MXene-based Blue Energy Harvesting: A New Pathway to Overcoming the Pressing Challenges of the Water-Energy-Food (WEF) Nexus

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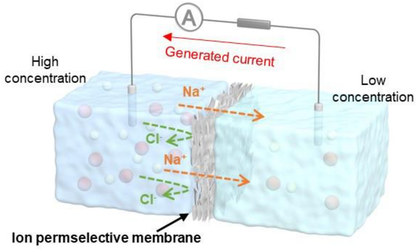
Blue Energy: Salinity Gradient Energy & Membranes

- **Salinity gradient energy (SGE)** is a clean, sustainable, and renewable energy source
- In principle, ~ 0.8 kWh could be obtained when 1 m^3 of freshwater flow into the sea, which could result in nearly 2.4 ~ 2.6 TW of **SGE** based on the worldwide flow of freshwater (all the major rivers)*
- Accordingly, **SGE** could account for >20% of the global energy consumption nowadays
- For **SGE** harvesting, **semipermeable & exchange membranes** are needed to separate two reservoirs filled with fresh (less salinity) & sea (higher salinity) water



* Nature Reviews Chemistry, 1, 0091 (2017)

Alshareef et al., Adv. Mater. (2022)

Current Limitations

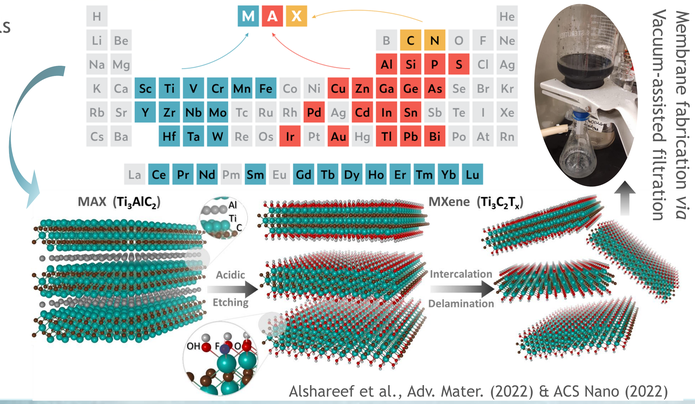
- Low electric power density of **0.16 ~ 0.26 W/m²**
- Short life-time
- Severe biofouling

Solutions: Emerging Layered Membranes

- Scalable fabrication
- Higher ionic/molecular flux
- Tunable pore sizes & interlayer spacing

Family of MXenes: Transition Metal Carbides/Nitrides

- **MXenes** are a family of two-dimensional (2D) layered nanomaterials
- **MAX** (layered metal carbides/nitrides): **Parent phases of MXenes**
- **MXenes** are obtained by selectively removing the **A** element from their parent MAX phases, using acidic etching methods

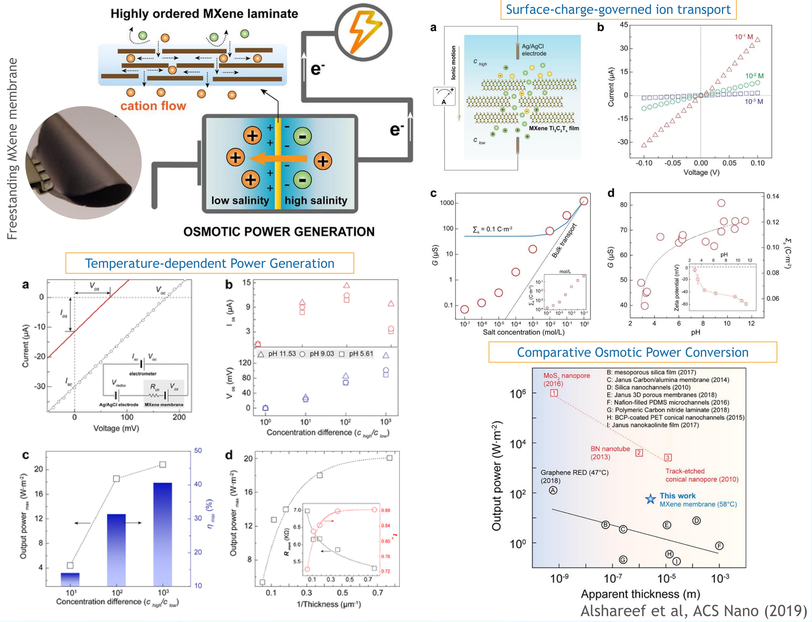


Alshareef et al., Adv. Mater. (2022) & ACS Nano (2022)

