2019 Student Conference

Abstracts

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1. Alain Moriana – University of Wollongong

Exploring ferroelectric domain engineering through ceramics texturing, for underwater acoustics applications

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Many underwater acoustic transducers, such as sound navigation and ranging (SONAR) systems, are based on piezoelectric materials, taking advantage of the direct (receiver) and converse (transmitter) piezoelectric effects. Relaxor ferroelectric single crystals have been researched actively in recent years due to their significant enhancements to acoustic transducer performance. However, single crystals are limited in applications due to the complexity of fabrication, composition inhomogeneity, high cost and time of synthesis as well as the inferior mechanical properties compared to their ceramic counterparts, limiting their transition to SONAR systems. In parallel to single crystals, textured piezoelectric ceramics are being studied based on the template grain growth process (TGG). Advantages include reduced cost of manufacturing, significant performance enhancements compared to polycrystalline piezoelectric ceramics and machinability for easier industrial transition into SONAR systems.

In this study, $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ ceramic systems were explored using $BaTiO_3$ template seed crystals in an effort to induce texturing, hence maximising piezoelectric response by focusing on properties favourable for SONAR systems: High electromechanical coupling (k_p), piezoelectric strain constant (d_{33}) and coercive field (E_C). As of present, it is possible to achieve d_{33} values almost twice that of their polycrystalline counterparts with only moderate degrees of crystalline texturing. With further refinement in slurry composition, ceramic post-processing and tape casting conditions, it is possible to further increase piezoelectric response by inducing higher degrees of texturing. These techniques could also be implemented in other ceramic/template systems such as PIN-PMN-PT and PMN-PZT.

2. Emily Kibble – University of Western Australia

Macrophage infectivity potentiator (Mip) proteins as novel anti-virulence targets in pathogenic Neisseria.

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Neisseria meningitidis is the bacterial causative agent of invasive meningococcal disease (IMD). The rate of IMD in Australia is increasing, with over 250 cases in 2018. Therefore, there is increased need for novel drugs against *N. meningitidis.*

Macrophage infectivity potentiator (Mip) proteins are found in a wide range of pathogens, and are known to be important in survival of bacteria within host macrophage cells. Mip proteins represent potential broad spectrum anti-virulence drug targets due to their conserved enzymatic and drug binding domains across species. While most bacteria are known to have one Mip protein, *N. meningitidis* encodes for two different Mip-like proteins. We hypothesise that both Mip proteins are important novel anti-virulence targets in *N. meningitidis*.

Deletion of the genes encoding for Mip proteins in *N. meningitidis* has resulted in various effects, including increased bacterial clumping and significantly decreased bacterial survival within macrophage cells. Both Mip proteins have been recombinantly expressed and purified, and have been found to be active enzymes which can be inhibited. Novel inhibitors are being tested against recombinant Mip protein, and have been tested against *N. meningitidis.* These inhibitors have been shown to have an inhibitory effect on the enzymatic activity of purified recombinant Mip, and result in a significant decrease of bacterial survival within macrophages. Mip and Mip-like proteins have been shown to have an important role in macrophage cell infection and survival, and represent an important set of anti-virulence targets in *N. meningitidis.*

3. Harry Veivers – University of Queensland

Effect of fibre length on carbon fibre reinforced composite thermomechanical performance

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Composite material technologies, particularly using continuous fibre reinforcement, have long been synonymous with high performance and tailorable material properties which enable significant lightweighting improvements over traditional monolithic aluminium and steel structures. However, the use of short fibres over continuous reinforcement is highly desirable given their increased lightweighting potential, excellent manufacturability and associated low processing cost. Given the rising need for improved thermal management and high temperature capability of Defence platforms, such as small arms, this work aims to investigate the effect of carbon fibre length on the thermomechanical performance of short fibre composites.

