



# **ICMSE 2011**

**2<sup>nd</sup> International Conference on Manufacturing  
Science and Engineering**

**April 9-11, 2011, Guilin, China**

**Organized By:**

**Guangxi University**

**Guilin University of Electronic Technology**

**University of Wollongong, Australia**

**Korea Maritime University**

**Hong Kong Industrial Technology Research Centre**

# CONFERENCE MAP GUIDE

## Guilin, China



## Guilin DaZheng Hot Spring Holiday Hotel



ICMSE 2011 SECRETARIAT

Any question, please contact the secretariat: +86 13533523123

# **2<sup>nd</sup> International Conference on Manufacturing Science and Engineering (ICMSE 2011)**

## **Organized By:**

Guangxi University

Guilin University of Electronic Technology

University of Wollongong, Australia

Korea Maritime University

Hong Kong Industrial Technology Research Centre

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Prof. Ping Zou, Northeastern University, China  
Prof. Zhihai Han, Xi'an Jiao Tong University, China

## **Conference Website**

<http://www.icmse.net>

# SCHEDULE OF THE CONFERENCE

## April 9 (Saturday)

14:00—22:00

Registration, Sequence Hall, Guilin Da Zheng Hot Spring Holiday Hotel

18:00—19:30

Dinner, Aurantiacus Chinese Restaurant,1/F (丹桂轩)

## April 10 (Sunday)

8:30—8:40

Open Ceremony, Ballroom,3/F

8:40—10:00

Keynote Speeches

10:00—10:20

Tea Break

10:20—11:40

Keynote Speeches

12:00—

Lunch, Aurantiacus Chinese Restaurant,1/F

14:00—15:30

Parallel Sessions (A, B, C, D, E)

15:30—15:50

Tea Break

15:50—17:30

Parallel Sessions (A, B, C, D, E)

18:00—

Welcome Dinner, Aurantiacus Chinese Restaurant,1/F

## April 11 (Monday)

8:40—10:00

Keynote Speeches Ballroom,3/F

10:00—10:20

Tea Break

10:20—11:40

Keynote Speeches

12:00—

Lunch, Aurantiacus Chinese Restaurant,1/F

14:00—15:30

Parallel Sessions (A, B, C, D, E)

15:30—15:50

Tea Break

15:50—17:30

Parallel Sessions (A, B, C, D, E)

18:00—

Dinner, Aurantiacus Chinese Restaurant,1/F

## Morning, April 10, 2011

### Plenary Session (8:30 AM—12:00 AM)

Ballroom,3/F (大正厅)

#### Co-Chairmen

Prof. Jianmin Zeng, Guangxi University, China

Prof. Huaiying Zhou, Guilin University of Electronic Technology, China

Prof. Tianlong Gu, Guilin University of Electronic Technology, China

Prof. Daoguo Yang, Guilin University of Electronic Technology, China

Prof. Zhengyi Jiang, University of Wollongong, Australia

Prof. Yun-Hae Kim, Korea Maritime University, Korea

Prof. Shanqing Li, Research Institute, Baosteel, China

8:30—8:40

Opening Speech

8:40—9:20 Keynote Speech

**Baicheng Liu**, Academician of Chinese Academy of Engineering and Professor of Tsinghua University, China

9:20—10:00 Keynote Speech

**Weidong Huang**, Yangtze Fund Scholar and Professor of Northwestern Polytechnical University, China

10:00—10:20 Keynote Speech

Tea Break

10:20—11:00 Keynote Speech

**Olaf Diegel**, Professor of Auckland University of Technology, New Zealand

11:00—11:40 Keynote Speech

**Zhengyi Jiang**, Professor of University of Wollongong, Australia

12:00—

Lunch



## Afternoon, April 10, 2011

**14:00 PM—17:30 PM**

**Parallel Session A: Manufacturing Process Technology**

**Ballroom-First Room, 3/F (大正一厅)**

**Chairman: Prof. Jian Luo, Chongqing University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. A Novel Sensorless Control of a Two-Axis Planar Motion Stage for Precision Positioning (D5314)  
Songyi Dian, Hang Dong, Wei Gao
2. The Structure and Electrochemical Properties of BDD Deposited on Ti Substrate by MWCVD (D5445)  
Feng Liu, Wenjun Wang, Juntao Wang, Liwei Xiong, Yonglei Xin, Xiangbo Li
3. Numerical Simulation of Effect of Slip Conditions on PVC Co-Rotating Twin-Screw Extrusion (D5671)  
Yinghan Cao, Jinnan Chen, Jiong Peng
4. Cavitation Erosion Characteristics of an Iron-Based Coating Prepared by High Velocity Arc Spraying (D5771)  
Zhihua He, Yuping Wu, Hongbin Sun, Yuan Zheng, Yu Dong, Sheng Hong and Gaiye Li
5. Study on Defect of 304 Stainless Steel Industrial Condensation Board in CO<sub>2</sub> Laser Welding (D7190)  
Jian Luo, Keliang Xue, Fei Li, Junfeng Xiang, Dengke Yin
6. Improving Pattern Recognition Rate by Gaussian Hopfield Neural Network (D5901)  
Shang-Jen Chuang, Chien-Chih Kao, Fang-Tsung Liu, Chiung-Hsing Chen
7. Improvement on the Manufacturing Process of the Dental Surgical Guide Made by a 5-axis CNC Drill Press (D6013)  
Wei-chen Lee, Kan-Shan Shih, Ching-Hang Huang, Shan-chen Chung
8. A Numerical Study on the Uplift Behavior of under-Reamed Anchors in Silty Sand (D6014)  
Shih-Tsung Hsu

9. Study of Heat transfer of Steel Solidification Process (D6067)  
Yan Jin, Zhibing Tian, Xuegong Bi
10. On the Hardfacing Performance Optimization after Plasma Transfer Arc Experiments (D6073)  
Ming-Der Jean, Ming-Cheng Li, Tzu-Hsuan Chien, Ching-Jyi Chen
11. A Study on Dieless Incremental Sheet Metal Forming using Water Jet Technology (D6175)  
Kai He, Jiuhua Li, Qun Luo, He Mao, Ruxu Du
12. Microstructure and Cavitation Erosion Behavior of Carbide-Based Coating Deposited by Electrical Arc Spraying (D6256)  
Sheng Hong, Yuping Wu, Hongbin Sun, Yuan Zheng, Qifan Dai, Zhihua He, Gaiye Li
13. High Air Pressure in MQL Deep Hole Drilling Workpiece Temperature (D6411)  
Bruce Tai, David Stephenson, Steve White, Albert Shih
14. A New Axial Upsetting Process for Large Ingots with Large Ratio of Height to Diameter (D6434)  
Jian Lan, Chengding Li, Yulong Qiu, Lin Hua
15. Transient Heat Conduction in Functionally Graded Materials by LT-MFS (D6531)  
Ning Zhao, Leilei Cao, Hui Guo
16. A Multiple view Assembly Process Representation Based on Three Dimensional Models (D6584)  
Lihong Qiao, Yixin Zhu
17. 3D Finite Element Modeling of the Machining of Ti6Al4V Alloys (D6655)  
Nancy Yang, Shoujin Sun, Milan Brandt and Wenyi Yan
18. A Rapid Process For Fabricating Microfluidic Devices With A Low-Cost Uv Curable Resin (D6711)  
Shu-Ming Kuo, Chao-Chi Yang, Jien-Tai Hsieh and Che-Hsin Lin
19. Thermal Deformation Prediction in Machine Tool Model by Using Transfer Functions with Time Delay (D7876)  
Fumihiko Suzumura, Hiromasa Makihara, Kozo Ohtani, Masahiro Ikeda, Gonojo Katayama

