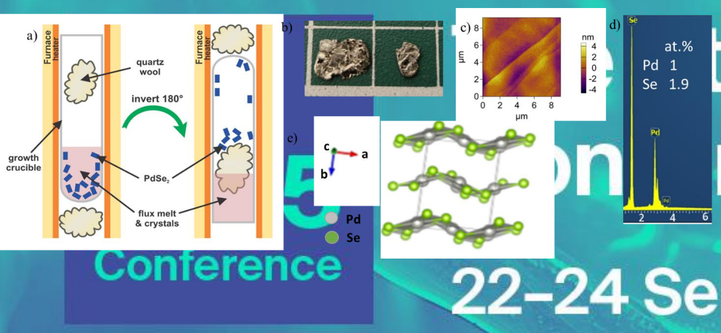
PdSe$_2$ single crystals were obtained by the self-flux (high-temperature solution) method. Selenium (Se) was used as a solvent/flux (Fig.1(a)). Due to the high vapor pressure of Se and the exothermic reaction between two elements, quartz ampoules with a wall thickness of 3 mm, a diameter of 20 mm and a length of 100 mm were used. In these amp



Exfoliated PdSe2 supported on graphene oxide as an electrocatalyst for efficient water splitting

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INTRODUCTION & AIM

Efficient hydrogen evolution reaction (HER) in alkaline media is crucial for advancing sustainable hydrogen production but remains a significant challenge due to sluggish reaction kinetics. Two-dimensional transition metal chalcogenides (TMCs) have emerged as promising electrocatalysts, offering tunable electronic properties and abundant active sites. Among them, palladium selenide **($PdSe_2$) stands out for its catalytic potential**. However, the intrinsic conductivity and dispersion of $PdSe_2$ limit its performance. To overcome these drawbacks, graphene oxide (GO) can serve as a conductive scaffold, improving charge transport and catalyst stability.

This study aims to develop a composite catalyst based on exfoliated $PdSe_2$ nanosheets integrated with GO to enhance HER activity in alkaline electrolyte.

The **specific objectives** are to:

- ✓ Exfoliate bulk $PdSe_2$ to increase the density of accessible active sites.
- ✓ Utilize GO as a conductive and dispersive support for the nanosheets.
- ✓ Evaluate the electrocatalytic performance of $PdSe_2$–GO toward HER in alkaline media and compare it with pristine $PdSe_2$.