Key Properties of MXenes

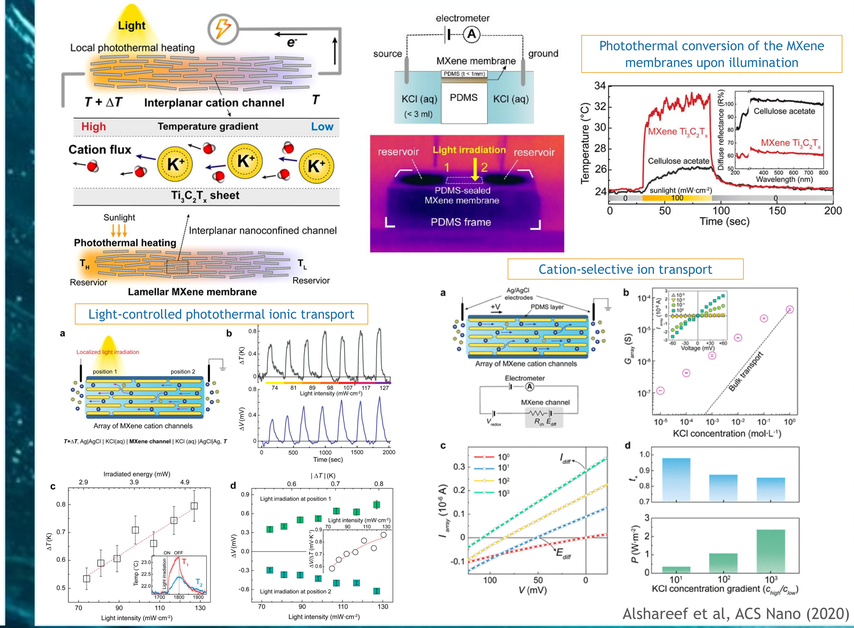
- Rich surface chemistry leading to **ultrahigh charge selectivity**
- **Sub-nanometer** scale interplanar **regular** & **straight** capillaries
- **Solution-processability** & **Significant Photothermal behavior**
- Structural **integrity**
- High **aspect ratio**

MXene Membranes as Nanofluidic Osmotic Power Generators



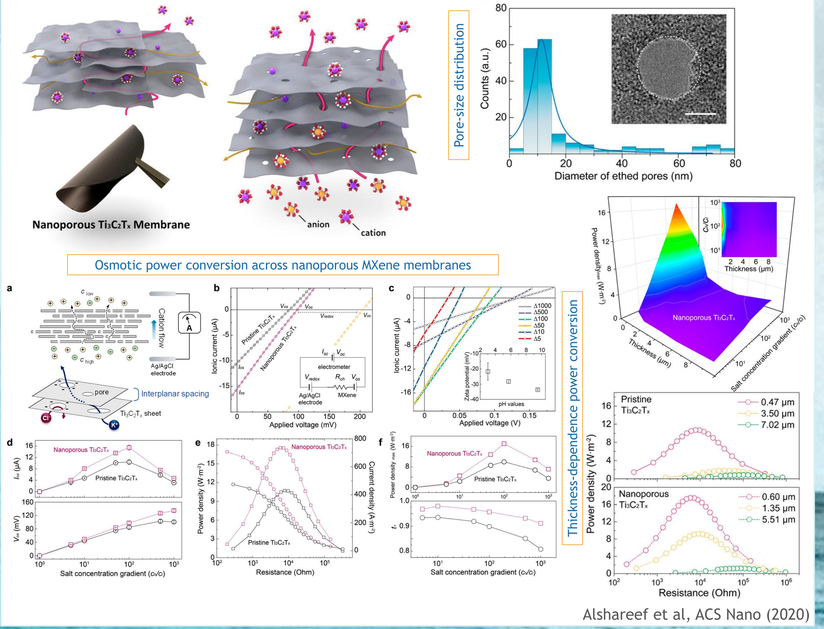
Alshareef et al, ACS Nano (2019)

Photothermoelectric Response of MXene Confined Ion Channels



Alshareef et al, ACS Nano (2020)

Porous MXene for Highly Efficient Salinity Gradient Energy Harvesting



Alshareef et al, ACS Nano (2020)