## Afternoon, April 10, 2011

**14:00 PM—17:30 PM**

**Parallel Session B: New and Advanced Materials**

**Ballroom-Second Room, 3/F (大正二厅)**

**Chairman: Prof. Rongmin Wang, Northwest Normal University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Effect of High Magnetic Field on Diffusion Behavior of Carbon in Pure Iron (D2357)  
Yan Wu, Shiyang Wang, Xiang Zhao, Liang Zuo
2. The Effect of Hot-Rolled Coiling Time on the Texture of a New Cold-Rolled Non-Oriented Electric Steel (D2645)  
Guanqiao Hu, Yan pin Zeng, Hailin Chen
3. Carbon Nanolines Grown on Carbon Cloth Prepared by a Two-Step Method (D2905)  
Cailiu Yin, Guofu Wen, Qizhong Huang, Ping Zhou, Liangming He, Jianlie Liang, Baorong Liu
4. Study on High Performance Fe<sub>3</sub>Si-Si<sub>3</sub>N<sub>4</sub>-SiC Composite Preparation and Its Application in Blast Furnace (D3557)  
Yong Li, Xiaoyan Zhu, Yawei Zhai, Jiaping Wang, Wendong Xue, Junhong Chen, Jialin Sun
5. High Performance Si-Si<sub>3</sub>N<sub>4</sub>-SiC Sagger Composite Materials Preparation and Its Attack Mechanism After Usage (D3904)  
Yawei Zhai, Yong Li, Lei Liu, Xiaoyan Zhu, Jiaping Wang, Jialin Sun
6. Synthesis, Characterization and Optical Properties of a Novel Piperazine Derivative Microcrystal (D4026)  
Changshun Ruan, Yuanliang Wang, Maolan Zhang, Bingbing Zhang
7. Applying Ultrasonic Testing to Detect Hole Defect Near the Surface (D5597)  
Ming-Kuen Chang, Hua-Sui Sun, Jyun-Cang Ciou
8. A Study of Test for Polyethylene / Modified Montmorillonite Nanocomposites (D5592)  
Ming-Kuen Chang, Jia-Ying Lin, Yan-Huei Peng, Jian-Jhih You, Yu-Ming Wang

9. Mineral Sequestration of CO<sub>2</sub> Using Basic Oxygen Furnace (BOF) Steelmaking Slag (D4168)  
Guojun Ma, Hui Tang, Yibiao Jin
10. High Quality Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub>-C Slide Gate Properties Adding Si-Fe Sintered by both Nitrogen and Carbon Monoxide Atmosphere (D4311)  
Yong Li, Lei Liu, Yawei Zhai, Wendong Xue, Junhong Chen
11. Synthesis and Characterization of Pyrochlore Lead Zinc Niobate Nanopowders Derived from Zn<sub>3</sub>Nb<sub>2</sub>O<sub>8</sub> Precursor (D4566)  
Phakkhananan Pakawanit, Supon Ananta
12. Sliding Wear Behavior of Cu-10Fe-3Ag in Situ Composite (D4758)  
Yong Li, Danqing Yi, Ruiqing Liu, Shunping Sun
13. Large-Scale Patterning and Assembly of Carbon Nanotubes by Microfluidic Hydrodynamic Focusing (D5506)  
Mei Liu, Yan Peng, Qiuquan Guo, Jun Luo and Jun Yang
14. Effect of Quenching Temperature on Microstructures and Mechanical Properties of Boron-Nickel-Added Nb-Treated HSLA H-Beams (D5683)  
Xiao Wang, Zuocheng Wang, Xiebin Wang, Xianda Li, Junqing Gao, Xiuling Zhao, Changxing Dong
15. Gallium and Arsenic Recovery from Waste Gallium Arsenide by Wet Refined Methods (D8938)  
Wei Ting Chen, Yung Chuan Chu, Jian Ming Wei, Lung Chang Tsai, FangChang Tsai, Chun Ping Lin, Chi Min Shu
16. Study on Interfacial Properties of Ultra-high Performance Concrete Containing Steel Slag Powder and Fly Ash (D5999)  
Yanzhou Peng, Kai Chen, Shuguang Hu
17. Theoretical Analysis of Thin Film Oxide as Insulator of Planar Micro-Coils (D6037)  
J. Yunas, A. A. Hamzah and B. Y. Majlis
18. Numerical Simulation for Direct Reduction of Pure Zinc Oxide Pellet Containing Carbon (D6447)  
Xiuwei An, Jingsong Wang, Xuefeng She, Yingui Ding, Qingguo Xue
19. Experimental Study of the Steel Type Buckling Restrained Braces (D6533)  
Xiaodong Li, Xiuli Wang

## Afternoon, April 10, 2011

**14:00 PM—17:30 PM**

**Parallel Session C: Materials Processing Technology**

**Ballroom-Third Room, 3/F (大正三厅)**

**Chairman: Prof. Yuandong Li, Lanzhou University of Technology**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Study on Creep Deformation of Reactor Coolant Pump Rotor-Can during Vacuum Hot Bulge Forming Process (D2184)  
Zhi Zhu, Liwen Zhang, Guanyu Song, Dongjiang Wu
2. Statistical Analysis of Micro-crack Parameters for PPy-coated Fiber Strain Sensors Applicable for Large Deformation (D2487)  
Junpu Wang, Pu Xue, Xiaoming Tao
3. Study on Machinability and Polishing Performance of 1CrMn2MoVTiB Non-Quenched and Tempered Plastic Mould Steel (D2646)  
Cairu Gao, Shunhu Zhang, Anyang Wang, Dewen Zhao
4. Preparation of Semisolid AM60 Alloy by Novel Sleafinoculation Method (D2767)  
Yuandong LI, Bo Xing, Ying Ma, Tijun Chen, Yuan Hao
5. Color Stability of Heat-treated Okan Sapwood During Artificial Weathering (D2770)  
Qiang Shi
6. Model and Imitation of The Cycle Temperature Fields And Deformations of Coke Drum (D2850)  
Sunyi Chen
7. Micro Plastic Part Fabrication Using Custom Made Vertical Injection Molding Machine (D3028)  
M. Azuddin, Z. Taha, I. A. Choudhury
8. Hydrogen Embrittlement of Low Carbon HSLA Steel during Slow Strain Rate Test (D3046)  
Jingwei Zhao, Young Soo Chun, Chong Soo Lee
9. Changes in the Bacterial Community Structure under Different DO Concentrations with New Method for Nitrate Removal (D3196)

