Scalable metamaterial thermally sprayed catalyst coatings for nuclear reactor high temperature solid oxide steam electrolysis.

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Scalable metamaterial thermally sprayed catalyst coatings for nuclear reactor high temperature solid oxide steam electrolysis

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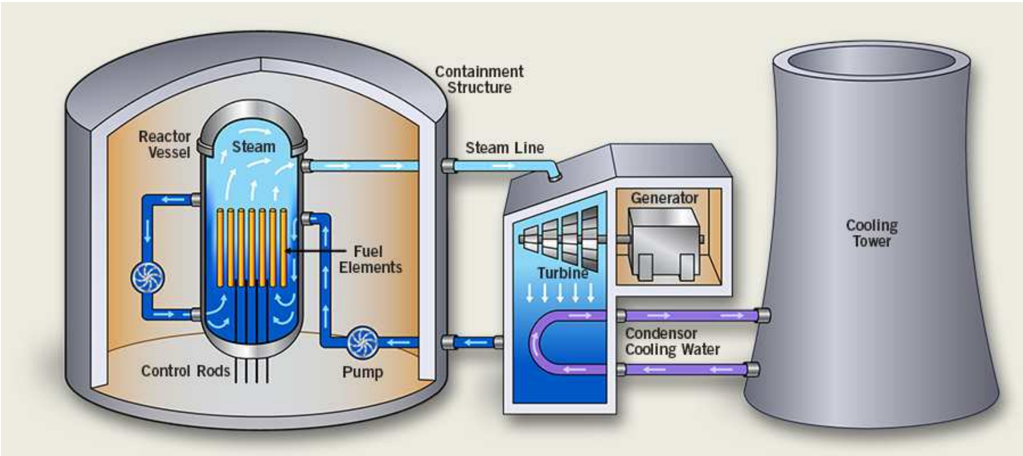
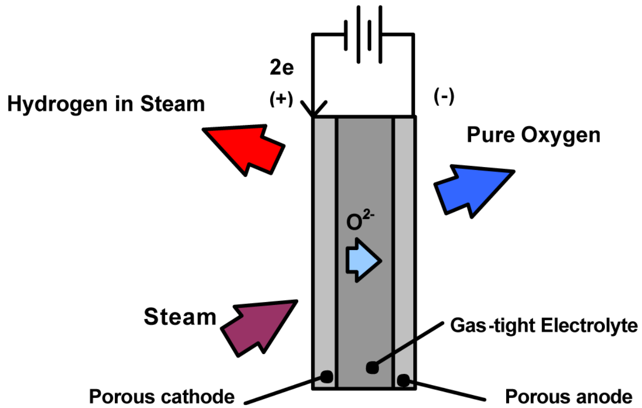
Uses of H2?

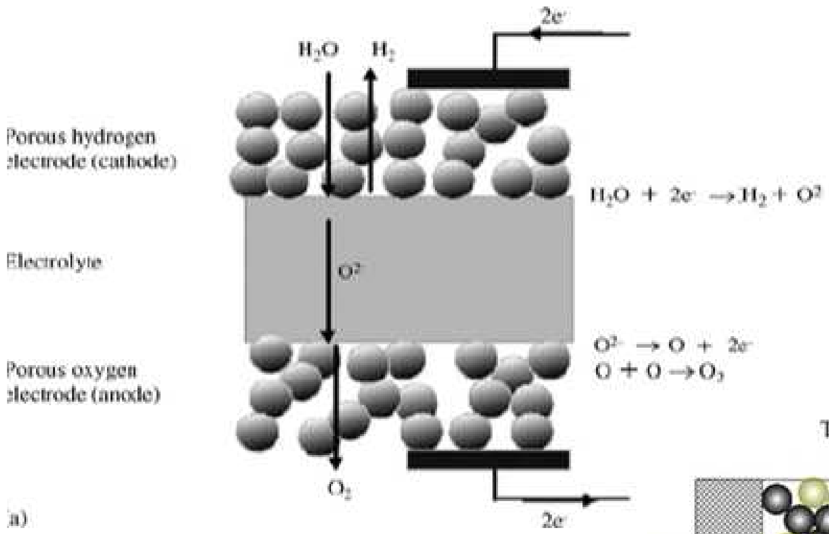
- Current use: refining petroleum, treating metal, producing fertiliser and processing foods.
- H2 fuel cells produces electricity via an electrochemical process wide uses such as powering mobile phone, laptop, supply electricity to electric power grids, supply backup or emergency power in buildings and off grid power supply
- Burning hydrogen for electricity generation – blending with natural gas
- Hydrogen use in vehicles – fuel cells can power vehicles – advantage longer range
- Burning hydrogen for domestic heating and cooking – blending with natural gas
- So what are the challenges – production, storage and transportation

