

UCD School of Electrical, Electronic and Mechanical Engineering

Research in Micro-Manufacturing

Professor Gerry Byrne Fellow IOM<sup>3</sup>

Materials Ireland Conference  
22<sup>nd</sup>-23<sup>rd</sup> April 2008

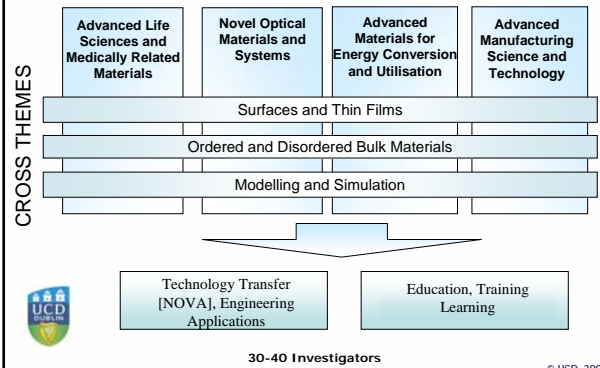


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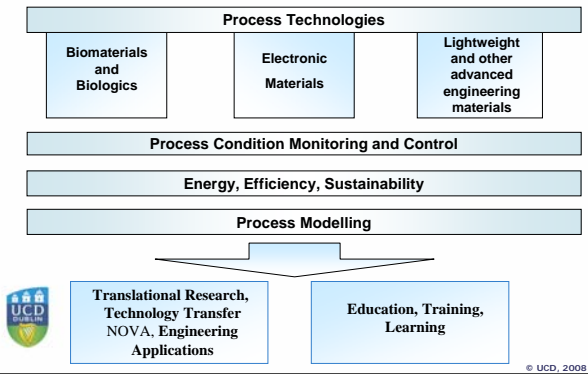
Scoil na hInnealtóireachta  
Leictreach, Leictreonaigh agus  
Mheicniúil UCD



### SEAM Internal Structure – Four Tech Platforms



### SEAM Technology Platform IV: Advanced Manufacturing



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### Sample Projects from Academics involved in Micro-Manufacturing Research

Byrne  
Gilchrist  
Browne  
Dowling  
Stanton

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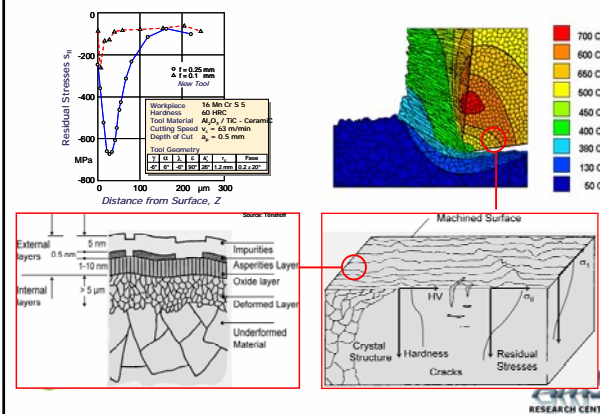
Micro-Manufacturing Research

Prof. Gerry Byrne

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### Micro-Engineering "The Importance of Surface"



### Micro-Engineering "The Importance of Surface"

#### The Changing Requirements of Functional Surfaces

Surface Functionality and Performance Levels

1900-1970	1970's	1980's	1990's	2000-2010
<b>Application Examples</b> - Piston - Valve - Turbine	<b>Application Examples</b> - Piston - Valve - Turbine - Aircraft Landing Gear	<b>Application Examples</b> - Piston - Valve - Turbine - Aircraft Landing Gear - Medical Implants	<b>Application Examples</b> - Piston - Valve - Turbine - Aircraft Landing Gear - Medical Implants - Microelectronics	<b>Application Examples</b> - Piston - Valve - Turbine - Aircraft Landing Gear - Medical Implants - Microelectronics - MEMS
<b>Functional Requirements</b> - Form - Surface Roughness (Ra, Rz, Rt) - Wear Resistance - Corrosion	<b>Functional Requirements</b> - Surface Roughness (Ra, Rz, Rt) - Fatigue Resistance - Corrosion	<b>Functional Requirements</b> - Surface Roughness (Ra, Rz, Rt) - Fatigue Resistance - Corrosion - Chemo-Mechanical Fatigue Resistance - Optical	<b>Functional Requirements</b> - Surface Roughness (Ra, Rz, Rt) - Fatigue Resistance - Corrosion - Chemo-Mechanical Fatigue Resistance - Optical - Microcomponent Strength & Flexibility - Multifunctional Surfaces - Biomechanics	<b>Functional Requirements</b> - Surface Roughness (Ra, Rz, Rt) - Fatigue Resistance - Corrosion - Chemo-Mechanical Fatigue Resistance - Optical - Microcomponent Strength & Flexibility - Multifunctional Surfaces - Biomechanics - SNOM - PhotoThermal Microscopy - Total Reflection X-Ray Fluorescence
<b>Measurement Methods</b> - Optical Interferometry - Tactile - Pin on Disk etc. - Integrating Sphere	<b>Measurement Methods</b> - Stylus Profilometer (Ra, Rz, Rt) - Wohler Test	<b>Measurement Methods</b> - CMM Mapping - Laser Profilometer - AFM - Stylus Profilometer (Ra, Rz, Rt)	<b>Measurement Methods</b> - White Light Interferometry - Micro-Raman Spectroscopy - Nanoindentation - HRTEM - Etch, SEM, TEM - STM	<b>Measurement Methods</b> - SNOM - PhotoThermal Microscopy - Total Reflection X-Ray Fluorescence

