thead>
<tr>
<th>Time</th>
<th>Paper ID</th>
<th>Title, Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00-15:20</td>
<td>C1(Invited)</td>
<td>Surface modification of SCM435 by water cavitation using ultrasonic wave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Masataka Ijiri, Daichi Shimonishi, Hiroki Fukunaga, Fumiya Kito, Kumiko Tanaka, Toshihiko Yoshimura</td>
</tr>
<tr>
<td>15:20-15:35</td>
<td>C2</td>
<td>Micro-Joining of stainless steel sheets via plasma surface activation with intelligent induction heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tomoki Sato, Tatsuhiko Aizawa, Tomomi Shiratori, Yoshio Sugita</td>
</tr>
<tr>
<td>15:35-15:50</td>
<td>C3</td>
<td>Effect of polygonal ferrite on the strain aging properties of API X65 pipeline steels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sang-In Lee, Hwan Gyo Jung, Byoungchul Hwang</td>
</tr>
<tr>
<td>15:50-16:05</td>
<td>C4</td>
<td>Manufacturing multiple-strengthened nanocrystalline steel via elevated-temperature severe plastic deformation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jung Gi Kim, Nariman Enikeev, Marina Abramova, Marina Karavaeva, Jae-Bok Seol, Chan-Gyeong Park, Ruslan Valiev, Hyoung Seop Kim</td>
</tr>
</tbody>
</table>

### Session IV: Measuring and controlling of micro/nano forming, and Nanocrystallization and nanomechanics *(Room 2, R2)*

*Chairman: Prof. Cho-Pei Jiang*

<table>
<thead>
<tr>
<th>Time</th>
<th>Paper ID</th>
<th>Title, Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00-15:20</td>
<td>D1(Invited)</td>
<td>Dislocation network formation in coherent twin boundary in face-centered cubic metals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jong Bae Jeon, Tae Hoon Nam, Eunsol An, Gerhard Dehm</td>
</tr>
<tr>
<td>15:20-15:35</td>
<td>D2</td>
<td>Micro-cracks evolution of NiAl alloys by in-situ tensile testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zhen Lu</td>
</tr>
<tr>
<td>15:35-15:50</td>
<td>D3</td>
<td>Investigation of deformation-induced surface roughening based on microstructure analysis in polycrystalline metal sheets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kanta Sasaki, Yannis Korkolis, Koji Kakehi, Tsuyoshi Furushima</td>
</tr>
<tr>
<td>Time</td>
<td>Contents</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>15:50-16:05</td>
<td>D4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multi-response optimization to study single point incremental forming for thin sheet</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Xiao Xiao, Van-Cuong Do, Chan-Il Kim, Young-Suk Kim</em></td>
<td></td>
</tr>
<tr>
<td>16:05-16:20</td>
<td>Coffee Break</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Keynote Speech Session III (Room 1, R1)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Chairman: Prof. Yeong-Maw Hwang</em></td>
<td></td>
</tr>
<tr>
<td>16:20-16:45</td>
<td>Keynote Speech VII</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Understanding rate sensitivity in titanium alloys using micromechanics</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Prof. Tae-Sung Jun (Incheon National University, South Korea)</em></td>
<td></td>
</tr>
<tr>
<td>16:45-17:10</td>
<td>Keynote Speech VIII</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Study on the interfacial adhesion between chalcogenide glass and mold in the microstructure molding process</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Prof. Tianfeng Zhou (Beijing Institute of Technology, China)</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18:00 – 20:00 <strong>Dinner</strong>, D’Medley Buffet, 2nd floor of POSCO International Center</td>
<td></td>
</tr>
</tbody>
</table>
Effects of configurations of copper embedded substrates on warpage behavior during packaging process

Abstract: With the advance of the semiconductor industry and in response to the demands of ultra-thin electronic products, packaging technology has been continuously developed. Thermal bonding process of copper flip chip packages is a comparatively new bonding process in packaging technology, especially for substrates with embedded copper traces. But the relevant process parameters and deformation mechanism are not well known. Embedded copper trace substrates usually warp during the packaging process, which causes a gap between the solder balls and the copper traces, and eventually leads to bonding failure. In this paper, a finite element software ANSYS is used to simulate the thermal deformation behaviors of the substrate during the heating packaging process of an embedded copper trace substrate. A geometric configuration with the same area occupation ratio equivalent to the real structure is constructed to make the simulation of warpage behaviors of the substrates feasible. Taguchi method is used to analyze the effects of the thickness and the area occupation ratio of each layer, on the warpage displacements. Finally, an empirical equation for the warpage displacement is also established.

Keywords: Thermal warpage, Flip chip package, Embedded copper trace substrate, Taguchi method
Monday, October 16, 2017
09:05-09:30 Room 1 (2nd floor)

Prof. Ming Yang

Graduate School of System Design, Tokyo Metropolitan University, Japan

**Development of a novel resistance heating system for micro-forming by modifying die surface**

**Abstract:** Application of resistance heating in micro-forming processes is effective for improving formability of thin foils and accuracy of products. Current flows to micro products can achieve a rapid heating time with very low heating energy owing to the size effect of heat capacity and electrical resistance. Also, it is reported that heating temperature by resistance heating depends on the current density. To control temperature distribution of such as micro product especially thin foils, the heating property depending on the dimensions and own electrical resistivity of the workpiece has to be taken into account. Furthermore, the positioning of electrodes and shape of the products might affect the current density distribution. In previous research, the author propose a novel heating system, controlling the electrical resistance of the die surface by using high density plasma nitriding and annealing process. When current flows from the die, heat generation occurs only on the die surface because the die surface has higher electrical resistance. Therefore the thin foils can be heated by heat conduction from the die. As a result, higher temperature about 700 °C by this method with 17A is achieved and the feasibility of the proposal method is confirmed. However this temperature result is more or less affected by oxide film of the die surface. It is difficult to control temperature because oxide film is brittle and easy to peel off. The author approaches another surface modification process and deposition ceramics of thickness 1 to 5 μm to the die surface on CVD/PVD in this paper. The reason for choosing ceramics as materials of materials is to have not only excellent mechanical property but also high electrical resistance. Firstly heating 1×2 mm rods of three kinds of materials, SUS304, Ti, Cu, is carried out to verify fundamental property of this method. Moreover hot forming of 0.2 mm thickness SUS304 sheet is carried out to confirm applicability of this method to micro-forming.