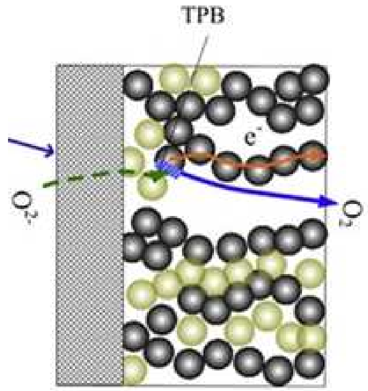
Excess heat and Electricity from Nuclear Reactor to Solid Oxide Electrolyser

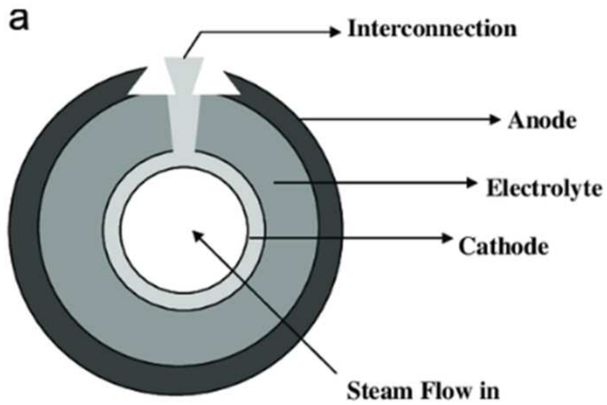


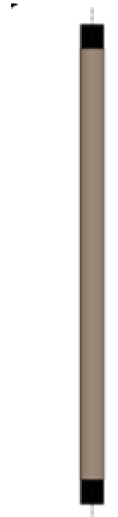


Solid Oxide Electrolyser Working Principle







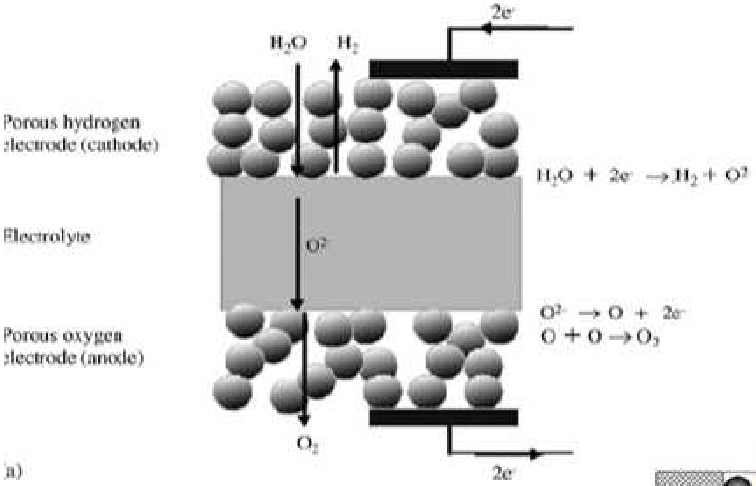


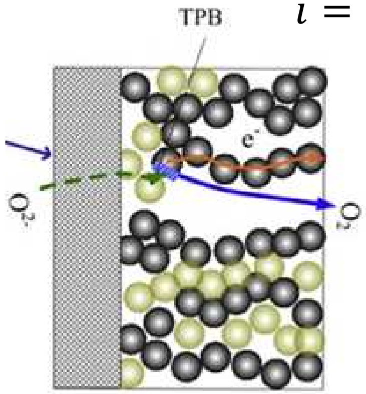
Single tube

Cathode: $H_2O + 2e^- = H_2 + O^{2-}$
Anode: $O^{2-} = ½\ O_2 + 2e^-$
Overall: $H_2O = H_2 + ½\ O_2$

Cathode: Ni-YSZ porous, 500 µm
Electrolyte: YSZ dense, ion conductor, 20 µm
Anode: LSM-YSZ, 50 µm
Length: 0.4m