It is widely established that the length of short fibre reinforcement significantly influences the mechanical performance of composite materials, in particular the strength, stiffness and impact toughness. In the past, limited polymer matrix materials have been available which are able to meet the challenges of high temperature environments. As a result, the effect of short fibre length on the thermomechanical properties of polymer matrix composites has yet to be comprehensively investigated. By investigating this at high temperatures, it is expected that a characteristic model can be developed to characterise the effect of fibre length. It is anticipated this will lead to the increased implementation of short fibre composites and advanced polymer composites by providing improved modelling and material selection capability and performance confidence. Ultimately, this will allow for significant improvements in lightweighting and reductions in processing cost to these platforms.

Initial investigations have led to the integration of advanced polymer matrix materials into next generation small arms technology, leading to significantly improved lightweighting and thermal management. Future work will utilise TGA, DMTA, uniaxial tension and 3-point bending to develop the characteristic model. Ultimately, this will be validated through implementation into a next generation small arms demonstrator system where it will enable.

Key Words: Lightweighting, Small Arms, High Temperature, Material Characterisation

4. Jasmine Proud – Victoria University

Development of a wearable device to reduce risk factors associated with injury during military manual handling tasks

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In Australia, 41% of industry injury claims are due to manual handling tasks, costing $14.58 billion annually. In the Australian Army, 78% of physically demanding tasks are considered manual handling, which increase the risk of musculoskeletal injury. This has led to a need for an exoskeleton system that can support, move and adapt to repetitive, fatiguing tasks. The predecessor to this exoskeleton system is the development of a stand-alone wearable device that could assist personnel in reducing risk factors associated with injury due to manual handling tasks.

Laboratory experiments using biomechanical task analysis based on military manual handling protocols is being performed. This will provide full body kinetic and kinematic measurements of participants during lift to platform tasks with increasing load. These measurements will be analysed for predictive factors of external loading above a participant's capability, which is indicative of an increased injury risk. A prototype wearable device will be developed using embedded predictive algorithms and rapid prototyping methods. The device will then be evaluated through objective and subjective measures during human trials.

This research will contribute a novel wearable device that provides feedback to military personnel during manual handling for reducing risk factors associated with injury. The embedded predictive algorithm will also be used as an assist-as-needed control strategy for the development of an active exoskeleton in future work.

5. Jemma Gasperoni – La Trobe University

Understanding the genetic regulation of behaviour

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From the developing embryo to the adult brain, the tight regulation of our genes is important for variations seen in our behaviour. Our study focusses on PLAG1, a transcription factor known to be expressed in the hippocampus, hypothalamus and cortex, areas crucial for learning, memory and emotional behaviours. More specifically, we are looking at these regions during development where we hypothesise that a lack of PLAG1 will significantly alter the development and ultimately the function of these key areas.

Using our *Plag1* knock-out (KO) murine model we will investigate the effect of PLAG1 deficiency at a cellular level. The data that we have collected thus far show a significant decrease in the number of proliferating cells in the developing cortex of KO mice. This will be followed up by suite of cell culture assays to assess the proliferative, survival and differentiation potential of embryonic neural stem cells in the absence of PLAG1. Using anti-sense morpholino oligonucelotides (morpholinos) to transiently inhibit PLAG1 translation in zebrafish, we will use this model to further characterise PLAG1's role during neurodevelopment and adult behaviour. Overall, this work will contribute to our understanding of the underlying genetic regulation of neurodevelopment and how this subsequently influences adult behaviour. Expanding our understanding of the genetic components of behaviour provides us with the opportunity to one day predict how an individual will respond, act and learn in a given task, situation or environment based on their genetic makeup.

6. Pragathi Dissanayaka – University of Wollongong

The Effects of Reoccurring Weld Repairs on the HAZ of a 690MPa, Quenched and Tempered Steel

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Considering the through life support of Australia's ageing submarine fleet, it is crucial to understand the microstructural effects when carrying out multiple weld repairs. The submarine hulls are fabricated with a 690 MPa, quenched and tempered (Q&T) steel. Reoccurring weld repairs are an essential part of the maintenance program, which include; pad weld repairs for the rectification of corrosion damage, welding and re-welding of temporary support attachments to the hull and internal access cut-outs require full penetration welds for rejoining the hull.