Liu Shao, Zuxin Xu

10. Optimal Design of the Guide Mechanism of Vertical Ring Rolling Mill (D3392)  
Xiaokai Wang, Lin Hua, Chunle Zhu
11. Experimental Analysis of an Instrumented Charpy Impact Using Signal Processing Approach (D3433)  
M. B. Ali, S. Abdullah, M. Z. Nuawi, M. M. Padzi and K. A. Zakaria
12. Characteristics Distribution in PEM Fuel Cell (D3500)  
Hong Sun, Yuhou Wu
13. Sintering and Electrical Properties of Ce<sub>0.8</sub>Sm<sub>0.2</sub>O<sub>1.9</sub> Solid Electrolyte Modified by Addition of MnO<sub>2</sub> (D3630)  
Yifeng Zheng, Lucun Guo
14. Automatic Hyperbaric Welding of Sub-sea Pipelines Repair (D3745)  
Canfeng Zhou, Xiangdong Jiao, Long Xue, Jiaqing Chen, Xiaoming Fang
15. Pulse Discharge Strengthening of 16Mn Welded Joint and Mechanical Performance (D3772)  
Yuming Fu, Xuan Chai, Lijuan Zheng Hui Li
16. Effect of Position between Upper die and Workpiece on Cold Rotary Forging (D3773)  
Xinghui Han, Lin Hua
17. Electrochemical Micro-Drilling with Ultra-Short Pulses (D3831)  
Lih-Wu Hourng, Zhi-Wen Fan
18. Numerical Analysis of Coupled Finite Element with Meshfree in Bulging Process of Sheet Elastic Flexible-Die Forming (D3961)  
Zhongjin Wang, Binxian Yuan, Jianguang Liu
19. The Effects of ZigBee Position with Different Hidden Layers in Back-Propagation Neural Network (D7575)  
Fang-Tsung Liu, Chien-Erh Weng, Chien-Ming Huang, Huang-Chu Huang
20. Study of Methods for Minimizing Construction Delays: Evidences from a Developing Country (D7592)  
Towhid Pourrostam, Amiruddin Ismail

## Afternoon, April 10, 2011

**14:00 PM—17:30 PM**

**Parallel Session D: Design and Manufacturing**

**Meeting Room-1, 3/F (一号会议厅)**

**Chairman: Prof. Shiquan Zhou, Huazhong University of Science and Technology**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. The Influence of Crack on The Sound and Vibration Characteristic of Gear Structure (D2369)  
Renping Shao, Zhifeng Xu, Jie Ma
2. Thermal Stability Determination, Anti-Biodegradation, and Thermal Degradation of Nitrocellulose with Various Nitrogen Content by DSC and FT-IR (D8939)  
Yung Chuan Chu, Fang Chang Tsai, Wei Ting Chen, Lung Chang Tsai, Chi Min Shu and Chun Ping Lin
3. RDX Kinetic Model Evaluation by Nth Order Kinetic Algorithms and Model Simulations (D8941)  
LungchangTsai, Jian-MingWei, Yung-ChuanChu, Wei-Ting Chen, Fang-Chang Tsai, Chi-Min Shu and Chun-Ping Lin
4. Study on Active Control of Structural Frequency Response (D3238)  
Xingwu Zhang, Xuefeng Chen, Shangqin You, Xiao He, Yijie Wang, Zhengjia He
5. Performance Optimization and Comparison of TMD, MTMD and DTMD for Machining Chatter Control (D3293)  
Min Wang, Yanlin Zhang, Tao Zan
6. Research and Development of UG-Based CAD/ CAM System for Turbine Blade (D6882)  
Fangjie Ren, Shiquan Zhou, Jian Li, Zhiqian Wan
7. Analysis of Formed Platelet Thermal Wrinkling in Platelet Transpiration Cooling (D3909)  
Yongfa Hou, Weiqiang Liu
8. Preparation of Bauxite-Based Homogenized Mullite Groggs with Bauxite and Coal Gangue (D4035)

Zhongzheng Yang, Shunbo Zhao, Zhanfang Gai, Huanqiang Liu

9. A Finite Element Cavitation Algorithm Using Free Mesh for Mechanical Face Seal (D4120)  
Jinghao Li, Xiangfeng Liu, Weifeng Huang, Yuming Wang
10. A Numerical Integration Method of Dynamic Finite Element Analysis (D4210)  
Xing-Pei Liang
11. Structure Improvement of the Principal Axis of A CNC Vertical Boring-milling Machine (D5385)  
Qinghai Luo, Wenwu Peng, Pengfei Zhang
12. Analysis on Bistable Response of a Disk-rod-fastening Rotor (D5638)  
Li Cheng, Zhengwen Qian
13. Experiments and Modeling of a Rotatable-Direction-Valve in Bionic Undulating Propeller (D5739)  
Haijun Xu, Cunyun Pan, Qiang Li, Fudong Gao
14. Design and Force Analysis of a Roller-type Garbage Sorting Equipment (D6180)  
Zhaoxia Cui, Hengjie Du, Yuzhu Zhao, Sijia Guo
15. The Vibration Characteristics of a Large Flexible Vibration Isolation Structure with Finite Element Analysis and Modal Test (D6667)  
Liubin Zhou, Tiejun Yang, Wanpeng Yuan, Hui Shi, Zhigang Liu
16. Identification of Excitation Source Number using Principal Component Analysis (D6817)  
Jianchao Dong, Tiejun Yang, Xinhui Li
17. Kinematics Analysis of the Wedge Clamping Device of PET Bottle Blowing Machines (D7747)  
Tengan Zou, Cunyun Pan, Xiaojun XU, Xiang Zhang
18. Research on Dynamical Model of Horizontally Vibrating Conveyor (D7859)  
Yumin He, Qiang Liu, Jianxiao Zheng
19. Vibration Characteristic of Shell-Shafting Coupled System Induced by Propeller Exciting Force (D8049)  
Yipeng Cao, Liaoyuan Li, Wenping Zhang



## Afternoon, April 10, 2011

**14:00 PM—17:30 PM**

**Parallel Session E: Advanced Manufacturing Systems**

**Meeting Room-3, 2/F (三号会议厅)**

**Chairman: Prof. Ching-Kuo Wang, Hwa Hsia Institute of Technology, Taiwan**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Flocking Task Research for Multiple Mobile Robots Based on Evolutionary Game Model (D2283)  
Ye Ye, Nenggang Xie, Yuwan Cen, Qingyun Liu
2. Mechatronic Cooperative Design and Simulation of a Multi-Axis Bar Tacking Machine (D2432)  
Xiaohui Xie, Qiang Sun, Cuicui Zhao, Cui Ma, Ruxu Du
3. Hardware-in-the-Loop Simulation System in the Development of Temperature Controller of Plastic Extruder (D5793)  
Jialin Xu, Guokun Zuo, Jianhua Chen
4. Uncertainty Quantification of a Flapping Airfoil with a Stochastic Velocity Deviation Based on a Surrogate Model (D2468)  
Liangyu Zhao, Xiaqing Zhang
5. A Fault Detecting System of Intelligent Detection and Diagnosis (D2788)  
Renping Shao, Yonglong Li, Wentao Hu
6. The Application of Inertial Measurement Unit in Inertia Parameter Identification (D2920)  
Bo Wang, Zhongxi Hou, Xianzhong Gao, Shangqiu Shan
7. Orientation Workspace Analysis of a Novel 3SPS+1PS Symmetrical Parallel Manipulator Based on Unit Quaternion (D2925)  
Jingli Yu, Gang Cheng, Shuai Zhang, Dekun Zhang
8. Study on Process of Microwave Magnetizing Roast for Low—Grade Hematite (D3397)  
Jie Li, Baowei Li, Bangwen Zhang and Lei Wang
9. Effect of Tidal Fences on the Stress and Deformation of Bridge Structure (D8119)

