**Types of Hydrogen Separation Membrane:**

Firstly, Membrane can be Natural and Synthetic then It is divided into Organic (polymer), Inorganic and Mixed-matrix(Hybrid) [1]. (Classification are showed in Figure).

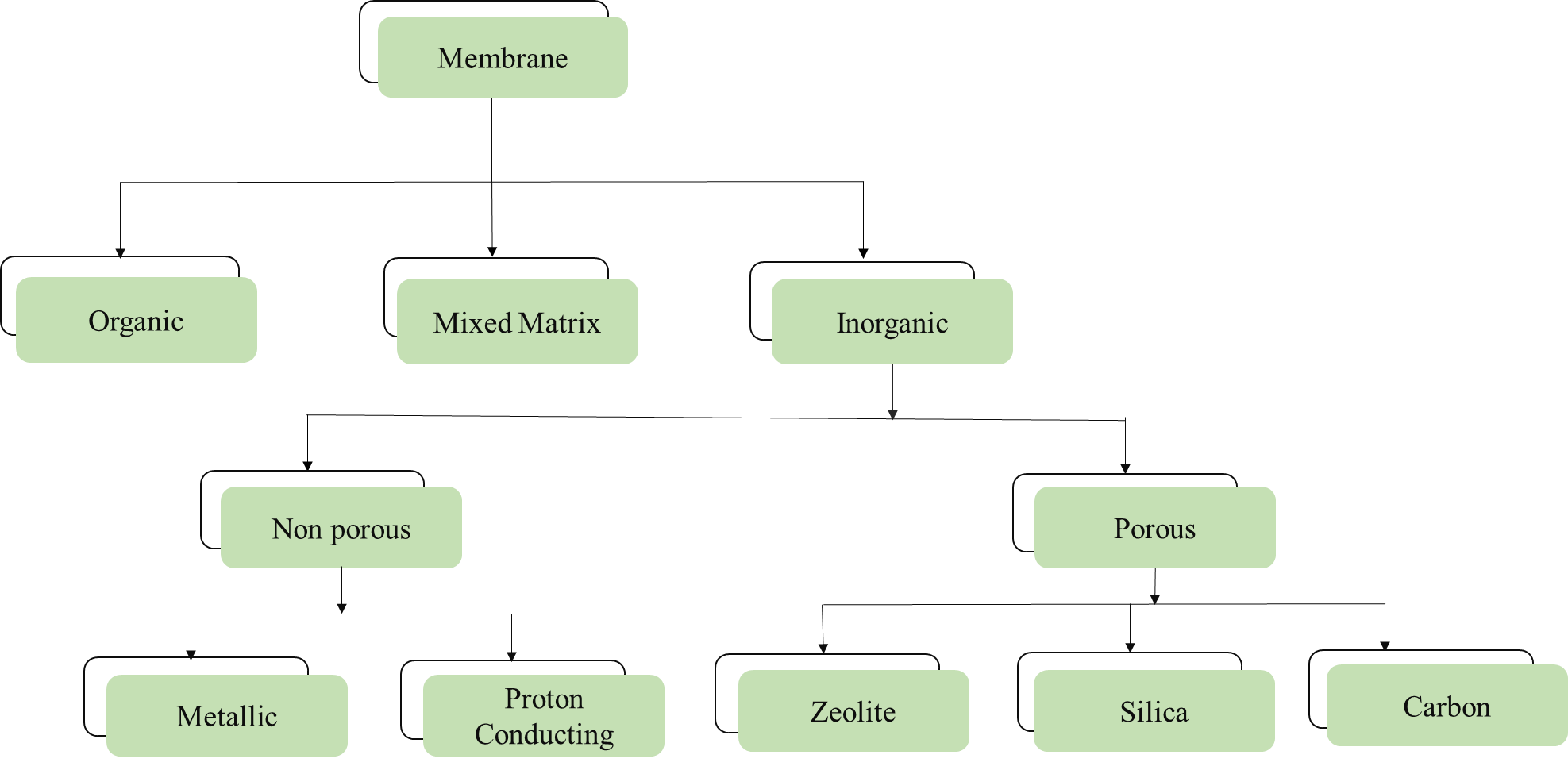


Figure: Classification of Membrane [2].

**Inorganic Membrane:**

Inorganic membranes are usually used for the purpose of isolating light gases like H2 from a gas mixture. Inorganic micro porous membranes are more affordable and can withstand higher temperatures (25°C-900°C) than others membranes [3]. Inorganic micro porous membrane transports H2 mostly in molecular sieving method, which separates H2 (the smaller kinetic diameter **Figure**), from CH4 and other bigger component from gases mixture. To successfully isolate hydrogen, the pore diameter of porous membranes must be less than 2 nm (e.g., microporous) [4]. Basically, Inorganic membranes are particularly appealing for hydrogen separation because they can resist high temperatures and pressures. Inorganic membranes are classified into two types: porous and dense (non-porous) [5]. In contrast, fractionation in porous membranes (silica, zeolites, and carbon) is based on differences in size, shape, and/or affinity between permeating molecules and the membrane [6].