**Keywords:** Micro-forming, Joule heating, Resistance heating, Surface modification
What can we additionally estimate through nanoindentation?

**Abstract:** Over the past 3 decades, nanoindentation has been used to measure the various mechanical properties of the small volume in a material at much smaller loads and size scales than conventional micro-/macro-indentations. Now, the nanoindentation technique is being considered not only as a characterizing tool but as a promising technology for better understanding of the mechanisms of small-scale mechanical/physical behavior from materials science viewpoints. In this talk, I would like to attempt to show which properties can be "additionally" estimated by nanoindentation and then to explain how this becoming-somewhat-old technique can be "still" very useful for developing new structural materials based on the examples of its applications to the structural materials processed by severe plastic deformation.

**Keywords:** Nanoindentation, Micro-/Nano-Mechanics
Keynote Speech IV

Prof. Tatsuhiko Aizawa

Department of Engineering and Design, Shibaura Institute of Technology, Japan

**Fine micro-texturing into stainless steels via the plasma printing with chemical etching**

**Abstract:** An array of micro-punches and mechanical parts is needed in the micro-manufacturing. In particular, the miniature mechanical systems or MEMS required for the small-sized parts in the scale of 10 to 100 μm with the geometric accuracy of 1 μm. Except for the use of silicon technologies, this kind of micro-fabrication was thought to be difficult or nearly impossible. The present paper was concerning with the micro-fabrication of miniature nozzle chips with the outer diameter of 50 to 100 μm with the geometric accuracy of 1-2 μm. First, the micro-nozzle head shape was designed by CAD and directly drawn onto the AISI304/AISI316 plate with use of the maskless lithography. In second, the high density plasma nitriding system was employed to make selective nitrogen super-saturation only into the unprinted substrate surface at 673 K for 14.4 ks. Owing to this selective nitriding, the printed surface of substrate had bare hardness, 200-250 HV, of AISI304/AISI316 with less nitrogen contents in the trace level. The unprinted surface had higher hardness than 1500 HV with significant nitrogen solute content more than 5 mass%. Since this nitrogen super-saturated surface has sufficient corrosion toughness and chemical inertness, the printed surfaces were only etched chemically. Through these three steps, the micro-nozzle chips with complex shaped inner channels were successfully fabricated as an array. Three dimensional profilometer, the scanning electron microscopy and the laser microscopy as well as the micro-hardness testing were employed to demonstrate the geometric accuracy of these micro-nozzle chip and chip array.

**Keywords:** Plasma printing, Chemical etching, Nitrogen super-saturation, Micro-nozzle chip
Keynote Speech V

Monday, October 16, 2017
13:55-14:20 Room 1 (2nd floor)

Prof. Cho-Pei Jiang
Institute of Mechanical and Electro-Mechanical Engineering, National Formosa University, Taiwan

Recent development of three-dimensional printing for dental restoration device fabrication

Abstract: Three-dimensional printing (3DP) is changing the fabrication method and applying into varying fields because it can form the customization model with lower price and efficiency. In the dental application, the process for dental restoration device such as crown and dental bridge has been limited to lost-wax technology. This method has been used over 100 years but the dental technician utilizes the 3DP technique gradually, which uses computers instead of manual or mechanical tools. It is known as digital dentistry.

Digital dentistry uses computer-assisted devices such as intraoral scanners. Dentist can instantly design restoration device by visualization device and record the patient’s digital data. This treatment progress is far quicker and safer than writing it all on paper. The use of computer aided designing (CAD) and computer aided machining (CAM) resulting in making artificial teeth simply but the investment cost of CAD/CAM is high limiting its promotion.

Dr. Jiang’s Lab is one of the pioneers in academic organization to develop the affordable dental 3D printers. Using the developed 3D printer, the dental restoration device such as zirconia artificial teeth, temporary crown and orthodontic appliances can be fabricated with high speed and quantifiable accuracy but lower cost. Therefore, this speech introduces the trend of digital dentistry and the recent development of Taiwan’s 3D printing technology.

Keywords: Dental restoration device, Three-dimensional printing, Zirconia, Occlusal splint
Keynote Speech VI

Monday, October 16, 2017
14:20-14:45 Room 1 (2nd floor)

Prof. Myoung-Gyu Lee

Department of Materials Science and Engineering, Korea University, South Korea

Linking microstructure level of properties and macroscopic responses in metals using crystal plasticity simulations

Abstract: Crystal plasticity finite element (CPFE) method can be used to predict macroscopic behavior of metals on the basis of microstructural properties and can replace the complicated mechanical experiments. In the present study, the CPFE was applied to identify macroscopic properties of two metals, i.e., an aluminum alloy and a steel. Firstly, the tribological characteristic of an Al 3003 alloy was characterized based on the microstructure-level CPFE simulation results. In particular, the anisotropic behavior of Al 3003 was accurately predicted using the CPFE. Secondly, the CPFE was coupled with a crystallography-based dislocation hardening model to predict non-proportional plastic behavior of an ultra-thin ferritic stainless steel sheet. The simulated results using the newly proposed model for two-step tension (tension followed by tension in other directions) were compared with the experimental results. The predicted results were in good agreement with experimental data. The current works have great significance in such a way that a number of experimental complications or problems can be solved using the CPFE scheme.