100 mm / cm<sup>2</sup> Planarity (semiconductors)  
 100 mm / cm<sup>2</sup> Planarity (semiconductors)  
 - Microquarterned Surfaces  
 - Zero Stiction  
 - Microcomponent Strength & Flexibility (Brittle Materials)  
 - Optical Scatter  
 - Multifunctional Surfaces  
 - Biomechanics

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### Microgrinding of Semiconductor Materials

- Research Domain
  - Rotational Grinding of Semiconductor Substrates
  - Meso-Scale Kinematics of Engagement
- Research Objectives
  - Development of Meso-Scale Simulation Algorithms
  - Predict Local Surface Finish, Integrity and Forces
  - Experimental Validation and Process Optimisation
- Commercial Objectives
  - Design of Intelligent Tool Technology
- Status Update
  - Simulation Software Developed and Validated
  - Technology: "Proof-of-Principle" Established

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### Chemical Mechanical Planarisation (CMP) of Semiconductor Surfaces

The Micro-Scale

Carrier Head  
 Wafer  
 Polishing Pad  
 Slurry  
 Al Platen

640 mm

Polyurethane Pad  
 Slurry pH = 10.5  
 Abrasive Particles < 100nm  
 Pressure = 70 kPa  
 Platen speed = 40 rpm  
 Carrier speed = 40 rpm  
 Slurry flow rate = 150 ml/min

CMP Tool in UCD

FEA Model of Contact Stresses in CMP

- Research Objectives
  - Model Stresses at Interface in CMP
  - Determine Key Parameters and Optima
  - Appraise Control Systems
  - Develop "Intelligent Tooling"

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### Laser Hardening by High Power Diode Laser

- Research Domain
  - Laser Surface Hardening
  - High Power Diode Laser Technology
- Research Objectives
  - Model and Optimise for Specific Materials
  - Experimental Validation of Model
- Commercial Objectives
  - Licence in Ireland
- Project Outcomes
  - Technology Licensed in Ireland
  - Significant Transfer of Know-How
  - Advanced State-of-the-Art in Tribology

Laser Hardening Technology at UCD

Thermal Modelling of Laser Hardened Surfaces

Presentation of Award for Licence

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Prof. Michael Gilchrist

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### Injection Moulding of Micro-scale Features

- Research Domain
  - Micro-moulding
  - Polymers and Composites
- Research Objectives
  - Modelling of Melt-Mould Interaction
  - Knowledge of Material-Mould Response
- Commercial Objectives
  - Assist Industrial Development
- Status Update
  - Project due to commence July 2008

Microstructure of Moulded Virgin Polypropylene

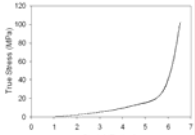
Distribution of Fibre Reinforcement in Melt

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### Mechanical Response of Biological Skin


1. Research Domain
  - Performance of Precision Surgical Instruments
  - Cutting of Skin and Surrogate Materials
2. Research Objectives
  - Mechanical Response of Nonlinear Materials
  - Predictive Performance of Tool-Tissue Interaction
3. Commercial Objectives
  - Improved Efficiency and Design of Surgical Blades and Cutting Tools
4. Status Update
  - Experimental Devices Designed and In Use
  - Quantitative Models being Developed




Nonlinear Stress-Strain Response of Skin Surrogate



Tip of Carving Knife (scale bar = 100µm)



Stained Collagen Fibres in Skin

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## Micro-Manufacturing Research

Dr David J. Browne

Phase Transformation Research Group



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### Bulk Metallic Glass Tooling for Micromanufacturing

1. Research Domain
  - Micro-scale Tooling
  - Metallurgical Engineering: Materials Science
2. Research Objectives
  - High Performance and High Precision BMG and Composite Metallic Tooling
  - Micro-moulds for Polymeric (medical) Devices
3. Commercial Objectives
  - Assist Industrial Development
  - Develop New Tooling Technology for Medical Device Industry
  - Other Spin-off Applications
4. Status Update
  - Project Commenced March 2008.
  - Initial BMG Samples Being Tested.



