Conference Report: Advanced Architectures in Photonics Mykonos, Greece, September 2016

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The second biennial conference on Advanced Architectures in Photonics took place between the 26th-29th September 2016, on the Greek island of Mykonos. Talks given at the conference covered a broad range of materials, devices and applications in photonics. There were 3 plenary lectures, 12 invited talks, and a total of 28 contributions. The relatively small size of the conference and wide range of research areas meant that many discussions provided interesting and useful insights.

During the conference, I presented a talk entitled "Nanoporous Distributed Bragg Reflectors for Optical Microcavities in Non-Polar GaN", which covered our recent work in the Cambridge Centre for Gallium Nitride on novel photonic architectures realised in GaN for high-temperature single photon sources. My talk centred on porous GaN as a material for constructing distributed Bragg reflectors and optical microcavities, and it attracted a variety of questions and comments. One question related to the pore size and morphology, and whether this could be tuned to create a flatter and less diffuse boundary to potentially improve the quality factor of the cavities. Another was about the challenges that might be encountered in coupling blue light from our devices efficiently into an optical fibre.

A selection of research from the broad range presented at the conference is given in the following sections.

Plenary Lectures

Prof. Sir Colin Humphreys - The amazing science, technology and applications of gallium nitride LEDs

Colin Humphreys' plenary lecture provided an overview of GaN technology as applied to blue light-emitting diodes, and showed how GaN grown on silicon substrates has been commercialised to lower costs even further. The lecture included discussion of the numerous scientific discoveries that are associated with GaN LEDs – perhaps most remarkably the discovery of how electrons are localised in InGaN quantum wells by thickness fluctuations, while holes are localised by indium content variations. An overview of the remaining problems and exciting future applications of GaN to water purification and LiFi completed the lecture.

Prof. Barry Luther-Davies – Supercontinuum generation in the mid-infrared

Prof. Luther-Davies' plenary lecture on supercontinuum generation in the mid-infrared gave an overview of the need for bright sources of broadband MIR radiation in spectroscopy, metrology and optical interference tomography. Current solutions include globars, which are not sufficiently bright, and synchrotron radiation which can only be generated at large central facilities. Chalcogenide glasses containing S, Se or Te give the required nonlinear dispersion and transparency for supercontinuum generation of MIR, a process where a high-power femtosecond pulse of laser energy is spectrally broadened to cover several octaves of infrared radiation as it propagates in such a glass. Prof Luther Davies' talk covered advancements in both the narrowband femtosecond source of IR, and the development of chalcogenide fibres and waveguides to use this pulse for supercontinuum generation. Se-based glasses were reported to emit a spectrum 2.5 octaves wide, extending to 12 μm. Birefringent waveguides made in this material also showed polarised emission of MIR, desirable for application in micro-spectroscopy.

Dr Martyn Pemble – Recent Advances in the Fabrication and Application of Colloidal Photonic Crystals (CPCs): Large Area Roll-to-Roll Assembly of CPCs for OLED and OPV Applications, and Waveguide Fabrication for Optical Interconnect Applications

Dr Pemble presented a manufacturing technique for colloidal photonic crystals (CPCs), developed and refined in the University of Cork, and the Tyndall Institute, Ireland. The technique is an application of the Langmuir-Blodgett method for self-assembly of photonic crystals, where dielectric spheres floating on a solvent are slowly drawn on to a substrate as it is withdrawn from the solution. Dr Pemble's group have optimised a roll-to-roll process for the continuous manufacture of such crystals, creating large-area coatings on flexible substrates suitable for OLED or organic solar cell applications. ALD coating of the PC was also shown to be integrable in a roll-to-roll process, which allows for modification of the film's optical and physical properties. The creation of inverse opals in SiO_2, using PMMA spheres and TEOS as a liquid precursor was also described, and such a structure was shown to function as an effective underlayer for single-mode optical waveguides. These waveguides could find application in chip-to-chip optical links.