Keywords: Crystal plasticity, Material properties, Multiscale, Finite element
Understanding rate sensitivity in titanium alloys using micromechanics

Abstract: Titanium alloys are used as structural load bearing components in aeroengines. In service, these alloys are subjected to significant cyclic loading, with high thrust (i.e. stress) excursions during take-off, a load-hold during flight and unloading on landing. The load-hold has been shown to have a significant effect on the fatigue life performance of many dual phase titanium alloys, where a significant hold at maximum load can reduce the number of cycles to failure by an order of magnitude or more when compared with simple ‘saw-tooth’ load-unload fatigue cycle. This is known as the dwell debit.

Recently, it has been demonstrated that failure is dominated by local microstructure in these alloys, including the presence of a rogue grain combination. During the load-hold, stress is shed from a ‘hard’ grain to a neighbour ‘soft’ grain and local regions of very high stress form [1]. Time dependent stress amplification at local microstructural regions during this load shedding process near the interface is thought to play a prominent role in facet formation. In practice this effect is mitigated by use of dwell insensitive alloys and careful maintenance schedules but management of this phenomena costs the aerospace industry significantly (~£100ms/year). The motivation of this study is to understand the dwell process and in particular to characterise fundamental mechanisms within dwell sensitive Ti-6Al-2Sn-4Zr-2Mo and dwell insensitive Ti-6Al-2Sn-4Zr-6Mo alloys [2]. These alloys have complex dual phase (alpha-HCP and beta-BCC) microstructures that make interpretation of large scale experimental macro-mechanical test specimens especially complicated. We have chosen to fabricate ‘simple’ single colony micro-pillars containing different internal microstructures of pure-alpha phase and mixed alpha+beta phase of particular crystallographic orientations to trigger (near-) single slip in uniaxial deformation. These micro-pillars have been tested in an Alemnis displacement controlled nanoindentation system within the SEM. Tests have been performed with variable strain rates and load-relaxation tests to extract out rate sensitivities of the different slip systems and to understand the role of the alpha and beta phases and local interfaces. To complement and aid interpretation of these tests we have performed crystal plasticity finite element modelling (CP-FEM), with the aim of gaining physical insight into these important micro-mechanical mechanisms. We will present our combined
measurements of the different rate sensitivities of these individual slip systems in these alloys.


**Keywords:** Deformation, Rate sensitivity, Micromechanical testing, Titanium alloys
Study on the interfacial adhesion between chalcogenide glass and mold in the microstructure molding process

Abstract: Microstructure arrays with special functions are widely needed in the imaging and navigation systems, and the infrared glass microstructure array is able to improve the infrared thermal imaging quality. Due to the difficulties of the processing technology, the application of microstructure array for infrared optical component is still in the initial stage. Chalcogenide glass (ChG) is an excellent infrared thermal imaging material and is suitable for precision molding. This paper studies the molding process of microstructure array on the ChG surface. Firstly, the cylindrical molding experiments are carried out and the interfacial adhesion between chalcogenide glass and mold is analyzed. Secondly, the effect of chalcogenide glass internal stress on interfacial adhesion is investigated by finite element method (FEM) simulation, and spherical molding preform is adopted to reduce stress concentration. Finally, the chalcogenide glass microstructure arrays are fabricated with spherical chalcogenide glass preform. By comparing the shape of the molded chalcogenide glass microstructure arrays with that of the corresponding microstructure arrays on the mold, the shape transferability is evaluated.

Keywords: Chalcogenide glass, Microstructure array, Precision molding, Interfacial adhesion
Session I: Micro/nano forming processing and application

Chairman: Prof. Myoung-Gyu Lee
Place: Room 1 (2nd floor)
Time: 10:10-12:05

Paper ID: A1 (Invited)

Micro-embossing properties of a metallic glass/aluminum clad sheet
Kwang Seok Lee

1) Korea Institute of Materials Science (KIMS), South Korea

Abstract: Metallic glasses are known to have good process ability within supercooled liquid region, enabling near-net-shape fabrication through a conventional mold casting followed by controlled warm deformation. However, size limitation of the metallic glasses critically hindered them from utilizing wide industrial application. Another deficiency is that these non-equilibrium alloy systems show an easy tendency to crystallize when annealed or deformed for considerable time in the SLR, which affects many different physical properties of the materials. Hence, process window has to be carefully controlled since thermally induced structural relaxation followed by crystallization typically causes embrittlement and poor formability.

We have, therefore, attempted in this study to report on the way of enlarging application field of monolithic metallic glassy sheets: warm embossing of a quaternary ZrCuNiAl metallic glass/aluminum 1050 thin clad sheets within supercooled liquid region. At 320 °C, conforming to the temperature below Tg, only partial micro-embossing was possible. On the other hand, full micro-embossing seems to be possible at 360 °C and 400 °C, conforming mid-temperatures within supercooled liquid region, though the surface oxidation takes place. This implies that a large dimension of micro-embossed conical arrays has been successfully fabricated under the feasible forming rate and temperatures within supercooled liquid region. Also defect- or crack-free interface between metallic glass and aluminum during warm embossing for short exposure for 210 seconds was confirmed.