Electrochemistry





$$V = V^{rev} + \eta_{ohm} + \eta_{conc,cath} + \eta_{conc,an} + \eta_{act,cath} + \eta_{act,an}$$

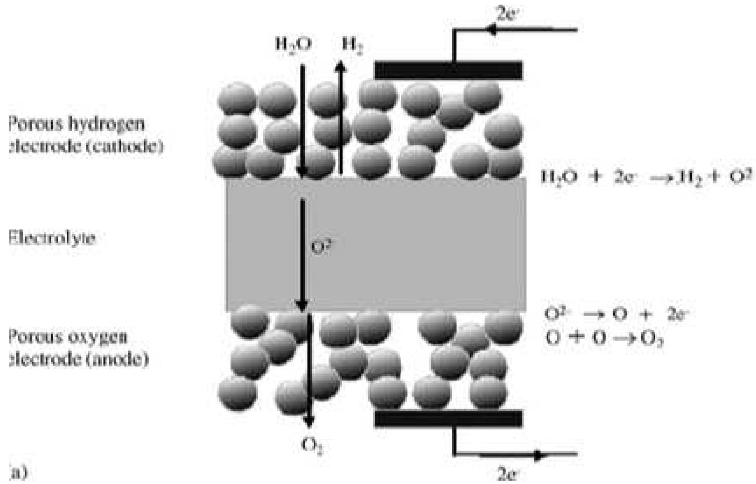
$$\eta_{conc,an} = \frac{RT}{4F} \ln[\frac{C_{O_2}^{TPB} T}{C_{O_2,ref} T_{ref}}]$$

$$i = i_{o,an} \left(\frac{C_{O_2}^{TPB}}{C_{O_2,ref}} \right)^{\gamma_{O_2}} \left\{ \exp\left(\frac{2\alpha F \eta_{act,an}}{RT} \right) - \exp\left(- \frac{2(1-\alpha) F \eta_{act,an}}{RT} \right) \right\}$$

CFD modelling

- Continuity and momentum
- Heat transfer
- Species concertation (i.e. H_2O, H_2, O_2)
- Species source term:

$$S_{H_2} = i/2F$$

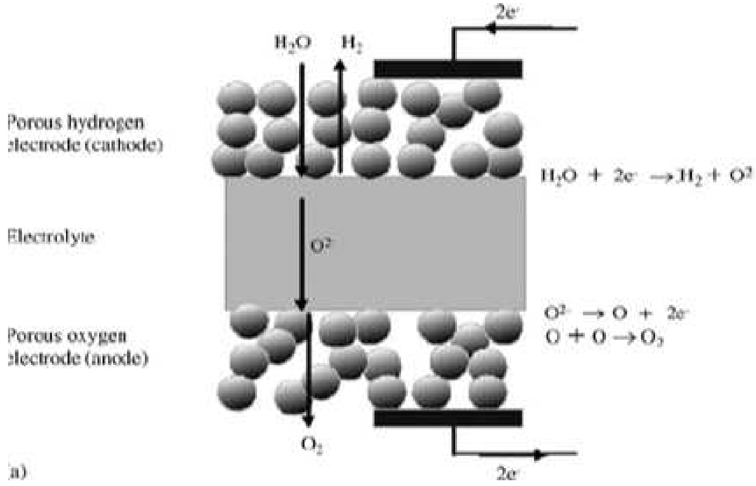


CFD modelling

- **Electron and ionic transport:**

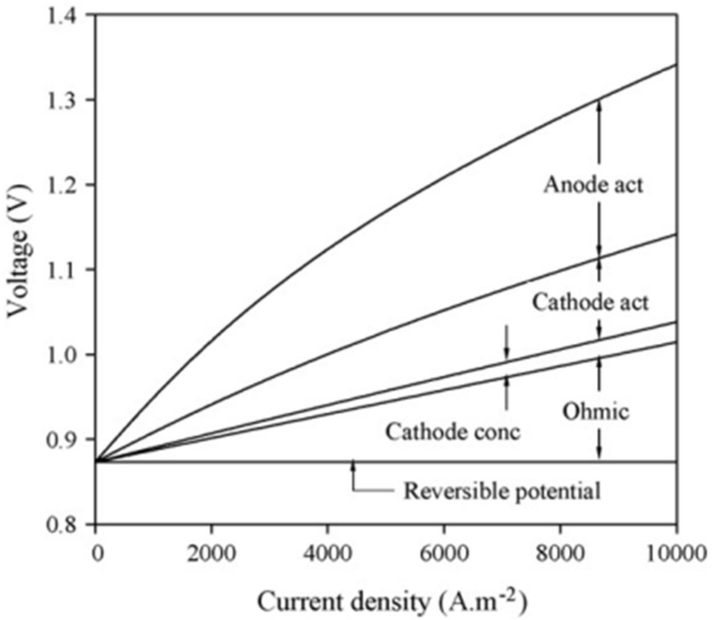
$$\Delta.(\sigma\Delta\phi) = 0$$

$$\sigma_{ion} = \frac{100}{0.3685 + 0.002838e^{\frac{10300}{T}}}$$



- **Gas phase diffusivity through porous electrodes – multicomponent diffusivity, or dilute gas and Knudsen diffusivity**

An I-V curve is an effective way to explain SOEL performance



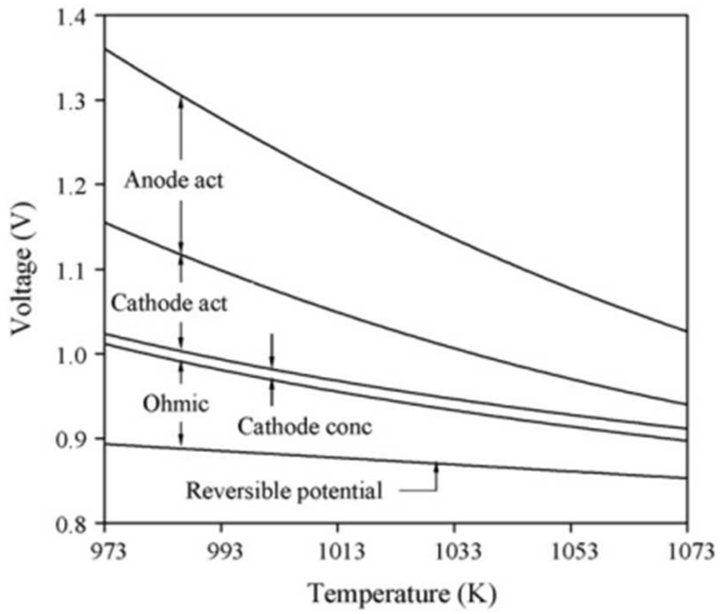
J. Udagawa et al. (2007) - doi:10.1016/j.jpowsour.2008.01.069

Higher current density, higher production rate of H_2, but higher voltage i.e. higher power required