METHOD

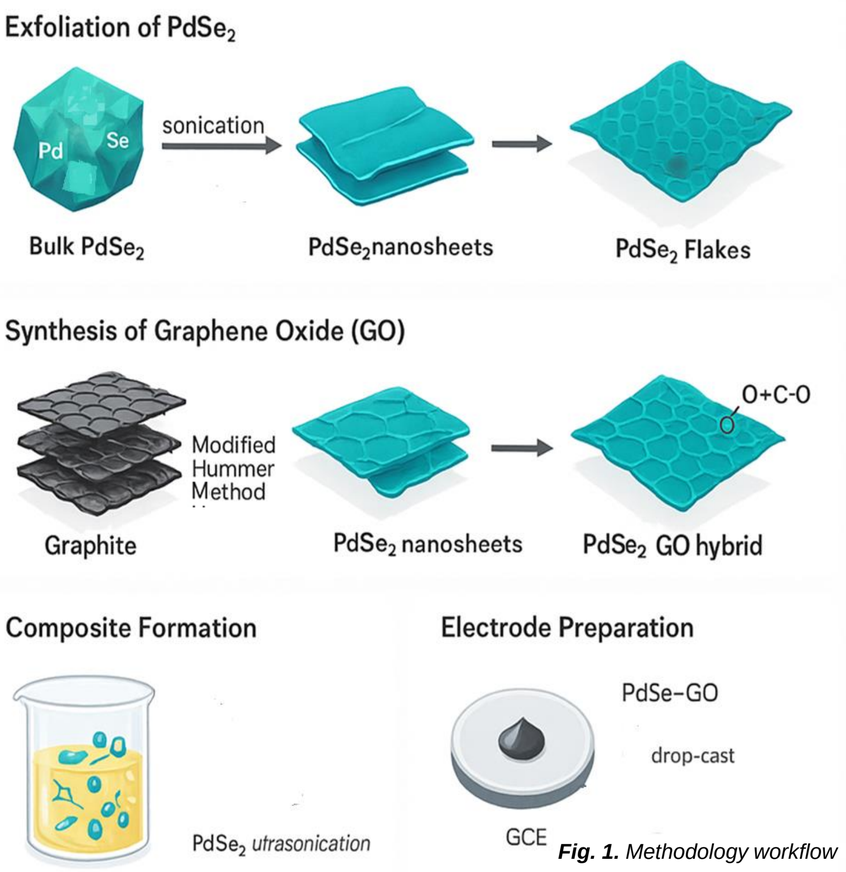

Fig. 1. *Methodology workflow*

RESULTS & DISCUSSION

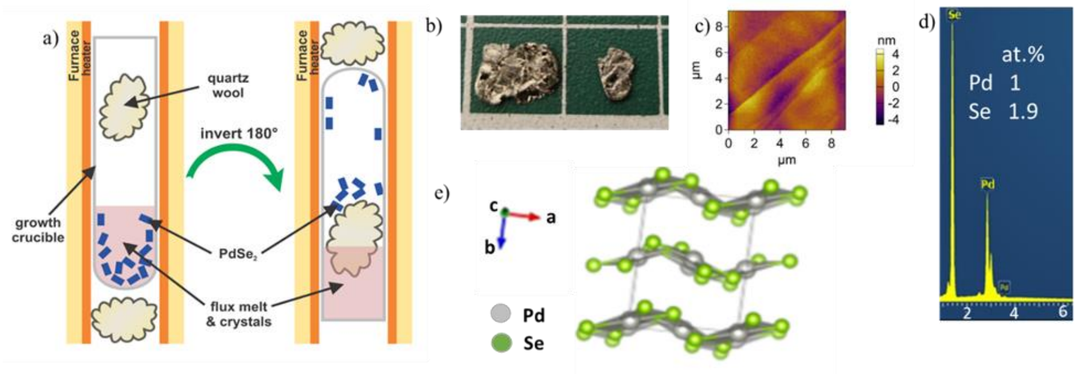

Fig. 2*. (a) Diagram of self-flux (high-temperature solution) growth method, (b) photo of shiny crystals of PdSe2; (c) AFM image of cleaved crystal layered structure;(d) EDS spectrum analysis (atomic %), Pd/Se ratio:1/1.9 and (e) representation of the crystal structure of PdSe2 along the b-axis (gray spheres – Pd, green spheres –Se ions).*

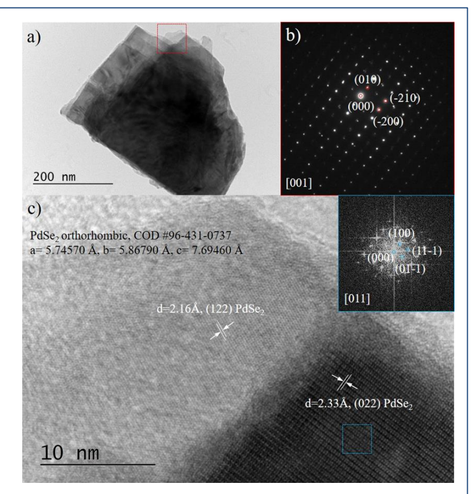

Fig. 3. (a) Bright Field TEM image, (b) the corresponding SAED pattern and (c) HRTEM image and the Fast Furrier Transform pattern from the blue square area (inset) of $PdSe_2$ crystal

Fig. 4. SEM image of exfoliated $PdSe_2$ crystal

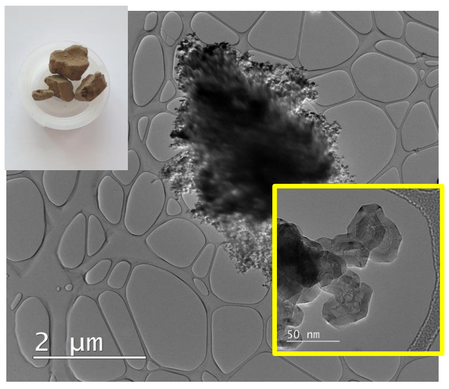

Fig. 5. *Bright Field TEM image of GO – inset zoomed image and real image of the as prepared GO*

Electrochemical test set-up

1. *Electrochemical Test Cell* ***– Standart three electrode***
2. *Erf-* ***RHE***
3. *Ec-* ***Pt-wire***
4. *Ew-* ***GC or Freudenberg***
5. ***Electrolyte*** *– 25% KOH*
6. S_{Ew} **= 0.28 /1 cm²**