Keywords: Micro-embossing, Metallic glass, Clad, Interface
Research on uniaxial tensile mechanical properties of TA2 pure titanium foil under ultrasonic vibration

Chunju Wang\textsuperscript{1)}, Yang Liu\textsuperscript{1)}, Bin Guo\textsuperscript{1)}, Debin Shan\textsuperscript{1}), Manman Zhang\textsuperscript{1})

\textsuperscript{1}) Harbin Institute of Technology, China

Abstract: Metallic materials show softening effect during ultrasonic vibration assisted plastic forming. TA2 commercial pure titanium materials with different grain sizes are prepared by heat treatment. Tensile tests are carried out using ultrasonic vibration assisted uniaxial tensile device. The influence of ultrasonic vibration on flow stress and elongation of the material with different grain sizes is analyzed. Fracture morphologies of the samples are observed by SEM. The results show that the flow stress and elongation decreases with the increasing of grain size. Ultrasonic vibration is able to reduce the flow stress and elongation and soften the material to some extent. The smaller the grain is, the more obvious the effect of ultrasonic vibration is. Also, the number of dimples in the middle of the fracture increases under ultrasonic vibration.

Keywords: Ultrasonic vibration, Softening effect, Flow stress
Deformation behavior of sheath material of superconducting MgB2 wires

Young-Seok Oh1), Ho Won Lee1), Seon-Myung Park1), Duck-Young Hwang2), Seong-Hoon Kang1)
1) Korea Institute of Materials Science (KIMS), South Korea
2) Kiswire Advanced Technology, South Korea

Abstract: For large-scale applications of MgB2 superconducting wires, it is important to make kilometer-long wires with uniform superconducting characteristics at all parts of the wire. MgB2 mono wire consists of MgB2 powder and sheath materials that protect superconducting material. Several mono wires are bundled together to form a Multi-filamentary wire. In the manufacturing processes of MgB2 wire, the boron particles penetrate into the relatively weak sheath material and breakage of wire can occur when deformation concentrated on locally thinned sheath material. Because the breakage of sheath material makes intermetallic compounds which cause degradation of superconducting properties, it is very important that the thickness of sheath material must be maintained uniformly during the manufacturing process. In this study, we investigate deformation behavior of sheath material with different powder density and accumulated strain on MgB2 wires. Multi-filamentary MgB2 wires with 1mm diameter were fabricated by drawing and groove rolling processes with different density of MgB2 powder mixture. Deformed shape and thickness changes of sheath material were observed by optical microscopy depending on the diameter of wire and density of powder. The local hardness of sheath material was measured by Vickers hardness tester. The thickness distribution of the sheath material was more uniform and the local hardness of sheath material is lower for the MgB2 wire made by groove rolling compared to that made by drawing. Therefore, the rolling process is more advantageous for making uniform filaments because of its uniform distribution of thickness and low hardening of sheath material.

Keywords: MgB2 Superconducting wire, Sheath material, Groove rolling, Drawing
Development of warm microforming method utilizing pulsed-current
Ichsan Indhiarto¹), Tetsuhide Shimizu¹), Ming Yang¹)
¹) Tokyo Metropolitan University, Japan

Abstract: Prior researchers showing electric current can reduce flow stress in metalforming, called electroplasticity effect [1]. Due to Joule Heating, the deformed material still exposed by side effect from forming in elevated temperature. In attempt to resolve this, forming with assistance of pulsed-current was investigated. Prior research found the rms of current density as the main contributor of electroplasticity [2]. But it was also discovered on relatively same rms current density value, the flow stress differs with different peak current density. However, deep research on peak current density effect to reduce stress flow in relatively cool temperature has not been conducted. Thus further investigation in effect of peak current density while maintaining relatively constant rms value and low temperature need to be done.

Uniaxial tension test was performed on pure titanium sheet. Peak current density and rms current density isolated from each other by utilizing low duty cycle. Based on prior research [3], pulse frequency and rms current density kept to be constant to provide better control on contributing variable. Pulse width change according to nominal peak current to produce relatively constant rms current.

With that method, contribution to electroplasticity effect from elevated temperature, rms value of current density, and pulse frequency can be minimized. Thus effect of peak current density on material stress flow to achieve warm microforming can be properly investigated.


Keywords: Electroplasticity, Pulsed-current, Peak current density, Cold microforming
Effect of ultrasonic vibration on piercing of fine grain SUS304 sheet

Ken Mita\textsuperscript{1)}, Jun Hu\textsuperscript{1)}, Tetsuhide Shimizu\textsuperscript{1)}, Ming Yang\textsuperscript{1)}
\textsuperscript{1)} Tokyo Metropolitan University, Japan

Abstract: Recently as demand for micro devices increases, micro fabrication technology which enables high productivity, low cost, and good qualities of the formed micro parts has attracted attention. However, size effect exists during the miniaturization of parts, such as in a micro piercing process. In particular, problems such as the surface roughness and the variation in processing precision occur, so that the application of fine grain materials has been studied. The miniaturization of the piercing process leads to an increase of fractured surface and acceleration of tool wear. This is because the ductility of the material decreases due to the refinement of the grains, and the deformation resistance increases.

In attempt to resolve this, piercing with assistance of ultrasonic vibration was investigated. Prior research found that micro piercing with assistance of vibration decreases shearing load and improves ductility of the material [1]. It is attributed from stress superposition and acoustoplastic softening [2]. On the other hands, prior researchers showing that the grain size affects flow stress when the thickness of specimen decreases to micro scale [3]. However, the influence of ultrasonic vibration on different grain size of the specimen has not yet been investigated.

To investigate the ultrasonic vibration effect on micro piercing, experiment was conducted on stainless steel sheet with two different grain sizes. The frequency of 60kHz and three different amplitudes were adopted in ultrasonic vibration. With this method, as the amplitude of ultrasonic vibration increases, the maximum shearing load tends to decrease. Thus effect of ultrasonic vibration amplitude on fine grained materials to reduce flow stress could be investigated.