Zhaode Zhang, Zhenxing Cheng, Xinglan Bai

10. Dirty-Face Game Analysis on Mixed Traffic Flow at Unsignalized Intersection (D3485)  
Lu Wang, Neng-gang Xie, Rui Meng
11. Fluid-Structural Coupling Analysis of Composite Material Blades for the Offshore Wind Power Generator (D3960)  
Gwo-Chung Tsai, Jyun-Cian Dong Tung-Chen Cheng, Yu-Yi Chu, C. K. Feng
12. Morphology and Formation Mechanism of Martensite in Steels with Different Carbon Content (D3990)  
Yunping Ji, Zongchang Liu, Huiping Ren
13. Analysis, Design, and Simulation of the Biomimetically Facial Material on the Humanoid Robot (D4105)  
Ching-Kuo Wang
14. Analysis and Implementation of Coulomb's Frictional Material on the Wheeled Platform of Moving Robots (D4529)  
Ching-Kuo Wang
15. 3D FE Modeling of Three Rolls Cross Rolling Process of a Rotary Disk Part (D4463)  
Xiumei Zhou, Lin Hua, Dongsheng Qian
16. Some Improvements of Genetic Programming in Data Fitting (D5075)  
Jie Hu, Jiaquan Feng, Dalin Chen
17. On-Machine Illumination Technique in Industry Machine Vision (D5152)  
Zhongren Wang, Yanhua Wu
18. Special Purpose Five-Axis Machine Tool for Manufacturing a Precision Cam (D5483)  
Chenhua She, Kaisheng Li, Zhihao Zheng
19. Finite Element Analysis of Blanking Process by Superimposing Ultrasonic Vibrations (D5924)  
Weiching Yeh, Tsuhsiao Chu, Shiuansheng Wang, Kuanghua Fuh, Kuanhun Chen
20. Tool Path Design Methods for High Efficiency Die Cavity Machining with CAD / CAM Technology (D7934)  
Dong-Mei Xu, Jinn-Jong Sheu, Bo-Wen Chang

## Morning, April 11, 2011

### Plenary Session (8:40 AM—12:00 AM)

Ballroom,3/F (大正厅)

#### Co-Chairmen

Prof. Jianmin Zeng, Guangxi University, China

Prof. Huaiying Zhou, Guilin University of Electronic Technology, China

Prof. Tianlong Gu, Guilin University of Electronic Technology, China

Prof. Daoguo Yang, Guilin University of Electronic Technology, China

Prof. Zhengyi Jiang, University of Wollongong, AU

Prof. Yun-Hae Kim, Korea Maritime University, Korea

Prof. Shanqing Li, Research Institute, Baosteel, China

8:40—9:20

**Baixin Liu**, Academician of Chinese Academy of Sciences and Professor of Tsinghua University, China

9:20—10:00

**Shandong Tu**, Yangtze Fund Scholar and Professor of East China University of Science and Technology, China

10:00—10:20

Tea Break

10:20—11:00

**Shanqing Li**, Professor of Research Institute, Baosteel, China

11:00—11:40

**Daoguo Yang**, Professor of Guilin University of Electronic Technology, China

12:00—

Lunch

## Afternoon, April 11, 2011

**14:00 PM—17:30 PM**

**Parallel Session A: Manufacturing Process Technology**

**Ballroom-First Room, 3/F (大正一厅)**

**Chairman: Prof. Zhihai Han, Xi'an Jiaotong University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Effect of Severe Plastic Deformation on the Characteristics of a PM Aluminum Alloy (D6738)  
Marco Actis Grande, Robert Bidulsky, Jana Bidulska, Tibor Kvackaj
2. Research on CMP Characteristics Attribute to Groove Size (D6770)  
Yongchang Guo, Youngkyun Lee, Hyunseop Lee, Haedo Jeong
3. Analyses of Interfacial Thermal Stresses for DLC/WC-co (D6791)  
Jun Zhang, Yang Li, Xinli Wei
4. Effect of Preheating Temperature on the Cooling Curves of BW Quenching Media (D6976)  
Zhiting Gao, Yan Yanfu
5. Effects of Rare Earth Elements Erbium and Cerium on the Properties of Hardfacing Alloy (D7013)  
Di Zhang, Zhen Luo, Tao Yuan, Rui Wang
6. Microstructural Study of Nanostructured ZrO<sub>2</sub> Based Thermal Barrier Coatings Fabricated by High Efficiency Supersonic Plasma Spraying (D5803)  
Yu Bai, Zhihai Han, Hongqiang Li, Chao Xu, Yanli Xu, Chunhua Ding and Jianfeng Yang
7. Piezoelectric Behavior Based on Mixing-Doped in Lead Zirconate Titanate Ceramics and Application (D7286)  
Bing-Huei Chen, Long Wu
8. The Effect of Plate Plate Butt Welding Stress Distribution on The Welding Deformation (D7288)  
Tao Yuan, Zhen Luo, Hui Luo
9. Study of Stress in TiO<sub>2</sub> Films Grown by Electron-Beam Evaporation (D7300)

Tao Chen, Duoshu Wang, Yuqing Xiong

10. Microstructure and Phase Composition of Iridium Coating on Molybdenum after Heat Treatment at 1400°C (D7372)  
Wangping Wu, Zhaofeng Chen, Xin Lin
11. The Thermal Response Investigation of Functionally Graded Material Plates (D7620)  
Jianhui Tian, Changye Li, Yan Cao
12. Contact Analysis for Joint Interfaces of Machine Tools Based on a 3-D Anisotropic Asperity Model (D7627)  
Haitao Liu, Wanhua Zhao, Jun Zhang
13. Effects of Preform on Thickness Distribution of Hydroformed Y-Shaped Tube (D7657)  
Gang Liu, Junyang Peng, Xiaosong Wang, Shiqiang Zhu, Shijian Yuan
14. Three-Dimensional Numerical Simulation of Metal Flow in the Initial Stage of a Twin-Roll Strip Casting Process (D7743)  
Qinghua Zhang, Bo Wang, Weidong Zhang, Jieyu Zhang, Zhiyu Liu
15. Effect of Rare Earth(RE) La on Solid Solution of Second Phase Particle and Austenite Grain Growth in Steel Containing High Niobium (D7751)  
Wenzhong Song, Qi Fang, Huiping Ren, Zili Jin, Hui Chang
16. Tribology of Plasma Sprayed Al<sub>2</sub>O<sub>3</sub>-13%TiO<sub>2</sub> on AZ91D Magnesium Alloy (D7790)  
Sheng Lu, Zhiping Weng, Jing Chen, Li Fu
17. Process, Microstructure and Properties of Plasma-Sprayed Ceramic Coating on AZ91D Magnesium Alloy (D7800)  
Sheng Lu, Yan Chen, Jing Chen, Li Fu
18. Research on the Stress and Strain Field and Wall Thickness in Power Spinning of Ellipsoidal Heads with Variable Thickness (D7848)  
Jinhui Zhang, He Yang, Mei Zhan, Huabing Jiang
19. Simulating Design of Magnetic Fluids Lubricating Unit Structure with Porous Material (D6735)  
Rui HU, Zuomin LIU, Chunxia Xu
20. Shear Mode ZnO Thin Film Applied in FBAR Sensor (D8126)  
Chien-Chuan Cheng, Re-Ching Lin, Wei-Tsai Chang, Ying-Chung Chen and Kuo-Sheng Kao