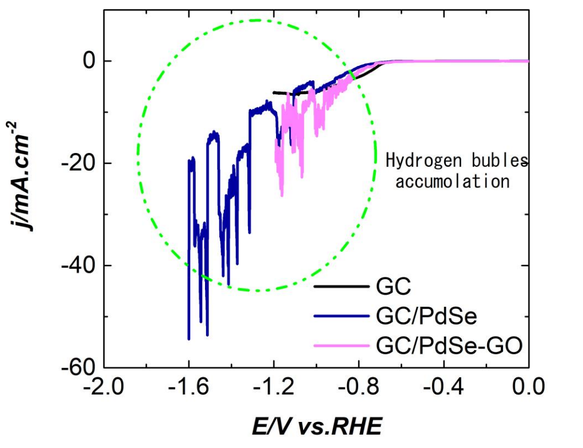

Fig. 6 *Cathodic polarisation curves of the PdSe and PdSe-GO/GC electrodes in 25% KOH, scan rate 1 mV.s-1*

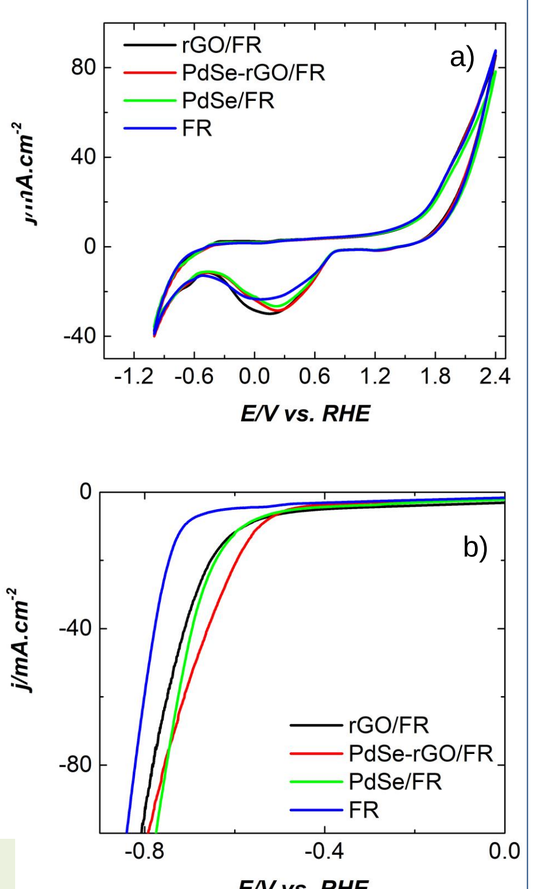

Fig. 7 (a) CV and (b)*Cathodic polarisation curves of the PdSe, rGO, PdSe-rGO/ Freudenberg electrodes in 25% KOH, scan rate 1 mV.s-1*

- ✓ The $PdSe^2$ flakes with sizes from 500 nm were successfully exfoliated from $PdSe_2$ single crystal grown by self-flux method.
- ✓ The as prepared GO has uniform and homogeneous structure with size of around 50 nm

$PdSe_2$ and $PdSe_2$–GO in HER
- •Pure $PdSe_2$ shows excellent long-term stability
- •$PdSe_2$–GO composite enhances catalytic activity
- •Hydrogen adsorption confirms HER interaction

PdSe/rGO catalysts on Freudenberg
- •PdSe shifts ORR to positive potentials
- •HER activity order: PdSe > rGO > PdSe–rGO > FR

CONCLUSION

- ❖ $PdSe_2$ and its composites with GO demonstrate promising electrocatalytic properties for HER and ORR in alkaline media.
- ❖ Pure $PdSe_2$ exhibits superior HER activity and long-term stability compared to composites and support materials.
- ❖ The electrochemical reduction of GO in the $PdSe_2$–GO system shows enhanced conductivity and dispersion, though further optimization is needed to maximize synergy. (also called $PdSe_2$–rGO)
- ❖ Compared to reported PdSe-based electrocatalysts (HER overpotential ~540 mV at 10 mA cm^{-2} for rGO–PdSe), the investigated $PdSe_2$ materials display lower overpotentials and improved stability, confirming their advantage as efficient catalysts.
- ❖ Future work will focus on tuning $PdSe_2$/rGO ratios and doping with transition metals (Ni, Co, Fe) to further improve performance and reduce Pd content.

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