Keywords: Piercing, Ultrasonic vibration, Fine grain materials, Shearing force
Circumferential sample-rotation during route B equal-channel angular pressing

Hak Hyeon Lee¹), Ki Chae Jung²), Jae Kun Lee³), Hong Lae Park⁴), Kyung-Tae Park²), Hyoung Seop Kim¹)

¹) Pohang University of Science and Technology (POSTECH), South Korea
²) Hanbat National University, South Korea
³) Poongsan R&D Institute, South Korea
⁴) Defense Industry Technology Center, South Korea

Abstract: Equal-channel angular pressing (ECAP), which is a representative process of severe plastic deformation (SPD) processes, has a unique feature that the cross-sectional dimension of the workpiece is preserved after the process. Due to this interesting feature, the ECAP process can control the mechanical and microstructural properties of the materials through repetitive passes. In this work, it is confirmed that the sample rotation occurs during repetitive passes of the ECAP process of the circular-shape workpiece. Although the equivalent strain of the workpiece processed by ECAP is generally known to be uniform along the longitudinal direction, interestingly, the sample rotation occurs during the repetitive passes and causes the inhomogeneous equivalent strain along the longitudinal direction. Thus, this investigation on the various process routes in ECAP was conducted using the finite element analysis. As a result, it was confirmed that the strain inhomogeneity between the top and bottom regions of the single-passed workpiece causes the sample rotation during the ECAP process. In addition, the higher the strain hardening exponent of the materials, the greater the sample rotation during the ECAP process because the strain inhomogeneity with respect to the cross-section is intensified by the formation of corner gap between the workpiece and die.

Keywords: Equal-channel angular pressing, Finite element method, Severe plastic deformation
Abstract: With the ever-changing technology, most of the components gradually toward the development of thin and light, micro-component is an inevitable trend. By using the forging, the metal material was directly pressed into the mold cavity to produce the micro internal gear with the plastic deformation of metal material. This micro gear producing process has the advantage of saving material and time. The main purpose of this paper is to explore a micro cup-shape internal gear with the module of 0.15mm for copper alloy (C1100) by forging process. On forging procedures, the teeth punch with a module of 0.15mm firstly was designed, and then the metal material was put into the lower die; when pressing stroke the material will be forced into the teeth cavity and to form a micro internal gear component. The microstructure of the material can be observed by metallographic treatment techniques, so that the flow of material at the time of filling is clearly available.

Keywords: Gear forging, Cup-shape internal gear, Forging process
Blow forming of metallic glass foil using a rapid heating system
Young-Sang Na1), Ka-Ram Lim1), Kwang Seok Lee1), Yong-Hak Lee1)
1) Korea Institute of Materials Science (KIMS), South Korea

Abstract: It is quite well known that bulk metallic glass (BMG) shows superplastic-like viscous deformation behavior in its supercooled liquid region. Blow forming was suggested and considered as a potential process for fabricating BMG parts such as cases or skins for electronic devices by employing superplastic-like deformation behavior of BMG alloys.

In this study, we investigated the effect of alloy’s fragility and heating rate on the blow forming ability of Zr-based BMGs. 2 Zr-based BMG alloys (Zr<sub>60</sub>Ni<sub>25</sub>Al<sub>15</sub> ternary BMG and Zr<sub>62</sub>Cu<sub>17</sub>Ni<sub>13</sub>Al<sub>8</sub> quaternary BMG) were selected for investigating the alloy’s fragility effect. In particular, we focused on the heating rate effects on the blow forming ability of a BMG alloy in the range of 10 K/s ~ 200 K/s. Infra-red heating system combined with light-guide rod was developed in order to realize the very rapid heating rate up to 200 K/s. It was concluded that the higher the heating rate, the better the blow forming ability of BMG alloys. In addition, it was clear that the fragile BMG alloy (Zr<sub>62</sub>Cu<sub>17</sub>Ni<sub>13</sub>Al<sub>8</sub>) showed better formability when compared with the strong BMG alloy (Zr<sub>60</sub>Ni<sub>25</sub>Al<sub>15</sub>)

Keywords: Metallic glass, Supercooled liquid, Blow forming, Gas pressure molding
Influence of different deformation routes on the mechanical properties and microstructures of micro-ECAP processed pure Mg specimen

Hejie Li¹), Ken-ichi Manabe²), Andreas Öchsner³), Kazuo Tada³), Zhengyi Jiang⁴), Tsuyoshi Furushima¹)

¹) The University of Tokyo, Japan
²) Tokyo Metropolitan University, Japan
³) Griffith University, Australia
⁴) University of Wollongong, Australia

Abstract: Due to the unique physical and mechanical properties of its products, the ultra-fine grained (UFG) technology has attracted lots of attention. In this technology, the significant feature is the microstructural refinement which is introduced through heavy straining in severe plastic deformation (SPD) techniques [1]. As one of the typical technology of SPD, equal channel angular pressing (ECAP) is very promising in producing the UFG material. In this study, the fully annealed pure Mg specimens are processed by a new developed micro equal channel angular pressing (MECAP). MECAP processes with different deformation routes are conducted to analyze their related influences on mechanical properties and microstructure of pure Mg specimen. During MECAP process, microstructure evolution along extrusion direction (ED) is analyzed by JEOL JSM-7100F Field Emission Scanning Electron Microscope (FE-SEM). Texture and grainsize and grain orientation are the current research focus on microstructure. The micro hardness test is employed to analyze the surface mechanical property. Based on the experimental results, relationship between different deformation routes, processing parameters and mechanical properties and microstructure of MECAP products will be investigated. Then a set of optimized MECAP processing parameters will be developed to further improve mechanical properties and microstructure of ECAP processed Mg product. Further medical application of this MECAP processed products will be explored in future.