Selected Presentations

Dr Maria Farsari – 3D patterning of ZnO nanostructures

Multiphoton absorption can be used to selectively polymerise a photoresist at a single point in a 3D volume. Using this lithography technique, 3D photonic structures such as wood-pile photonic crystals may be fabricated with a high degree of precision and without restrictions on their geometry. Dr Farsari presented work that focused on the functionalisation of such structures, using pulsed laser deposition to grow ZnO nanowires on a photonic crystal.

Dr Hiroshi Fudouzi – High quality and large colloidal photonic crystal film coated on flexible sheets

Colloidal photonic crystals formed of polystyrene nanoparticles embedded in a polymer matrix show a strong reflection at a particular wavelength. This structural colour depends on the lattice constant of the crystal, and Hiroshi Fudouzi's talk discussed how such crystals can be used as simple, low-maintenance strain gauges. Large-area fabrication of such crystals on

rubber sheets was reported, representing a step towards manufacturability and eventual application of this photonic architecture to long-term monitoring of large civil structures.

Prof. Thomas Krauss – Photonic Crystals for Biosensing and Imaging

Thomas Krauss delivered an interesting report of the work done in the University of York into the use of photonic crystals in biological applications. Guided-mode resonances in 1D or 2D photonic crystals are modified by the presence of adsorbed biological molecules, providing a possible platform for microscopy that is sensitive to the species of molecule present. Chirped gratings were also presented as a combined sensor and spectrometer, allowing relatively cheap CCD cameras to detect the position of the strongest resonance, and thereby determine the wavelength of this resonance without expensive hardware. Such photonic architectures could have applications in highly accessible point-of-care diagnostic tools.

Seiichiro Nakabayashi – Photosensitizer-conjugated ultrasmall carbo nanodots as multifunctional fluorescent probes for bioimaging

Quantum dots could provide a useful platform for creating fluorescent dyes and markers for imaging intracellular processes, without the problems such as photodegradation and nonspecific binding to lipid-rich areas that are associated with traditional organic dyes. However, semiconducting QDs such as CdSe/ZnS core-shell dots show acute in-vivo toxicity, making them unsuitable for this application. Fluorescein-conjugated carbon nanodots synthesised by microwave pyrolysis were reported as a bright and effective dye, and were shown to be usable for imaging endocytosis pathways in tobacco cells. The advantages over semiconductor QDs, which are cytotoxic, and traditional dyes which stain all the intracellular membranes, were also demonstrated.

Prof. Reinhard Carius – Nanostructure based light management in thin-film solar cells

Light management is very important to the performance of solar cells, particularly multi-layered cells with several active regions. Prof Carius presented the use of interface texturing as an anti-reflection technique in the context of amorphous and microcrystalline silicon two-

layer solar cells. In this application, it was shown that ordered photonic structures outperform random texturing for cell performance, with disordered photonic structures performing the best due to their wide stopband. Local characterisation of these textured layers using two-probe scanning nearfield optical microscopy was also presented, which allowed the light propagation to be investigated at a microscopic scale.

Dr Tomas Kohoutek – Solution Processing of a Chalcogenide Glass

Chalcogenide thin films are typically deposited using vacuum coating techniques. However, the solubility of chalcogens in amine solvents opens the possibility of using solution processing to form such films with an associated reduction in cost and increased scalability. Only As-S glasses are suitable for spin-coating using this technique, due to the difficulty in removing the solvent from other glass compositions, and it still requires post-deposition annealing which can cause deterioration of the film's properties. Tomas' talk focused on using electrospinning to overcome this limitation, forming dense nanofibrous films that permit easier extraction of the solvent – the architecture was shown to produce a solvent-free As-S film that did not require an anneal. This was accomplished using commercial roll-to-roll electrospinning equipment, and could be transferred easily to large-scale production. Other compositions, containing elements more environmentally friendly than As, are still under investigation.

Conclusion and acknowledgements

The conference was a great opportunity to meet academics from a broad variety of research areas linked by the overall theme of architectures in photonics. I took away a lot of ideas for my own photonic devices from informal discussions, and the interdisciplinary nature of the conference helped to make this an interesting and useful experience.

I would like to gratefully acknowledge funding from the UKNC, the EPSRC and Robinson College for allowing me to attend this conference. The next meeting will be in 2018, in Cambridge UK.