Table: Kinetic Diameters of gas Particles [7]

|  |  |
| --- | --- |
| Gas | Kinetic Diameter of Gas particles (Å) |
| Hydrogen (H2) | 2.890 |
| Carbon dioxide (CO2) | 3.64 |
| Nitrogen (N2) | 3.3 |
| Methane (CH4) | 3.758 |

**Zeolite:**

Zeolites are aluminosilicate solids that are three-dimensional, crystalline, hydrated, and made of tetrahedra building units linked to one another by oxygen atoms. Zeolites have cavities and channels which are distinct and filled with alkali or alkali earth Cations and water molecules. Zeolites are more appealing than other microporous materials due to their superior heating, mechanical, and chemical stabilities [8]. They provide consistent holes with molecular diameters and unique features for catalytic, ion exchange, adsorption, and membrane applications [9]. For various gas separation applications, zeolites can be produced in varied forms, particle sizes, and pore sizes. As zeolite membranes such as LTA, CHA, MFI, DDR, and FAU have been effectively produced for gas separation.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Zeolite** | **Support** | **Hydrogen**  **Permeability** | **Selectivity** | | | **Technique** | **Experiment**  **Condition** | **Ref** |
| **H2/CO2** | **H2/CH4** | **H2/N2** |
| STT | Silica | 2.8 × 10−8 mol·m−2·s−1·Pa−1 | **----** | 49.6 | **-----** | Hydrothermal | 0.2 MPa 298 K | [10] |
| MFI | Graphene Oxide | 1.3 × 10-5 mol m-2 s-1 Pa-1 |  | 245 |  | Colloidal |  | [11] |
| DDR3 |  | 1.8 × 10− 8 mol m− 2 s − 1 Pa− 1 |  | 124 |  | Hydrothermal | 0.4MPa  303 k | [12] |
| FAU | Al2O3 tubes | 1.9 × 10-7 mol m-2 s-1 Pa-1 |  | 9.9 |  | Hydrothermal | 1 Bar  50 °C | [13] |
| MFI | Alumina | 1.1 × 10-7 mol ·m-2 ·s-1 | 8.2 |  |  | Hydrothermal | 450°C | [14] |
| SSZ-13 | MDI | 4.27 × 10− 8 mol m− 2 s − 1 ⋅Pa− 1 |  | 427 | 35.6 | Hydrothermal | 2 bar  373k- 473k | [15] |
| SAPO-34 | α-Al2O3 | 6.96 × 10 -6 mol m -2 s -1 Pa -1 | 1.83 | 14.80 | 7.58 | Hydrothermal | 298 k | [16] |
| Si-CHA | α-Alumina | 1.44 × 10−6 mol m-2 s-1 Pa-1 |  | 85 |  | Hydrothermal | 0.2 MPa  298K | [17] |
| ZIF-7 | Alumina | 4.5 × 10−8 mol m−2 s−1 Pa−1 | 13.6 | 18.0 | 14 | Hydrothermal | 220°C | [18] |
| LTA (double layer) | α-Al2O3 | 2.1×10 -7 mol m -2 s-1 Pa -1 | 8.8 | 5.8 | 7.2 | Hydrothermal | 1 bar  373K | [19] |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Carbon** | **Support** | **Hydrogen**  **Permeability** | **Selectivity** | | | **Technique** | **Experiment**  **Condition** | **Ref** |
| **H2/CO2** | **H2/CH4** | **H2/N2** |
| PEK-C |  | 5260 Barrer |  | 311 | **142** | Pyrolysis | **30°C and 0.01 bar** | 20 |
| Cellulose hollow fiber |  | 111 GPU | **36.9** |  |  | **Pyrolysis** | **110°C and 10 bar** | 21 |
| 6FDA/BPDA-TMPDA |  | 3.4-7.5×10-8 mol m -2 s-1 Pa -1 |  | 400-500 |  | Pyrolysis | 1-8.3 bar  25**°C** | 22 |
| Kapton Polymide |  | 3.1×10-10 mol m -2 s-1 Pa -1 |  |  | 150 | Pyrolysis | Up to 6 bar  30**°C – 250 °C** | 23 |
| Phenol-formaldehyde novolac resin | Resin tube | 1.7×10-9-1.2×10-7 mol m -2 s-1 Pa -1 |  | 23.1-45.2 | 24.1-39.5 | Pyrolysis | 2 bar 25**°C** | 24 |
| Polymide |  | 3.4×10-7-6.0×108 mol m -2 s-1 Pa -1 |  | 132-631 |  | Pyrolysis | 10.8 bar 30**°C – 120 °C** | 25 |
| Polymide |  | 1.4×10-7 mol m -2 s-1 Pa -1 |  | 540 |  | Pyrolysis | 10 bar 80**°C** | 26 |
| OrL | α alumina tube | 1.3×10-7 mol m -2 s-1 Pa -1 |  | 584 | 293 | Pyrolysis | 1.1 bar 35**°C** | 27 |
| PPO/PVP | Alumina | 1121 Barrer |  | 160.9 | 163.9 | Pyrolysis | 2 bar 25**°C** | 28 |
| PI | Alumina | 376 Barrer |  | 16.4 | 33.2 | Pyrolysis | 2 bar 25**°C** | 29 |
| PEI | Alumina | 1300 Barrer |  | 174 |  | Pyrolysis | 2 bar 25**°C** | 30 |
| CHFM |  | 5×10-8 mol m -2 s-1 Pa -1 | 83.9 | 5700 | 800 | Pyrolysis | 2 bar 130**°C** | 31 |

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