Keywords: Micro-forming, Light-weight metal
Micro-bulging properties of Ti foils under ultrasonic vibration
Shaosong Jiang*1)
1) Harbin Institute of Technology, China

Abstract: The benefits of ultrasonic vibration auxiliary for metal forming have been shown by many studies. In this study, the effect of ultrasonic vibration on tensile behavior of Ti foils was investigated; then, the microstructure of different tensile samples was analyzed by transmission electron microscopy (TEM). The tensile tests showed that the flow stress decreased steeply when the ultrasonic vibration was applied, whereas the elongation of these samples increased. Additionally, the range of flow stress reduction was inversely proportional to the time for which ultrasonic vibration was applied. The TEM images showed that the parallel re-arrangement of dislocations could be observed and the mass of dislocation tangles was mostly absent in samples with ultrasonic vibration. The increase in plastic strain during tension tests with ultrasonic vibration of Ti foils has been successfully demonstrated to implement the micro-bulging process. This illustrates that the application of ultrasonic is a promising method to make structural parts.

Keywords: Micro-bulging, Ti foil, Ultrasonic vibration
Engineering design for super-hydrophobicity via the femto-second laser machining

Tomoki Hasegawa¹, Tatsuhiko Aizawa¹, Tadahiko Inohara², Kenji Wasa³

¹ Shibaura institute of technology, Japan
² LPS -WORKS Co.Ltd., Japan
³ TECDIA, Co. Ltd., Japan

Abstract: Hydrophobicity and super-hydrophobicity grew up as a key surface engineering to keep clean and fresh surface of products and to control the liquid flow on the product surfaces. The low energy surface has lower attractive capacity to other material atoms and molecules. In parallel with the chemical treatment, the idea of lotus effect was high-lighted to form the hydrophobic surfaces. Furthermore, the micro- or nano-texturing processes were developed with use of the femto-second laser to control the surface state from hydrophilic to hydrophobic conditions.

The present paper was concerning with the surface geometric design to control the contact angle and the micro/nano-texturing on to the metallic surface by the femto-second laser machining. The micro- and sub-micro textured surface was constructed onto the stainless steel substrate via the femto-second laser micro-texturing in the similar manner to the laser induced periodic surface structuring (LIPSS). Under the present LIPSS, the ripples with high spatial frequencies were formed on the micro-textured surface by the interference of the incident and refracted laser lights with the scattered or diffracted light near the surface. It is possible to create super-hydrophobicity surface by this micro-texturing.

The physical relations between the micro/nan-texture size and aspect ratio and the contact angles were investigated for thirty laser-treated specimens. Both the FFT (Fast Fourier Transformation) and inverse-FFT were utilized to make quantitative understanding on these relations between the surface geometries in the physical space and the spatial waves in the spatial frequency domain. The optimized fractal geometry for super-hydrophobicity was deduced and demonstrated by measurement of the contact angle up to 170°.

Keywords: Super-hydrophobicity, Femto-second laser machining, Micro- and nano-texturing
Micro-piercing of electromagnetic steel sheets by nitrided punch and die with nearly zero clearance

Etsuro Katsuta¹, Tatsuhiko Aizawa¹, Kunio Dohda²

¹ Shibaura institute of technology, Japan
² Northwestern University, USA

Abstract: The electromagnetic steel core was an essential element of electric motors. Reduction of the shear drops and burrs as well as the residual stresses was needed to significantly reduce the iron losses of sheets in piercing. In addition, the complex shape of motor core must be also transferred through the piecing die set. In the present study, a pair of piercing punch and core-die was fabricated to have nearly zero clearance between the outer diameter of punch and the inner diameter of core-die. The SKD11 nitrided punch and core-die were prepared and hardened up to 1500 HV by using the high density plasma nitriding system. This punch and core-die pair was fixed into a cassette die-set for CNC micro-stamping system. The electromagnetic steel sheet with the thickness of 0.505 mm was used as a work material. Table-top CNC stamping system was employed for shearing process to punch out the circular discs from the electromagnetic steel sheet. During this process, the loading transients were in-situ monitored to describe the relationship between the applied load and the punch stroke, and, to discuss the effect of nearly zero-clearance on the micro-piercing performance.

The piercing load - stroke histories were compared among the micro-piercing with different clearances. The fracture surface ratio as well shear drops and burrs were much reduced with decreasing the clearance. The electromagnetic sheets were blanked only with the burr height ratio of 3 % and the burnished surface area ratio of 90 %. The punch outer diameter was reduced down to 1 mm to discuss the micro-piercing behavior with increasing the aspect ratio of the punch diameter to the sheet thickness.

Keywords: Micro-piercing, Nearly-zero clearance, Electromagnetic steel sheets, Nitrided punch and die
Measurement of cyclic behavior of ultra-thin stainless steel sheets based on pre-straining and bending

Jun-Yeol Chae\textsuperscript{1)}, Shun-lai Zang\textsuperscript{2)}, Yangjin Chung\textsuperscript{3)}, Ji Hoon Kim\textsuperscript{1)}
\textsuperscript{1)} \textit{Pusan National University, South Korea}
\textsuperscript{2)} \textit{Xi’an Jiaotong University, China}
\textsuperscript{3)} \textit{POSCO, South Korea}

Abstract: Cyclic behavior of ultra-thin stainless steel sheets was measured using an inverse-optimization approach with pre-straining and bending. Tensile specimens were pre-strained, and three-point bending was conducted for the pre-strained specimens. By using the inverse finite element optimization with the surface layers, the combined isotropic-kinematic hardening parameters were found that minimize the error between the measured and predicted bending force-displacement curves. The effect of surface layers was analyzed.