## Afternoon, April 11, 2011

**14:00 PM—17:30 PM**

**Parallel Session B: New and Advanced Materials**

**Ballroom-Second Room, 3/F (大正二厅)**

**Chairman: Prof. Yongchang Liu, Tianjin University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Effect of Aging Treatment on Microstructure and Wear Behavior of a Nickel Based Hardfaced Coating (D6712)  
D. Kesavan, M. Kamaraj
2. Electrodeposited Crack-free CdS Thin Films Using Organic Solvents (D6893)  
Hainian Chen, Aimiao Qin, Lei Liao, Ping Tang, Songbo Xie, Qi Pang
3. Investigation of Nano-Powders made by Spark Discharging Reaction (D6907)  
Shen Zhou, Jianzhang Mai, Qitao Liu, Shiquan Zhou
4. A Study for Substituting Part of Raw Materials by Bottom Ash in Portland Cement (D7012)  
Hui-Mi Hsu, Hao-Hsien Chen, Sao-Jeng Chao, An Cheng, Cheng-Yang Wu, Chuan-Tsung Ma
5. Carbon Nanotubes with Uniform Wall Thickness Synthesized Via a Solid-Liquid Reaction (D7176)  
Cailiu Yin, Guofu Wen, Qizhong Huang, Xiufei Wang
6. Study of the Coefficient of Thermal Expansion for Steel Q235 (D7287)  
Jian-Xun Fu, Xiang-Dong Li, Weng-Sing Hwang
7. Recent Developments for Isochronal Transformation Kinetics Model and Their Applications (D7483)  
Yongchang Liu, Lifang Zhang, Xu Yang, Dongjiang Wang
8. The Detection of Different Physical Properties of Laser-Damaged HfO<sub>2</sub> Film on SiO<sub>2</sub> Substrate by Scanning Probe Acoustic Microscope (D7690)  
Wengang Yao, Qian Cheng
9. Effect of RF Sputtering Power on the Structural, Optical and Hydrophobic Properties of SiN<sub>x</sub> Thin Film (D8043)

Hongyu Liang, Qingnan Zhao, Feng Gao, Wenhui Yuan, Yuhong Dong

10. Stability of AZO Thin Films under the Environment of Hydrogen Plasma (D8067)  
Qingnan Zhao, Wenhui Yuan, Hongyu Liang, Weiyuan Wang, Pulei Yang, Yuhong Dong
11. Research on Reflectivity per Wavelength by Foaming Ratio of Plastics and Optical Characteristics (D8208)  
Earl Han, Sung Woon Cha, Young Ho Kim
12. Mechanical and Tribological Properties of PTFE Composites Filled with POB (D8223)  
Sha Zhang, Shibo Wang, Shirong Ge, Yong Mao
13. Synthesis, Characterization and Gas adsorption of Titania Nanotubes (D8510)  
Mohd Rafie Johan
14. Effect Analysis of Ar-N<sub>2</sub> Flow Rates on ZrN<sub>x</sub> Film by Pulsed Magnetron Sputtering using Design of Experimental Method (D8656)  
Hungjiun Wen, Fuhliang Wen, Kuo-Hwa Chang, C. H. Wen, Yulin Lo
15. Magnesium-based Hydrogen-storage Materials from Milling for Sulfo-Compound Hydrodesulfurization (D8697)  
Shixue Zhou, Minglin Zhang, Tonghuan Zhang and Haipeng Chen
16. Preparation of Potato Starch Graft Copolymer and Its Application in Functional Coatings (D6289)  
Menglan Jiang, Junfeng Guo, Rongmin Wang, Yongfeng Zhu, Xiaowen Wang, Junfeng Wang
17. Preliminary Research on Interfacial Evolution Behavior of Ti-Cu Laminated Composite Materials (D6338)  
Hongmei Yang, Peixian Zhu, Shenggang Zhou, Jian Xu, Huiyu Ma, Jiabin Guo
18. Combined Manufacturing Process of Electrochemical-Etching and Electroplating on Nanoporous Silicon for Its Metallization (D8767)  
Jia Chuan Lin, Meng Kai Hsu, His Ting Hou and Jia Chi Pan
19. Shear Mode ZnO Thin Film Applied in FBAR Sensor (D8126)  
Chien-Chuan Cheng, Re-Ching Lin, Wei-Tsai Chang, Ying-Chung Chen and Kuo-Sheng Kao

## Afternoon, April 11, 2011

**14:00 PM—17:30 PM**

**Parallel Session C: Materials Processing Technology**

**Ballroom-Third Room, 3/F (大正三厅)**

**Chairman: Prof. Xinhua Zhu, Nanjing University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Modeling and Analysis of Soft Contact in Robotic Grasping Using BondGraph Methods (D4160)  
A. Khurshid, A. Ghafoor, M. A. Malik
2. The Decomposition Mechanism of Titania Film with Nanotube Structure (D4423)  
Chien Chon Chen, Shih Hsin Chen, Shao Fu Chang, Mann Juin Kao, Wern-Dare Jheng
3. Influence of Heating Models on Necking Deformation during Tube Extrusion Process (D4706)  
Guihua Liu, Yongqiang Guo, Zhi jiang, Chunguo Xu
4. Advanced Interactive Device in Virtual Knee Arthroscopic Surgery (D4900)  
Yulei He, Jinfang Li, Hanwu He
5. Minimizing the Warpage and Sink Mark Depth in Injection-Molded Thermoplastics (D5085)  
Wei Guo, Lin Hua, Huajie Mao
6. Study on the Large Module Spur Gear Cold Forming Process by Means of Numerical Simulation (D5195)  
Qian Li, Yi Bian, Guihua Liu, Zhiping Zhong, Ying Chen
7. Research on Stress Calibration Technology on Aluminum of High-Speed Train Body Structure by Nondestructive X-Ray Method Measurement (D5215)  
Hua Ji, Hui Chen, Guoqing Gou, Da Li, Yan Liu, Wenbin Chen
8. Cutting Mechanism and Model for Cutting Al/Sicp Composites (D5229)  
Jicai Kuai, Feihu Zhang
9. Self-assembled Perovskite Epitaxial Multiferroic BiFeO<sub>3</sub> Nanoislands (D3024)



Qiming Hang, Xinhua Zhu, Zhenjie Tang, Ye Song and Zhiguo Liu

10. Fatigue Damage Assessment of the Engine Mount Bracket using a Statistical Based Approach (D5550)  
K. A. Zakaria, S. Abdullah, M. J. Ghazali, M. Z. Nuawi, M. M. Padzi
11. Fabrication of the Effective Counter Electrode for Dye-Sensitized Solar Cells (D6873)  
Rui Liu, Wein-Duo Yang, Jian-Fu Wu and Liang-Sheng Qiang
12. Investigation of the Performance of V-W Based Catalysts at Low Temperature for NO<sub>x</sub> Reduction with NH<sub>3</sub> (D7282)  
Xinna Tian, Youhong Xiao, Yongwei Chen
13. Thermoelectric Properties of Directionally Solidified Bi<sub>2</sub>Te<sub>3</sub> Alloys under High Thermal Gradient (D7411)  
Songke Feng, Shuangming Li, Qingyan Luo, Hengzhi Fu
14. Dielectric Properties of Zn-doped CCTO Ceramics by Sol-gel Method (D8375)  
Dong Xu, Chen Zhang, Xiaonong Cheng, Yuee Fan, Hongming Yuan, Liyi Shi
15. Photocatalytic Degradation of Methylene Blue by Modified TiO<sub>2</sub> under Visible Light (D8376)  
Zhao Zhao, Xuegang Luo, Xiaoyan Lin
16. Chromium Nitrided A283-C Steel as Bipolar Plate for PEMFC (D8485)  
Chang-Yong Choi, Dae-Geun Nam
17. Electrochemical Behaviour of Ce Doped Ta<sub>2</sub>O<sub>5</sub> Film Electrode (D8513)  
Yanhong Zhao, Lichun Hou, Wenfei Liu, Wenming Tong, Min Sun, Xiaojing Wang
18. Chemical Degradation of the Silicone Rubber in Simulated PEMFC Environments (D8600)  
Guo Li, Jinzhu Tan, Jianming Gong
19. Effect of Concentration on CO<sub>2</sub> Corrosion for Q235 Steel (D9004)  
Aijun WEI, Fuyong Huo, Huayi Jiang
20. Curved Layer Fused Deposition Modeling in Conductive Polymer Additive Manufacturing (D2385)  
Olaf Diegel, Sarat Singamneni, Ben Huang, Ian Gibson