In the process of fusion welding, a heat affected zone (HAZ) is generated next to the weld, potentially leading to the formation of local brittle zones (LBZ). It is understood that the coarse grain heat affected zone (CGHAZ) and inter-critically reheated coarse grain heat affected zone (ICCGHAZ) are the regions with lowest toughness. To investigate the occurrence and the influence to the overall performance of welds due to presence of these regions, a series of real weld repairs were conducted to simulate maintenance procedures. Data from these real welds was then used to setup simulated weld repairs using a Gleeble thermal mechanical simulator, which allowed LBZ's to be isolated and investigated. A range of microstructural and mechanical tests were conducted to investigate the effects of different thermal cycles and multiple thermal cycles on the parent plate properties.

The results of this study indicate that there is no considerable effect on toughness, hardness, residual stresses and microstructure in reoccurring repair welds compared to single repair weld.

It also envisaged that the results from the mechanical testing and subsequent characterization (optical, SEM, EBSD and TEM) will provide valuable guidance on the maintenance practices for damage repair on submarine hull steel.

7. Samuel Smith – University of Tasmania

Experimental development to investigate unsteady loading on a hydrofoil immersed in a turbulent boundary layer

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The unsteady interaction between multi-phase flow and the structural response of a hydrofoil involves complex phenomena key to the performance of propellers and control surfaces on marine vehicles. Despite recent extensive research into fluid-structure interaction of cavitating hydrofoils there remains insufficient experimental data to explain many of these observed phenomena. The dynamics of cloud cavitation about rigid and compliant 3D hydrofoils is investigated in a cavitation tunnel. The two hydrofoils have identical undeformed geometry of tapered planform with constant NACA 0009 section. Unsteady measurements of force and tip deformation were made simultaneously with high-speed imaging to enable correlation of forces and deflections with cavity physics. Two shedding modes have been identified, high and low, for both rigid and compliant hydrofoils although significant differences in peak amplitudes where observed. The high shedding mode that occurred at high cavitation numbers values varied in frequency with cavitation number and the high-speed imaging showed the dominant shedding mechanism to be due to re-entrant formation. The low shedding mode that developed at lower σ values where cavity lengths grew to about full-chord, occurred at a nominally constant frequency. In this case, the high-speed imaging showed the dominant mechanism to be due to shockwave formation. The flexibility of the compliant hydrofoil was found to notably increase the magnitude of the force fluctuations for the low frequency mode compared to the rigid foil. However, hydrofoil compliance was seen to dampen the fluctuating magnitude of the high frequency mode, despite being close to the hydrofoil's natural frequency.

8. Sarah Knowler – La Trobe University

The effect of antidepressants on the gut microbiota

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Changes to the structure of the gut bacterial community have been attributed to a range of factors including environment, diet, age, sex, mental health status and medication. However, in human studies it is difficult to adequately control these factors.

In this study, a mouse model of depression was utilised to investigate the effect of antidepressants on the gut microbiota, controlling for variables such as diet and environmental factors. Two classes of antidepressants were administered to adolescent mice over a three-week period. Faecal samples were collected pre, peri and post administration of antidepressants. Analysis of bacterial communities was completed using automated ribosomal intergenic spacer analysis (ARISA) and quantitative PCR (qPCR).

There were no differences in bacterial community structure and overall abundance in depressed mice compared to control counterparts. As a main effect, sex had the most significant impact on diversity in the bacterial community in faecal samples.

Sampling time-point was seen to effect both community structure and overall bacterial abundance. As these differences were observed in mice that did not receive antidepressants, it is likely that a change in developmental stage from adolescence to adulthood was the factor driving these results.

Whilst there were some differences in antidepressant treatment groups, these were not consistent across depression status, sex and sampling time-point. Overall, sex and sampling time-point were the underlying factors in any apparent differences between groups.

