

Developing scalable routes to photocatalytic coatings; exploring the chemical vapour deposition of metal oxide-based materials for solar fuels production and pollution remediation

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Abstract

For any technology to be translated from the laboratory to industry, the fabrication process should be inherently scalable and its components should be economical. In the Solar Coatings Group, we are focussed on developing scalable synthetic routes to photocatalytic materials, which can enable their uptake by industry. We are working on a number of technologies, and the focus of this talk will be on two of them: (i) photocatalytic coatings for window glass that can remediate surrounding NO_x pollution using ambient light and (ii) photocatalytic coatings for photoelectrochemical devices that can split water and produce clean H₂ fuel from sunlight. In both cases we are producing materials on the 50 cm² scale using chemical vapour deposition (CVD) (**Figure 1a**); a technique used widely by industry to grow coatings at scale with nanoscale control. These two aspects of my talk are summarised below:

NO_x pollution

NO_x (NO + NO₂) pollution is a major cause of poor health, and has a range of detrimental environmental consequences [1]. NO_x pollution can be remedied by photocatalysis using TiO₂, which can use ambient light to oxidise this toxin into the comparatively benign nitrate (NO₃⁻) [2]. Photocatalytic coatings of TiO₂ are mass produced on window glass using chemical vapour deposition (CVD), but currently show nominal activities towards NO_x remediation [3].

In this section of my talk, I will present how we used aerosol-assisted CVD (AA-CVD) to produce ~50 unique TiO₂ coatings on window glass by systematically varying the process parameters. The coatings produced showed wide ranging physicochemical properties, including differences in phase composition (anatase/ anatase: rutile composite), optical bandgap energy, surface roughness, charge carrier generation and charge carrier lifetime. Their photocatalytic activities towards NO gas was measured using ISO protocol (ISO 22197-1:2016) [4], and the observed relationships between the processing parameters, the physicochemical properties and photocatalytic activity are discussed.

Water splitting

Current H₂ demands are vast, with the industry valued in excess of \$150 billion. Today, most H₂ is produced from the non-renewable reformation of natural gas, and accounts for ~3% of total CO₂ emissions. Various renewable methods of producing H₂ are being developed, with solar-driven photoelectrochemical (PEC) water splitting seen as one of the most promising routes in terms of efficiency and potential cost [5]. Bismuth vanadate (BiVO₄) has emerged as one of the most PEC materials in water splitting devices. State-of-the-art systems have achieved solar-to-hydrogen (STH) efficiencies above 8%; nearing benchmark efficiencies for commercial viability [6].

In this talk, I will present the work we have done in my group on the development of scalable AA-CVD routes to high performance BiVO₄-based photoanodes (Figure 1b). I will also show how the intrinsic charge carrier behavior in these photoanodes was studied using time-resolved optical spectroscopies to reveal the kinetics of water oxidation, and provide insight on the reaction mechanism. And lastly, I will present our work on developing prototypes, incorporating these BiVO₄-based PECs into custom made reactors (Figure 1c).

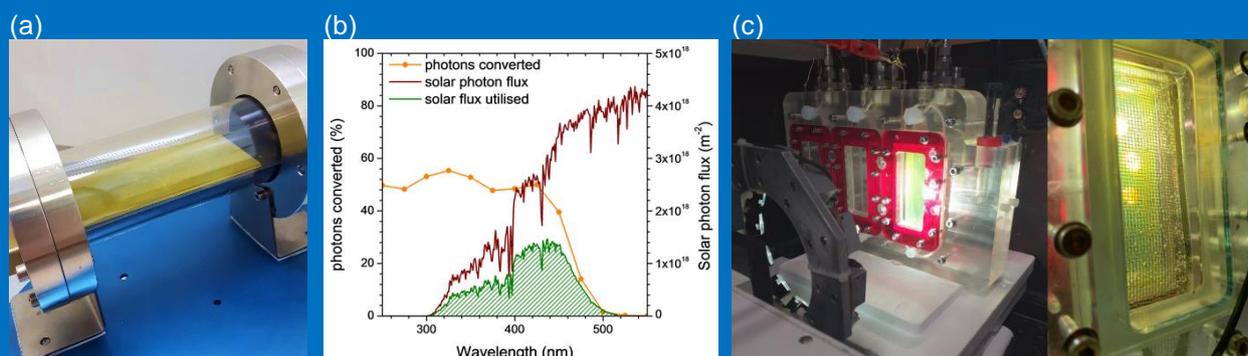


Figure 1: (a) the CVD reactor used to produce moderate scale photoanodes (50 cm² in size), (b) Incident photon-to-current efficiencies seen at 1.23 V vs RHE for an optimised BiVO₄-based photoanode in a neutral buffered electrolyte, and (c) the PEC water splitting prototype in action.

Biography



Andreas Kafizas is a Senior Lecturer in the Department of Chemistry at Imperial College London (ICL), and leads the [Solar Coatings Group](#). His research is focused on developing sustainable synthetic routes to photocatalytic coatings for a range of practical applications, including renewable fuels production (e.g. hydrogen fuel from water and carbon-based fuels from CO₂), air remediation (e.g. NO_x removal) and water remediation (e.g. arsenic removal).

Andreas completed his MSci in Chemistry in 2007, and PhD in Chemistry in 2011 at University College London. His PhD was focussed on the development of photocatalytic materials synthesised by chemical vapour deposition, and he was awarded the Ramsay Medal for best graduating doctor. In 2012, he was awarded the Ramsay Fellowship, where studied the charge carrier behaviour of photocatalytic materials for solar fuels at ICL. In 2016, he was awarded a Junior

Research Fellowship at ICL to develop heterojunction photoelectrodes for solar water splitting and CO₂ reduction. In 2018, he was awarded a Lectureship at ICL, and was promoted to Senior Lecturer in 2022. Andreas is the theme lead in Sustainable Power and Renewable Fuels at the Energy Futures Lab, and is a board member and Chair of ED&I at the London Centre for Nanotechnology. Andreas has published ~100 peer-reviewed articles and has written 6 book chapters (>6,900 citations, h-index of 52).

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