## Afternoon, April 11, 2011

**14:00 PM—17:30 PM**

**Parallel Session D: Design and Manufacturing**

**Meeting Room-1, 3/F (一号会议厅)**

**Chairman: Prof. Gang Wang, Tsinghua University**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Machining Characteristics of EDM using Gas Media (D8494)  
Yao-Jang Lin, Yan-Cherng Lin, A-Cheng Wang, Yuan-Feng Chen
2. Tool-Path Generation for Conical Groove of Cylindrical Cams by Small-Sized Cutting Tools (D8599)  
Yuan-Lung Lai, Jui-Pin Hung
3. Mechanical properties of Flip-Chip Solder Joints Effected by Electromigration (D8686)  
Yudong Lu, Yunfei En, Ming Wan, Xiaoqi He, Xin Wang
4. Development of an Ultrasonic-Vibration Microforming Apparatus (D8690)  
Jung-Chung Hung, Ching-Shyong Shieh
5. Observation and Removal of Atmospheric Micro-Contaminants on SUS304 Steel (D8776)  
Rongguang Wang, Mitsuo Kido, Suketsuku Nakanishi and Takuji Okabe
6. Comparisons on Flow and Temperature Fields for Water-collecting Box of Diesel Exhaust System (D8810)  
Xiaochuan Wang, Guo He
7. CFD-Based Multicomponent Model for Solidification of Casting Process (D8840)  
Gang Wang, Shoumei Xiong, Yiming Rong
8. Effects of Ultrasonic Power on Bonding Strength of Anisotropic Conductive Film Joint in Chip-on-Glass Assembly (D8869)  
Y. C. Lin, Hao Jin, Xiaonan Fang, Jun Zhang
9. High Stable Mechanism Design for Micro-Wire Transport System in WEDM (D8308)  
P. W. Wang, C. H. Yang, M. T. Yan

10. Applications of Piezoelectric Materials (D8314)  
Basem M. Badr, Wahied G. Ali
11. Nano-Process of SiC Ceramics by Molecular Simulation (D8901)  
Guozhi Liu, Ke Zhang, Yulan Tang, Hong Sun, Haiyan Gao
12. Effect of Cylinder Surface Treatment on Diesel Engine Performance (D8925)  
Zhiwei Guo, Chengqing Yuan, Peng Liu, Xinping Yan
13. Development of Experimental Method to Improve Sheet Metal Formability by Transverse Normal Stress (D9045)  
Zhe Wang, Xiaoming Lai, Zhongjin Wang, Qingxin Cui, Wentao Li
14. Study on Mixture Formation of Liquid LPG for a Center Injection DISI Engine (D6823)  
Boyan Xu, Dezhi Sun, Xiao Ma, Yunliang Qi, Yongwei Zheng, Shaoli Cai
15. Functional Steel Hardness and Wear Improving on a Basis of Phenomena of Grain Boundaries Phase Transition (D9115)  
Y. A. Minaev
16. Influences of Moisture Expansion on Motion Errors of Granite Hydrostatic Guideways (D9121)  
Fei Xue, Wanhua Zhao, Yaolong Chen
17. Interrelation Between Microstructure and Mechanical Properties of Heavy Section Ductile Iron Casting (D9149)  
Xiaogang Diao, Zhiliang Ning, Fuyang Cao, Shanzhi Ren, Jianfei Sun
18. Design of a New Multi-Channel High-Low Pressure Micro-Ejection System (D9153)  
Wei Yang, Qiang Yin, Jiao Zhang, Wendong Zhang
19. Research on Mechanism of Polymer Inhibiting Secondary Reaction in Clinker Leaching Process (D9178)  
Bo Gao, Yi Hao, Ganfeng Tu, Shengzhi Hao, Chuang Dong

## Afternoon, April 11, 2011

**14:00 PM—17:30 PM**

**Parallel Session E: Advanced Manufacturing Systems**

**Meeting Room-3, 2/F (三号会议厅)**

**Chairman: Prof. Shiquan Liu, University of Jinan**

(10 minutes for each presentation, including 2 minutes of answering questions)

1. Study on the Optimum Choice of Cutting-Tools in NC Machining Based on the Polychromatic Sets Theory (D5948)  
Enfu Liu, Xiaoyang Liu, Yixiang Fang, Zongbin Li
2. A Hybrid Approach for Part Geometry Optimization through Engineering Simulation (D6163)  
Ahmad Zia, Qiao Lihong, Cai Na
3. Modular Code, Combination and Database Management of NC Spiral Bevel Gear Machine Tools (D6168)  
Dianpeng Li, Qing Li, Taiyong Wang, Miao Hu, Xinhua Xiao
4. The Experimental Study on Wireless Short Distance System for Downhole Data Transmission (D6508)  
Hanxiang Wang, Hui Lou, Lin Li, Naihe Hou, Zhang Jian, Yanxin Liu
5. A Simple Synthesis of Mesoporous Silica Hollow Microspheres by Fast Hydrolysis and Condensation of Tetraethyl Orthosilicate (D9109)  
Shiquan Liu, Jiansun Rao, Haixia Wang, Hui Zhao
6. A System of Selective Non Catalytic Reduction of NO<sub>x</sub> for Diesel Engine (D6830)  
Boyan Xu, Haiying Tian, Zhang Yong, Yunliang Qi, Shaoli Cai
7. Study on Direct Hot Isostatic Pressing Technology for Superalloy Inconel 625 (D8352)  
Jiwei Wang, Qingsong Wei, Guocheng Liu, Yunkun He, Yusheng Shi
8. Design of an Intelligent Vehicle System for Storehouse Management Based on Image Processing and RFID Technologies (D7011)  
Wendong Li, Guowei Chen, Jing Chen, Xuejun Zhang
9. Research on Design and Magnet Assembly Process of Multivariate and Multi-Roll Permanent Magnetic Separator (D7188)