Main losses: Anode activation loss, then cathode activation loss and ohmic loss

Operating at 1023 K

An I-V curve is an effective way to explain SOEL performance



Higher temperature leads to better performance due to reduction in anode and cathode activation overpotential. However, it creates thermal stress and less durable cells

J. Udagawa et al. (2007) - doi:10.1016/j.jpowsour.2008.01.069

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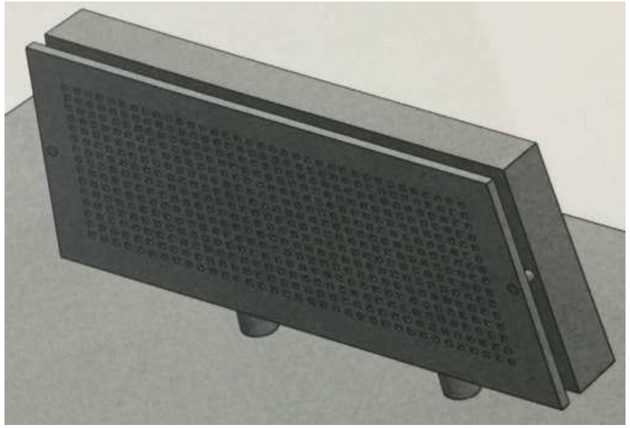
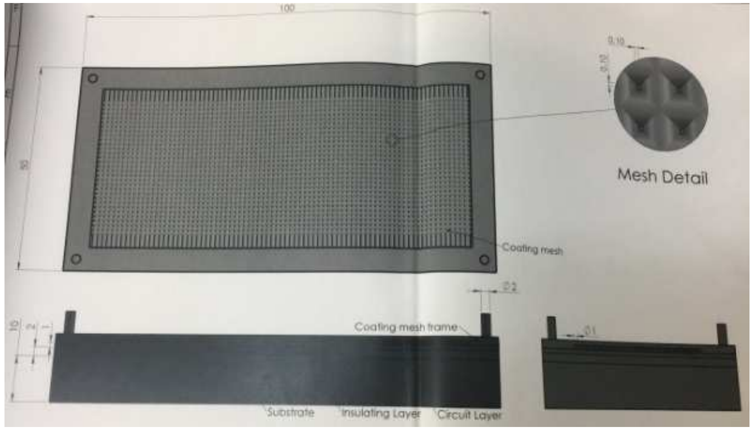
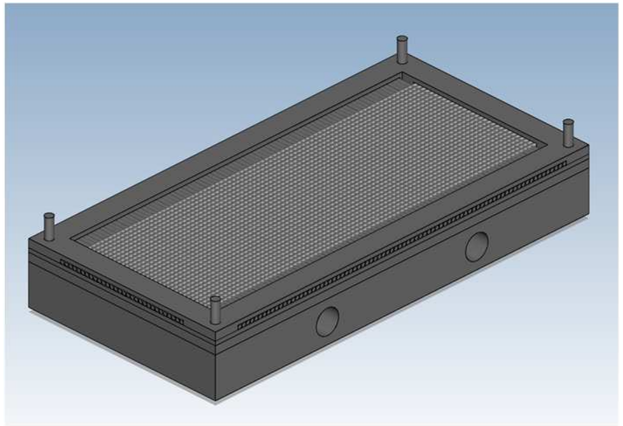
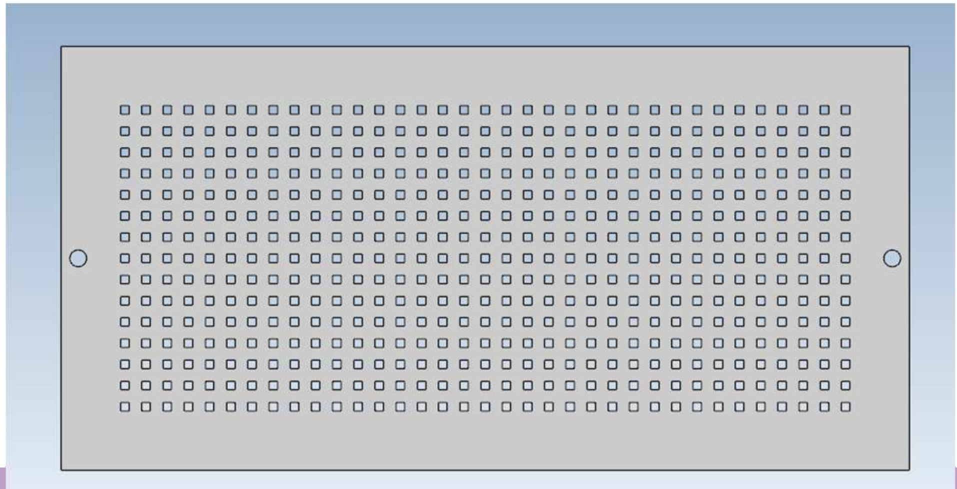
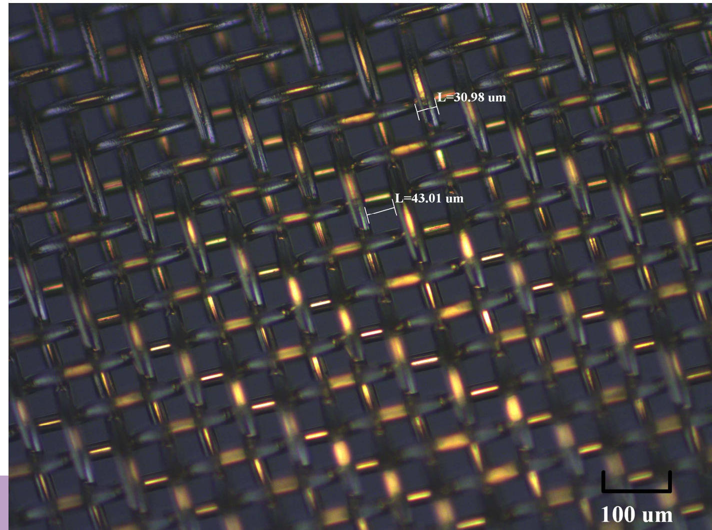
Improving performance using metasurface