Keywords: Bauschinger effect, Inverse optimization, Kinematic hardening, Surface effect
Surface modification of SCM435 by water cavitation using ultrasonic wave
Masataka Ijiri¹, Daichi Shimonishi¹, Hiroki Fukunaga¹, Fumiya Kito¹, Kumiko Tanaka¹, Toshihiko Yoshimura¹
¹ Tokyo University of Science, Japan

Abstract: This study investigated the removal of voids in steel by combining ultrasonic irradiation and water jet cavitation (WJC), which is a mechanical surface modification method. This technique is referred to as multifunction cavitation (MFC). When a water jet ejected by a nozzle impacts a metal surface, WJC leads to the generation of high pressure when the cavities within the water collapse near the surface. This pressure causes a slight deformation of the impacted surface region and introduces compressive residual stress due to the elastic constraints of the underlying and surrounding metal. If ultrasonic irradiation is applied to WJC bubbles with diameters of several hundred microns, the bubbles are subjected to alternating high and low sound pressures, which leads to high pressures and a high-temperature reaction field. In SCM435 of the alloy steel for mechanical structure processed by WJC, voids and cracks were observed in specimen inside in exchange for the compressive residual stress. On the other hand, no such defects were found in MFC processed specimens. Furthermore, the MFC process caused a more efficient conversion of tensile to compressive stress, and also improved the corrosion resistance of the material.

Keywords: Surface reforming, Water jet cavitation, Multifunction cavitation
Micro-joining of stainless steel sheets via plasma surface activation with intelligent induction heating

Tomoki Sato¹, Tatsuhiko Aizawa¹, Tomomi Shiratori², Yoshio Sugita³

¹ Shibaura Institute of Technology, Japan
² Komatsu--Seiki--Kosakusho, Japan
³ YS--Electric Industry, Japan

Abstract: Miniature products and members required for the micro-joining process to integrate them into the complex-shaped system with tailored functionality. Metallic micro-pump consisted of a joined assembly of several to ten thin stainless steel sheets by DC-pulse heating method at 1273 K for two hours. In the present paper, the plasma surface activation with intelligent induction heating was proposed as an alternative process to lower the joining temperature, to shorten the duration time and to reduce the production cost for high qualification of metallic micro-pumps.

Each stainless steel sheet was stacked into an assembly with the designated distances. RF/DC high density plasma with use of argon and hydrogen mixed gas activated the open sheet surface to reduce the oxide film thickness. This treated sheets were stacked again and shifted to the induction heating section in the nitrogen atmosphere. This stack of stainless sheets was successfully joined by the diffusion bonding at 973 K (or 700 °C) for 1.8 ks.

Keywords: Micro-joining, Plasma surface activation, Intelligent induction heating, Oxidized passive films
Effect of polygonal ferrite on the strain aging properties of API X65 pipeline steels

Sang-In Lee¹, Hwan Gyo Jung², Byoungchul Hwang¹

¹ Seoul National University of Science and Technology, South Korea
² POSCO, South Korea

Abstract: This study was concerned with the effect of polygonal ferrite (PF) on the strain aging properties of API X65 pipeline steels. Three kind of pipeline steels with different PF volume fraction were fabricated by varying rolling and cooling conditions, and then their microstructure was quantitatively examined using electron backscatter diffraction (EBSD) analysis. In order to simulate UOE pipe forming and coating processes for pipeline steels, tensile tests were conducted before and after 1% pre-strain and thermal aging at 200 °C and 250 °C. The PF fraction was increased with decreasing finish rolling and start cooling temperatures, while the fraction of bainitic ferrite was decreased with decreasing cooling rate after hot rolling process. The tensile tests results indicated that strength and yield ratio were increased, whereas ductility and work hardening exponent were decreased after the pre-strain and thermal aging due to strain aging phenomenon. It has been known that strain aging is associated with interaction of the mobile dislocation and interstitial atoms such as carbon and nitrogen in PF. The relatively soft PF is preferentially deformed and increases dislocation density during tensile testing. As a result, the steel with the highest PF fraction exhibited the largest decrease in uniform elongation after the pre-strain and thermal aging because mobile dislocation movement is restricted by the increased dislocation density after 1 % pre-strain.

Keywords: Polygonal ferrite, Strain aging, Pipeline steels
Abstract: Material strength is determined by the dislocation mobility during plastic deformation. In the metallic materials, each strengthening mechanisms act as obstacles to dislocation glide and the superior strength can be achieved by the maximal amount of obstacles. The elevated-temperature severe plastic deformation process supports to activate strengthening mechanisms by imposing large shear strain. Based on the multiple strengthening mechanisms with solute segregation engineering, we enhanced the strength of a single-phase face-centered cubic Fe−15 atomic percent Mn alloy, reaching values of 2.6 GPa. We found that solute segregation at grain boundaries and dislocations achieves higher strength of nanograin and nanotwinned structures than segregation-free counterparts with the same size domains and twins. The importance in the application of multiplicity in deformation mechanisms suggests the development of a wide range of strong nanotwinned, nanostructured materials with grain boundary segregations and featured by maximal density of these crystal lattice defects.

Keywords: Severe plastic deformation, Nanocrystalline materials, Multiple strengthening mechanism
Dislocation network formation in coherent twin boundary in face-centered cubic metals

Jong Bae Jeon¹), Tae Hoon Nam¹), Eunsol An¹), Gerhard Dehm²)
¹) Korea Institute of Industrial Technology, South Korea
²) Max-Planck-Institut für Eisenforschung, Germany

Abstract: Face-centered cubic (FCC) materials containing twins such as twin-induced plasticity (TWIP) steels and nano-crystalline copper and nickel exhibit an attractive combination of properties such as strength and ductility. Recently there has been thus a significant interest in the deformation behavior of FCC metals involving twins. Traditionally the coherent twin boundary (CTB) is regarded as a strong barrier to dislocation penetration unless dislocations run though the boundary or transfer with easy cross-slip. Although it is well established that slip is strongly affected by twin boundaries, the detailed aspects of dislocation-twin boundary interactions are not yet fully understood.