Future work will involve amplicon sequencing to fully investigate changes to the gut bacterial community in depression following the administration of antidepressants.

9. Scarlet Kong – University of NSW

Exploring electro-mechanical response of textured ceramics for underwater acoustic applications

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Piezoelectric materials have the unique ability to change their shape on application of an electric field, and conversely, produce electric charge under mechanical force. It is this reversible phenomenon that allows us to use these materials as acoustic transducers in underwater SONAR systems.

Typically, high performance or high strain piezoelectrics are in the form of single crystals. However, the complexity and cost of single crystal piezoelectrics growth is challenging, preventing their use in larger-scale SONAR systems. Meanwhile, polycrystalline piezoelectrics can be mass produced, but the variation in grain orientations reduces the overall performance of the ceramic.

Textured piezoelectrics, where the grain orientations are mostly aligned along one direction, have been found to achieve comparable performances to that of single crystals and potentially offers a more economical fabrication process. However, to achieve high performances in textured ceramics, the relationship between its complex microstructure and fabrication parameters must be understood.

The enhanced piezoelectric response of textured ceramics was studied by varying the grain orientation distribution and observing the changes in the overall strain. Through computational microstructural strain calculation, the effect of electric-field induced phase transformation strain improved as texture increased in the ceramic. The homogeneity of the grain-scale strain response also increased, developing single crystal-like behaviour. Structural characterisation through X-ray diffraction and scanning electron microscopy was also conducted to observe the changes in texture and grain orientations with varying fabrication parameters.

The combination of computational and experimental techniques expedites our understanding of textured microstructures in order to develop textured piezoelectrics with enhanced performance.

10. Stefan Lundgaard – Swinburne University of Technology

High strain rate behaviour of AlSi12 and 17-4 PH parts produced by Selective Laser Melting

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Metamaterials are an exciting field that provides capabilities for highly efficient and tuneable devices for phase and field modulation of light, resonators, wave-guides, absorbers, switches and detectors.[1,3] Perfect absorbers are of interest within the metamaterial family due to wavelength specific applications such as solar cells, photo-detectors and optical filters. Lithography-free multi-layer perfect absorbers avoid the need for lithography steps, streamlining the fabrication process and thus reducing cost. Thin film techniques allow for these metamaterials to be designed at sub-wavelength thicknesses, creating highly optimised structures with short fabrication times.

Here, we demonstrate a concept and fabrication of lithography-free layered Ti-SiO2 structures which has reduced reflectivity (black) that is tailored to the visible spectrum. The structure has enhanced absorbance and is easily tuned for reduced or minimal transmission. The multi-layered thin-film metamaterial is designed so that optical impedance matching produces minimal reflectance and absorption for a wide range of visible and infra-red (IR) wavelengths and incidence angles.[4]

A conceptual test using titanium metal and silicon dioxide thin films are ordered in specific layer thicknesses as shown in Fig. 1. The first absorber test has high absorption fraction up to 86% measured from 200 - 1400 nm at normal incidence. Layer thicknesses and their effect on incident wavelength will be discussed, assisted by simulations and experimental data. A range of other metals are also included and measured.