UCD Arc Melter



SEM Micrograph of BMG Composite (Hofmann et al. *Nature* 451, 2008, 1085-1089)

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### Microgravity Materials Science

1. Research Domain
  - Advanced Materials Processing
  - Computational Modelling
  - Space Experimentation
2. Research Objectives
  - Increase Knowledge for Improved Industrial Processing
  - Improved Data for Numerical Model Validation
  - Solidification and Foaming of Metals in Diffusion-Controlled Conditions
3. Commercial Objectives
  - Advanced Solidification and Casting Routes for Conventional Alloys and High Performance Intermetallics.
  - New Software for Materials Process Simulation.
4. Status Update
  - Microgravity Experiments performed May 2006.
  - UCD Front-Tracking Models Validated with Space Experiments.
  - Busy Pipeline of New Space Experiments.



ESA Astronaut on Space-walk working on *Columbus*, Feb. 2008



Space-Solidified Al-Si Alloy, May 2008




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## Micro-Manufacturing Research

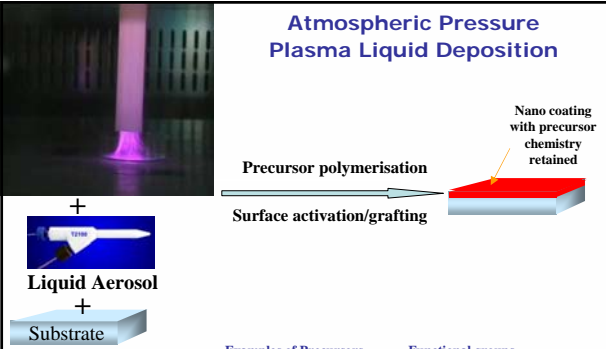
Dr Denis Dowling

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### Atmospheric Pressure Plasma Liquid Deposition




Precursor polymerisation

Surface activation/grafting

Nano coating with precursor chemistry retained

Liquid Aerosol + Substrate

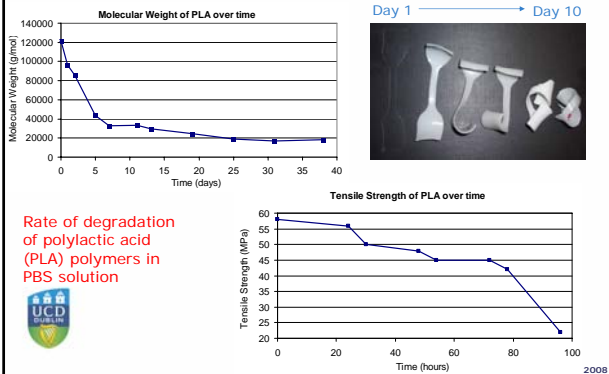
Examples of Precursors	Functional groups
Siloxane	SiO <sub>x</sub> and SiOR
Acrylic acid	- COOH
Mixed Precursors	composite coatings



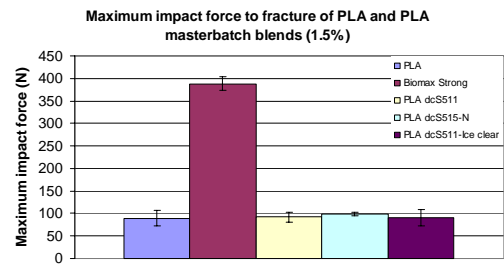
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## Biodegradable Polymers – PLA



## Blending of masterbatches into PLA



Study on how a range of different masterbatch additions during the extrusion of PLA sheet influenced impact strength

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Dr Kenneth Stanton

Ken will talk later

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“Microman” Industry Cluster  
Micro-Manufacturing of Centre of Excellence  
Focus: Medical Devices

1. Network of Irish Companies
2. Medical Devices Sector
3. Technology Roadmap of Micro-Manufacturing Challenges
4. Main Themes
  - *Advanced Manufacturing and Technology Development*
  - ☐ *“Micro Part Handling Solutions for the Factory of the Future”*
  - Micro Tooling and Moulding
  - Additive Layer Fabrication



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“GREP”  
International Graduate School for Micro Nano Engineering

1. 26 Partners International
2. Kick Off Feb 2008
3. Education/training Remit Masters and PhD
4. Prof Crean Project Leader



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