Honggang Jiao, Changliang Shi, Ruixia Tian

10. Fabrication of High Concentration Reflected Photovoltaic Module (D7307)  
Cheng-Yi Hsu, Yu -De. Chiang, Yuli Lin
11. DEWMA Control Chart for the Coefficient of Variation (D7589)  
Eui Pyo Hong, Hae Woon Kang, Chang Wook Kang
12. Impact of Float Loss on the Project Costs (D8008)  
Wei Lo, Yih-Tzoo Chen
13. Optimal Design for Fe-Cr-C Hardfacing Alloys with Anti-Wearing (D8015)  
Tao Yuan, Zhen Luo, Rui Wang
14. Physical and Electrical Properties of Lead-Free  $(\text{Na}_{0.5}\text{K}_{0.5})\text{NbO}_3$ - $(\text{Bi}_{0.5}\text{Na}_{0.5})\text{TiO}_3$  Ceramics (D8085)  
Chun Huy Wang
15. Temperature Rise and Heat Transfer in High Speed Machining: FEM Modeling and Experimental Validation (D8607)  
Gautier List, Guy Sutter, Xuefeng Bi, Abdenbi Boutiche
16. Calibration methods of an on-Line Inspection System on a Large-Scale Turning-Milling Machining Center (D8166)  
Yingshu Chen, Libing Liu, Zeqing Yang, Kai Peng
17. An Integrated Approach of CAD/CAM for Spatial Cam with Oscillating Cylindrical Rollers (D8437)  
Jeng-Nan Lee, Ying-Chien Tsai, Hung-Shyong Chen, Huang-Kuang Kung
18. A Study on Universal Design Product Development Combined with Value Engineering Approach (D8638)  
Seongjun Park, Jaeil Park
19. Compression Test on Cold-Formed Steel Built-up Back-to-Back Channels Stub Columns (D8658)  
Tina Ting Chui Huon, Lau Hieng Ho
20. Experimental Measurement of Friction Coefficient Applied to HSM Modeling (D5907)  
Guy Sutter, Gautier List, Xuefeng Bi, Jean-Jacques Arnoux, Abdenbi Boutiche







**ICMSE 2011**





# Curved Layer Fused Deposition Modeling in Conductive Polymer Additive Manufacturing

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**Keywords:** Curved Layer Fused Deposition Modeling, Conductive 3D printing, Additive Manufacturing.

**Abstract.** This paper describes a curved-layer additive manufacturing technology that has the potential to print plastic components with integral conductive polymer electronic circuits. Researchers at AUT University in New Zealand and the National University of Singapore have developed a novel Fused Deposition Modeling (FDM) process in which the layers of material that make up the part are deposited as curved layers instead of the conventional flat layers. This technology opens up possibilities of building curved plastic parts that have conductive electronic tracks and components printed as an integral part of the plastic component, thereby eliminating printed circuit boards and wiring. It is not possible to do this with existing flat-layer additive manufacturing technologies as the continuity of a circuit could be interrupted between the layers. With curved-layer fused deposition modeling (CLFDM) this problem is removed as continuous filaments in 3 dimensions can be produced, allowing for continuous conductive circuits.

## Introduction

Rapid Prototyping (RP) is an additive fabrication technology which creates complex 3dimensional prototypes in short times. The rapid prototyping process begins by taking a 3D computer generated file and slicing it into thin slices (commonly ranging from a few microns to 0.25mm per slice depending on the technology used). The rapid prototyping machine then builds the model one slice at a time, with each subsequent slice being built directly on the previous one. The technologies differ mainly in terms of the materials they use to build the part, and the process used for creating each slice of the model [1].

RP technologies now exist that can make plastic parts and parts in metals such as titanium, and even stainless steel [2]. Not only is the choice of materials and processes increasing, but the last few years have seen a significant reduction in the cost of these technologies.

Fused Deposition Modeling (FDM), the core technology used in this particular project, works by extruding a thin ribbon of plastic as the nozzle of the machine traces each slice. This is then repeated for each subsequent slice of the model. It, in fact, uses 2 deposition nozzles: One for the part material and another for the support material which is used to support overhanging parts [2].

The parts currently produced by FDM systems are reasonably strong plastic components that are well suited to basic functional testing and can easily be sanded and painted to reproduce the aesthetics of the production product thus also making them useful for consumer testing.

Though each RP technology has advantages and disadvantages over the others, one of the weaknesses common to all current flat-layer RP technologies is a relatively poor surface finishes caused by the 'staircase' effect on curved surfaces and a lamination weaknesses in a direction perpendicular to the layer direction (Fig. 1). If smooth surfaces are required for the component, the staircase effect can require sometimes substantial post-processing of the part (sanding and polishing) in order to produce smooth surfaces.

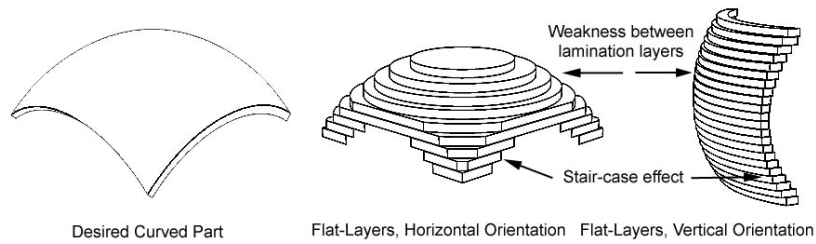


Figure 1. The staircase effect and lamination weakness problems caused by conventional flat-layer rapid prototyping.

This paper looks at the application of curved-layer FDM [3] (Fig 2) for producing plastic components with integral conductive tracks that allow for the elimination of wiring or printed circuit boards from products.

### Curved Layer Fused Deposition Modeling

This project included the development of a machine capable of constructing a part by depositing the layers of material as curved layers instead of the current flat layers. This new process could be named Curved-Layer Fused Deposition Modeling (CLFDM). The concept behind the technology is as follows: A substructure of ‘support material’ to the curved part is first created through existing flat-layer methods using a soluble support material. This support structure forms the base onto which the curved layers of product material can then be deposited by having the deposition head precisely follow the contour of the part (Fig. 2). The effect of these curved layers is to eliminate the staircase effect altogether, as well as removing the inherent lamination weakness in the direction of the layers.

The bulk of the research being carried out at different universities has been related to investigating alternative materials for FDM and working with a variety of materials including ceramics and metals [4], high performance thermoplastic composites [5] and metal/polymer composites [6]. While special FDM systems have been designed for experimental deposition of different types of materials with different techniques and much work has been done on the analysis of the mechanism of deposition [7, 8], very little research has been done on depositing material as curved layer. The literature on RP reveals a research project in which the Laminated Object Manufacturing process was used to create curved layers [9] at the University of Dayton in the USA but the results were limited by the ability to evenly stretch a material over a curved mandrel and the small range materials that could be used.

This CLFDM technology opens up an entirely new possibility of building complex curved plastic parts that have conductive electronic tracks and components printed directly as part of the plastic component. It is not possible to do this with existing flat-layer additive manufacturing technologies, particularly on parts that are curved, as the continuity of a circuit would be interrupted between the layers (Fig. 2). With curved-layer fused deposition modeling (CLFDM) this problem is removed as continuous filaments in 3 dimensions can be produced, allowing for continuous conductive circuits.

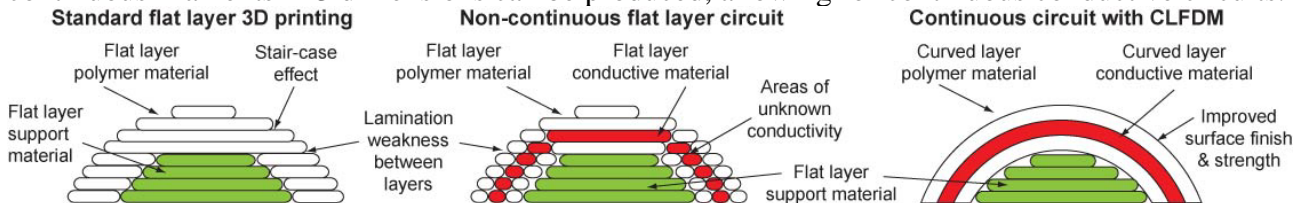


Figure 2. Curved layer vs flat layer for conductive polymers.