Faisal et al, 2021; https://link.springer.com/article/10.1007/s42247-021-00252-z

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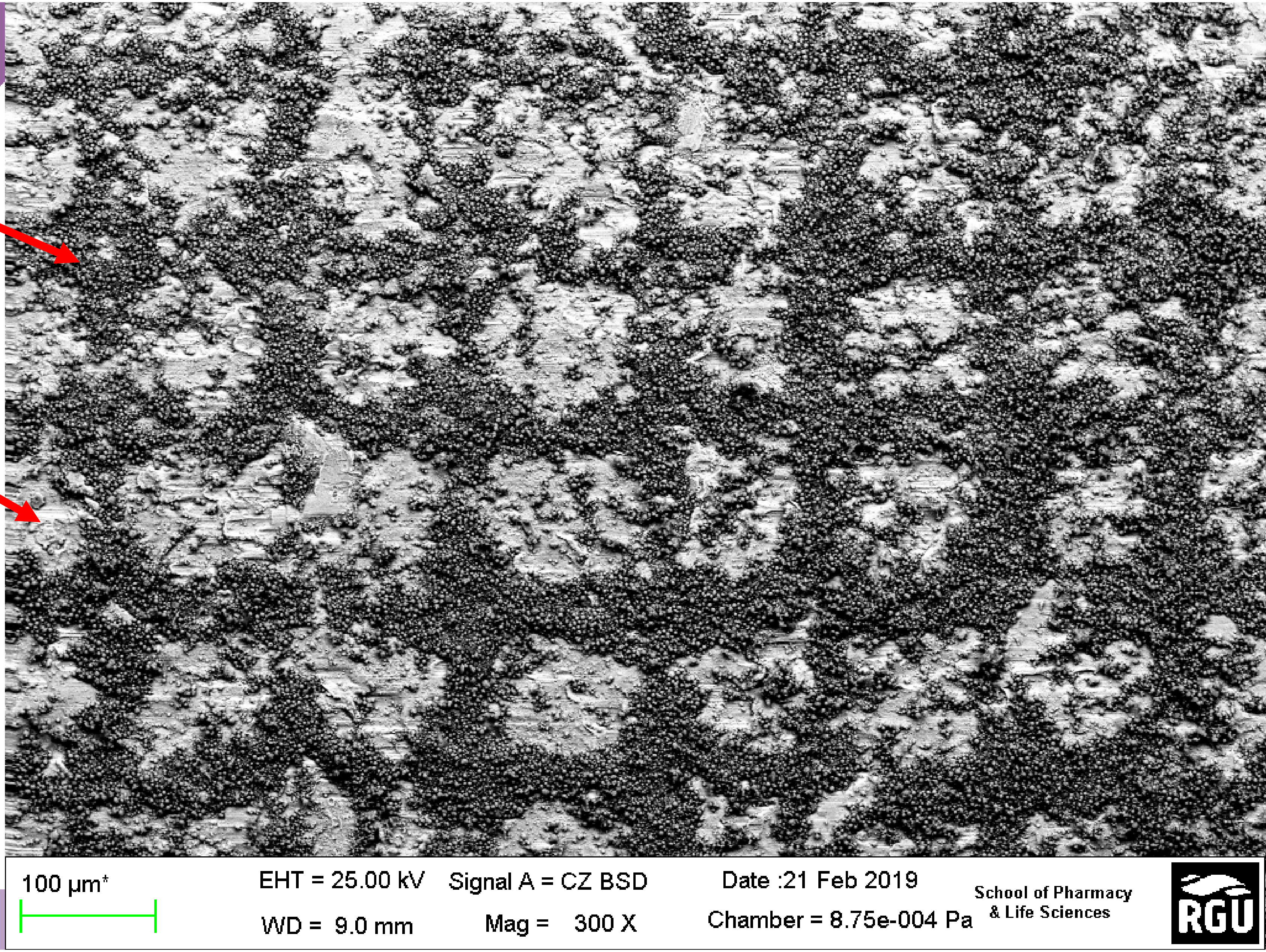
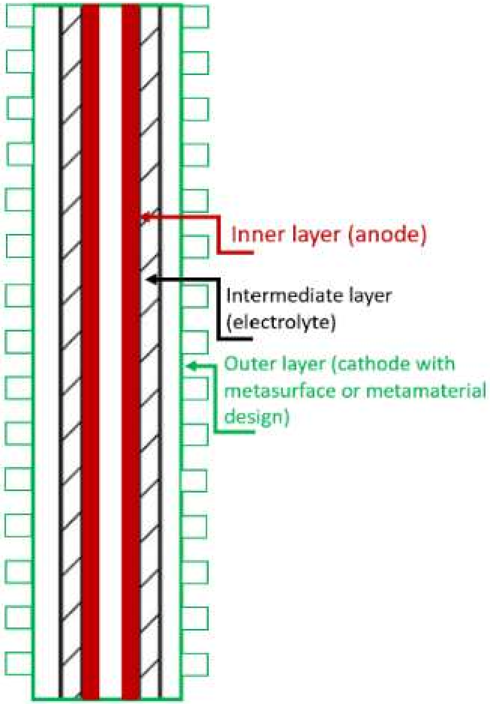
Sprayed Cr2O3 powders (through mesh)

Substrate (unsprayed area)



Thermal spray coating on cathode and anode for creating meta surface



SOEC in Bangladesh

- Waste Steam from Garment Factory
- Waste Steam and Electricity from Rooppur Nuclear Plant

Any Question?