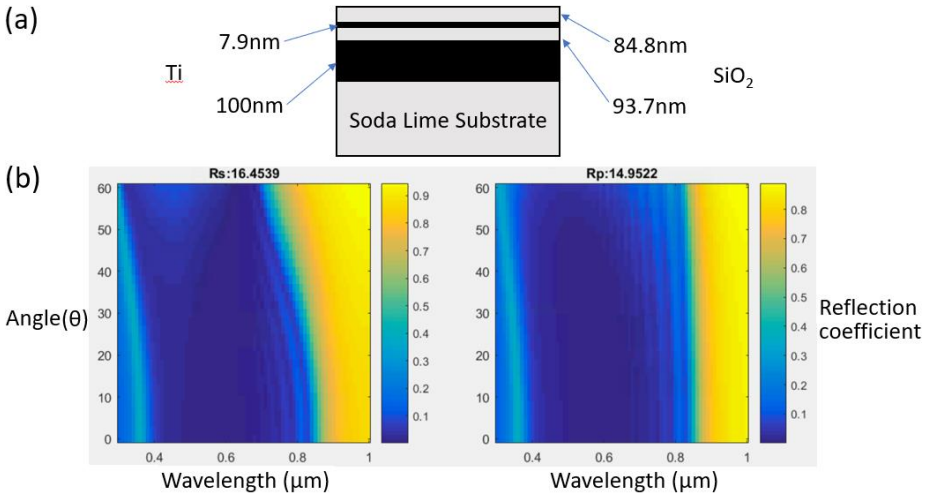

Figure 1. (a) Schematic of the absorber metamaterial using Ti (black) and SiO2 (grey) layers to promote light trapping and loss by absorption. (b) Simulation of reflection fraction of incident light from normal to 60_ for wavelengths ranging between 0.3 - 1 μm for both S polarised (left) and P polarised (right) for the sample shown in (a). Total film thickness is 286.4 nm.

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11. Stefan O'Toole – University of Melbourne

Exploring the Interface of Planning and Reinforcement Learning for Sequential Decision Making

Automated sequential decision making provides many real world benefits including such defence applications as discovering novel behaviours through simulations of manned and unmanned operations. Current theories of human cognition propose that a fast and associative system works in conjunction with a slow and deliberative one. Planning is a model-based method for decision making that can be likened to the latter, and Reinforcement Learning to the former. While Planning and Reinforcement Learning are usually considered to be far removed, there have been notable successes combining the two methods. To address questions about the extent of synergies between Planning and Reinforcement Learning and how such synergies can be successfully exploited, we propose several new Planning and Learning methods. We have improved upon a state-of-the-art planner's performance on stochastic shortest path problems and demonstrated the need for the incorporation of a learnt value function with the planner when playing the Atari-2600 games. Preliminary results on problems requiring deep exploration due to vast plateaus in reward functions have also shown an improved method of learning from a demonstration either from a human or planner. Future work will look to further exploit the synergies between Planning and Learning on multi-agent problems.

12. Steven de Candia – University of Tasmania

The Contribution of UNDEX Loading on Platform Response

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Underwater explosions (UNDEX) are a significant threat against the effectiveness of naval platforms. Understanding the interaction of UNDEX on a platform would improve how design and operational requirements are defined, and enhance the overall capability of the platform. A numerical study was performed to investigate how the shock wave and bubble loading from UNDEX affect the UNDEX-induced whipping response of a submerged platform. From the selected results presented here, we were able to qualitatively determine how these components contributed to the overall platform response, which may allow for a more targeted approach in countermeasures against the UNDEX threat.

13. Zhenyu Fei – University of Wollongong

Tailoring microstructure in armour steel welding

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The ballistic performance of armour steel welds using austenitic filler materials is poor on account of the disparity in the mechanical properties of the weld and base metals. Consequently, a novel Keyhole Tungsten Inert Gas welding process with a trapezoidal AISI309 austenitic stainless steel interlayer was developed to tailor chemical composition and microstructure by controlling the solidification sequence. Results show that the dilution rate in the weld metal region can reach up to 43.5% by placing specially designed interlayer in between base metal, providing a very great scope for microstructure modification. Detailed weld analysis was undertaken by X-ray diffraction, optical and secondary and transmission electron microscopy, energy dispersive spectroscopy and electron back-scattering diffraction. The results from Vickers hardness indents and Charpy impact toughness testing at -40 °C show that the properties of the weld metal region are comparable to that of the base metal. This is ascribed to the weld metal comprising a two phase microstructure of martensite and retained austenite which contribute to improvements in strength and toughness, respectively. More importantly, the tailored chemical composition, microstructure and low temperature phase transformation in the weld metal may dramatically reduce the tendency toward both solidification cracking and hydrogen assisted cold cracking.