FENCES: Ferroelectric nanocomposites for enhanced solar energy efficiency
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Ferroelectric bulk photovoltaic (BPV) effect

Charge separation via polarisation

Poor light absorption & transport
→ Low current
→ Max. eff. ~20%

Voltage generation using UV only

High voltage

Ferroelectric photovoltaic coupled to light absorber

Parallel arrangement

Visible light absorption → high current

Light absorption & charge transport

Voltage limited by built-in potential of junction (bandgap)
→ Max. eff. ~34%

Semiconductor absorber

Charge separation via junction

PVs

PEC

Electrolyte

Visible

Ferroelectric

UV

P

P

n-type

p-type
FENCES: synthesis

Photoactive material
BPV effect
Ferroelectric

Solution-based

Inorganic precursor
Hydrolysis/polycondensation reaction
remove organic template
750°C, 10 min
Porous thin film

- Surfactant agent: triblock copolymer Pluronic-P123
- Inorganic precursor: Barium acetate + titanium butoxide in glacial acetic acid

Pulsed Laser Deposition

ITX glass cleaned
spin-coating
Organic/Inorganic Hybrid
Laser beam
Target carousel
Vacuum chamber
Laser plume
Substrate
Heatable sample stage
Post with quartz window
MgO nanoparticles
mesoporous STO matrix
STD matrix
STD matrix
STD matrix
Thin films
320 nm
200 nm
Modelling (collaboration with Dr Keith Butler)

- Computational screening
- Equivalent circuits
- DFT: polarization & interfaces
- Finite Element

Characterisation

- XRD, Raman, SEM, PL, tr-PL, TAS etc...
- Coupled AFM, pc-AFM, PFM with tr-CL-SEM mapping
Nanostructured ferroelectric thin films

Inorganic precursor

- Surfactant agent: triblock copolymer Pluronic-P123
- Inorganic precursor: Barium acetate + titanium butoxide in glacial acetic acid

→ Porous BaTiO$_3$

ACS AMI, accepted (2022): 10.1021/acsami.1c17419
Nanostructured ferroelectric thin films

Adriana Augurio

Electrochemical poling

Electrolyte: 0.1M LiClO$_4$ (in propylene carbonate)

Ferroelectric Ceramic

DC Electric Field

10.13140/RG.2.2.31771.05921

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Nanostructured ferroelectric thin films

Adriana Augurio

PEC water splitting

- 3-electrode half cell configuration
- AM 1.5 simulated solar light
- 1 M NaOH electrolyte
- BaTiO$_3$ forms photoanode
- Testing activity for water oxidation
- Requires electron injection (at positive bias)
- Upward band bending promotes oxidation

PEC results confirm positive poling increases photocurrent density as expected

IPCE indicates effect strongest at short wavelength (due to wide bandgap)

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Nanocomposite photoelectrodes: BTO/Fe$_2$O$_3$

- Hydrothermal growth of Fe$_2$O$_3$ nanowires in BaTiO$_3$ pores
- 0.15 M FeCl$_3$ and 1 M NaNO$_3$
- 100°C for 1 h
- Annealed at 800°C (10°C/min) for 10 min

Fe$_2$O$_3$ nanorods grown within BTO pores
Nanocomposite photoelectrodes: BTO/Fe$_2$O$_3$

-8 V = ‘P$_{\text{up}}$’

+8 V = ‘P$_{\text{down}}$’
Atomic force microscope
Library Tours – MSc students
Aside: Salford University Z House

https://energyhouse2.salford.ac.uk/energy-house-labs/barratt-z-house/
Thank You

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