We here present the detailed reactions between dislocations and CTB, and the resultant formation of dislocation networks in several FCC metals using atomistic simulations. It is found that dislocation networks are mainly composed of sessile Frank dislocations and partially of sessile stair-rod and Hirth dislocations and glissile twinning dislocations. The density and type of dislocations in the networks were found to be dependent on the materials’ factors such as generalized stacking fault energy and also external factors like loading axis. The present work could provide insight to understand the source of the huge work-hardening rate and high stability of twin boundaries in FCC metals.

Keywords: Face-centered cubic materials, Twin boundary, Dislocation network
Micro crack evolution of nano alumina enhanced NiAl during high temperature in-situ tension
Lu Zhen$^{1}$

$^{1}$ Harbin Institute of Technology, China

Abstract: Nano alumina reinforced NiAl composites were prepared by powder hot pressing sintering. The in-situ tensile test at 960-1000°C was carried out for NiAl composites. The plastic deformation behavior of materials during high temperature tensile testing is analyzed. The formation and propagation of microcracks are observed in real time. Test results show that dynamic hardening occurs when the strain rate is suddenly increased during the high temperature tensile process. When the strain rate decreases suddenly, dynamic softening occurs. The process of material deformation is dominated by dislocation sliding at 960°C. The deformation of the material is enhanced during the deformation process, when the deformation temperature increases to 1000°C. As the strain rate increases from 10$^{-4}$s$^{-1}$ to 10$^{-3}$s$^{-1}$, there is no obvious expansion of the main crack in the observed region, while other regions appear new crack initiation and propagation. It shows that the work hardening of the material at the crack tip hinders the further expansion of the crack tip. Therefore, the crack can only nucleate and expand in the region where the other deformation resistance is relatively small. This phenomenon usually occurs during superplastic deformation of materials. It is also found that the nano Al$_2$O$_3$ particles can prevent the crack propagation, and the cracks will deflect and expand along the interface between the NiAl matrix and the Al$_2$O$_3$ particles. Before reaching the yield point, microcracks occur during the deformation of the material. However, through the development of cracks, the crack branching expansion and the crack bypassing the Al$_2$O$_3$ particle expansion increase the crack growth path, thus improving the high temperature toughness of NiAl. So, the NiAl showed good plasticity at high temperature.

Keywords: NiAl, In-situ tensile test, Plastic deformation behavior, Crack
Investigation of deformation-induced surface roughening based on microstructure analysis in polycrystalline metal sheets

Kanta Sasaki\textsuperscript{1)}, Yannis Korkolis\textsuperscript{2)}, Koji Kakehi\textsuperscript{1)}, Tsuyoshi Furushima\textsuperscript{3)}

\textsuperscript{1)} Tokyo Metropolitan University, Japan
\textsuperscript{2)} University of New Hampshire, USA
\textsuperscript{3)} The University of Tokyo, Japan

Abstract: Free surface roughening behavior of polycrystalline metal sheets during tensile deformation is investigated. Micro tensile specimens with three different crystal structures, aluminum alloy (fcc), copper alloy (fcc), mild steel (bcc) and magnesium alloy (hcp) are finely polished and tested under uniaxial loading. Prior to deformation, confocal laser microscope and electron backscatter diffraction (EBSD) are performed to characterize the initial surface texture and the microstructure. During plastic deformation, the surface roughening behavior and the microstructure evolution are continuously observed. A linear relation between arithmetic average of the roughness and true strain is observed in all of the samples. Based on the linear relation, roughness parameter which influence the slope of surface roughness is calculated. As EBSD results, different distribution pattern of Schmid factor is observed in each sample. From frequency distribution of Schmid factor, coefficient of variation of Schmid factor which represents the ratio of standard deviation to the mean is calculated. It can express the inhomogeneity of grains produce by crystallographic orientation and crystal structure. Roughness parameter is plotted versus coefficient of variation in each sample. The graph shows that magnesium alloy (hcp) with the largest coefficient of variation has the largest roughness parameter. It is also presented that copper alloy (fcc) with larger coefficient of variation have larger roughness parameter than aluminum alloy (fcc). Thus, this study suggests that distribution and that pattern of Schmid factor produced by crystal structure and crystallographic orientation have a significant influence on the increase of surface roughness. In addition, using oligocrystal aluminum alloy specimens strained by early plastic deformation level, the surface topology and microstructure are observed. From comparison between the surface topology and microstructure, it is found that surface topology is formed by out-of-plane deformation of grains in surface layer. Moreover, it is found that grains between grains with low Schmid factor forms valley on the surface. As results of plotting amount of out-of-deformation versus difference of Schmid factor between neighboring grain, it is shown that grains with larger difference of Schmid factor tends to form deeper valley. Thus, the study also suggests that grain-grain interaction induced by the difference of Schmid factor forms surface topology and it leads to surface roughening evolution.

Keywords: Deformation induced roughening, EBSD, Crystallographic orientation, Crystal structure
Multi-Response optimization to study single point incremental forming for thin sheet
Xiao Xiao¹, Van-Cuong Do¹, Chan-Il Kim¹, Young-Suk Kim¹
¹) Kyungpook National University, South Korea

Abstract: Single point incremental forming (SPIF) is a sheet forming technique suitable for rapid prototyping and small batch production. In the forming process, critical parameters are tool diameter, step depth, feed rate, spindle speed, etc. In this research work these parameters were used for aluminum and stainless steel sheet with 0.1 mm in thickness. Varying Wall Angle Conical Frustum (VWACF) model was used. The Taguchi method of experiment design with grey relational optimization was used to determine the optimized parameters in SPIF. The multi responses were considered including formability, forming force. The analysis showed that the step depth is the most effected parameter for the multi-response performance.

Keywords: Single point incremental forming, Thin sheet, Optimization