The elimination of the flat printed circuit boards (PCBs) and possibly even some of the electronic components, such as transistors, that are used in most electronic products creates a whole new type of product in which the housing of the product becomes its electronic circuit. This, in turn, could revolutionize the field of product design which would no longer be constrained by having to design around flat PCBs. It opens up new possibilities for miniaturization and could lead to a new paradigm in direct digital manufacturing in which the cost and size of many electronic components no longer affects the product as they are simply printed as part of the products plastic housing.

## CLFDM System Overview

Two CLFD systems were developed in tandem at the National University of Singapore and at Auckland University of Technology in New Zealand. On the system developed at NUS in Singapore composite material was extruded using an in-house, screw feed system mounted on a Sony Robokids Cartesian robot [fig. 3]. The Auckland University of Technology machine used a modified Fab@Home machine (Fig. 3) to extrude light curing polymer to create curved layer parts.

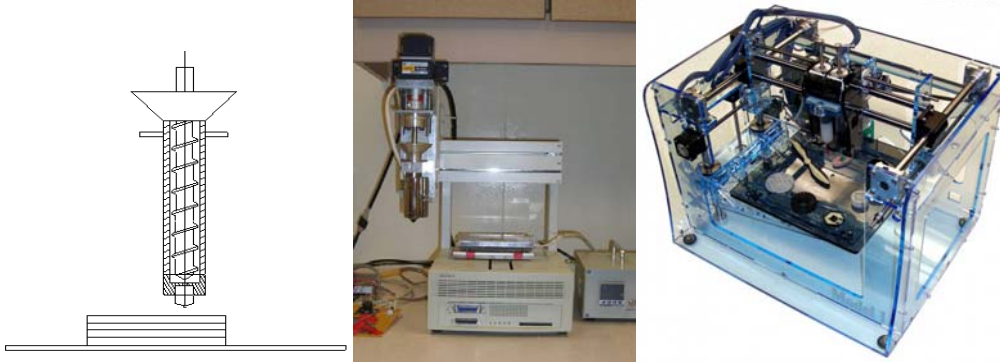


Figure 3. The Screw Extrusion System developed at NUS and Fab@Home system developed at AUT.

Software was written, in Matlab, that accepted an stl file of a curved part. The software used a simple algorithm to split the part up into the real component and its support material structure by examining the bottom most surface of the part. Any section of that surface that was not at the zero point of the part was considered to have support material below it. The support material component of the part was then put through an algorithm that sliced it up into flat layers (Fig. 4). The resolution was a variable that could be reduced or increased as needed. The algorithm started at the bottom surface and created a new flat plane above the first surfaces spaced away from the first plane by whatever thickness variable had been set. A second algorithm then created the curved layers for the real part by offsetting from the bottom-most surface to produce the next curved layer (Fig. 4).

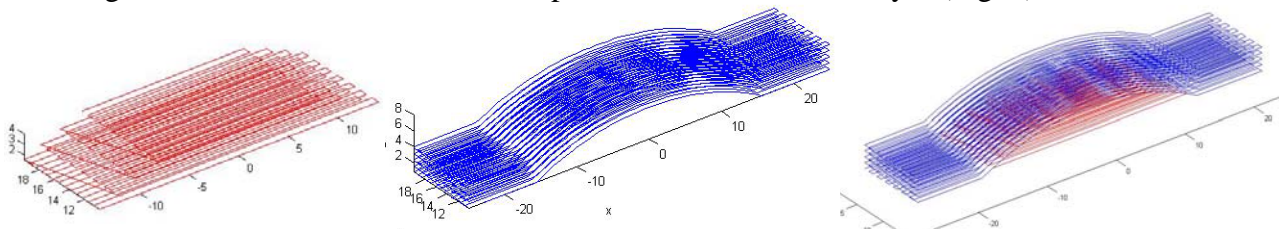


Figure 4. Matlab Program for flat support material structure, curved layer structure, and combined structure.

An algorithm was then used to combine the results of the other algorithms into a single text file containing first the tool-path for the support material, and then that for the build material (Fig. 4). The order of the combined file was critical, as the support material needed to be printed in flat layers before the build material was to be deposited as curved layers. The text file was then sent to the machine's microcontroller and used to control the appropriate x, y or z stepper motor to build first the support material structure, and then the real component on top of the support structure. The extrusion head, in the initial tests, was kept extruding at a constant rate. Through these systems, parts were successfully produced that demonstrated the principle of curved-layer fused deposition modeling.

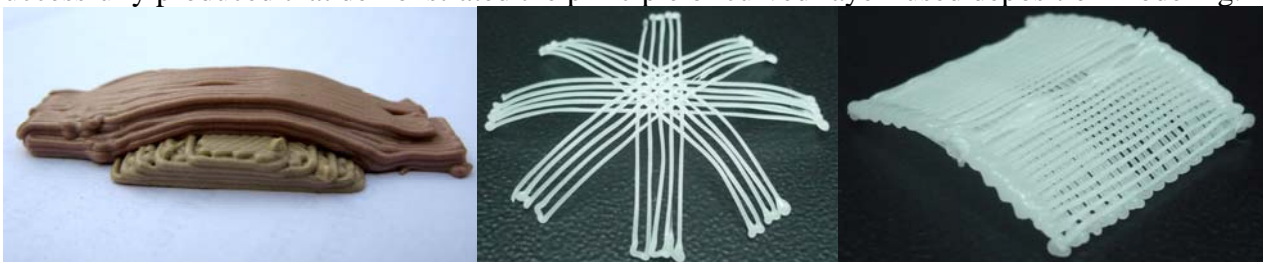


Figure 5. curved layer part produced by modified Fab@home rapid prototyping machine, And curved layer part produced by the National University of Singapore machine.

Figure 5 shows curved models using light curing polymer on the AUT machine, and parts made on the NUS machine using polymer made from short fibre reinforced composite material.

Work is now underway to allow the CLFDM system to print parts that contain tracks of conductive material within the plastic part itself. The conductive material project will extrude a polymer mixed with carbon nanotubes, and/or other conductive elements. The conductive polymer system will use three different deposition heads, one for each material. Work is also underway to develop effective methods of connecting components to such integral conductive tracks.

## CONCLUSION

This paper describes a novel process known as Curved-Layer Fused Deposition Modeling. This new technology has the potential of being able to print conductive tracks integral to a product which is not possible with conventional flat-layer technologies. This opens up a new field of design in which products might be designed without the restriction of designing around PCBs and wiring looms.

Proof-of-concept machines were built and software algorithms were written that allowed the system to create parts in which support material was first deposited as conventional flat layer structures, and build material was then deposited over the support structure as curved layers. The initial components built by the machine successfully demonstrated the proof-of-concept of Curved-Layer Fused Deposition Modeling.

The creation of the research platform now opens the field to further areas of investigation into curved-layer fused deposition modeling, the first of which is the printing of conductive polymer tracks as part of the other normal polymer tracks that make up the part.

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