|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **SL NO and Title** | **Objective** | **Raw materials** | **Method** | **Characterization** | **Results** | **Significant Results** | **Ref.** |
| 1. Development of LTA zeolite membrane from clay by sonication assisted method at room temperature for H2-CO2 and CO2-CH4 separation. | 1. To use environmental friendly resources.  2. To use low cost material to produce membrane.  3. To Improve Crystallization time and temperature of the reaction. | Bentonite clay, sodium hydroxide, Decaline, Hydrogen peroxide, Poly-diallyldimethylammonium chloride solution (20% in water), Acetone and distilled water. | Ultrasonic irradiation at room temperature and 100°C | XRD(Due to nano-dimension and low crystallinity of these bentonite clays, XRD pattern reveals few low intense and broad reflections for the main clay mineral (Montmorillonite) along with some mixed layer clays (Illite-Smectite) and Kaolinite in the diffractogram. Even minor amount of quartz produce sharp intense XRD lines due to its high crystal, 2θ range of 0–60°), IR, FESEM(FESEM image reveals only the presence of Montmorillonite clay with typical nano-plate like grains, while angular grains of quartz are rare), TGA | In the case of the H2 –CO2 system, an appreciable separation factor value was obtained of 16.12 at 100 kPa , 30°C and separation factor gradually decreased with increasing feed pressure. |  | 1. |
| 2. Effective Hydrogen purification from Methane via Polyimide Matrimid 5218- Deca- ® dodecasil 3R zeolite mixed matrix membrane. | 1. To enhance the neat polymeric membrane Hydrogen separation performance.  2. To improve its thermal and mechanical properties.  3. To examine the effects of DDR (as a zeolite with good gas separation properties) loading on properties and gas separation performance of the MMMs. | Polyimide Matrimid® 5218, 1-methyl-2-pyrrolidone, hydrophilic Aerosil®200 fumed silica, sodium aluminate, sodium hydroxide and 1-adamantamine hydrochloride. | Hydrothermal synthesis of DDR at 180 ◦C for 140 h, calcination at 500 ◦C for 48h. Sonication, Membranes were treated thermally at 250 ◦C in nitrogen environment. | XRD, DSC, TGA, FESEM  Pore size of DDA (3.6 × 4.4 Å) | H2 permeability and H2/CH4 selectivity are 34.90 Barrer and 375.27 at 1 bar and 25°C |  | 2 |
| 3. Preparation and characterization of polyvinyl acetate/zeolite 4A mixed matrix membrane for gas separation. | 1. To investigate the structural and thermal properties of the polymer and zeolite pair.  2. To separate the gas pairs CO2/N2 and H2/N2 at different operating conditions. | PVAc Polymer, Zeolite 4A( 3.8 Å), dichloromethane. | Sonication. | Optical microscope, FESEM, DSC, TGA, XRD and single gas permeation | Temperature increase from 30°C to 50°C has a positive effect on permeabilities with a maximum of (1.19) x 3.348 x 10-19 kmol m/(m2 s Pa) (barrer) for O2, (17.55) x 3.348 x10-19 kmol m/(m2 s Pa) (barrer) for H2 and (9.35)x3.348 x 10-19 kmol m/(m2 s Pa) (barrer) for CO2 and a negative effect on their selectivity over N2. And H2/N2 selectivity is 156. |  | 3 |
| 4. Improving the gas-separation properties of PVAc-zeolite 4A mixed-matrix membranes through nano-sizing and silanation of the zeolite. | 1. To investigate the effect of using nano-sized zeolite 4A particles on the membrane morphology and the gas separation performance.  2. To study the surface silanization of zeolite nanoparticles in order to investigate the effect of modification on particle dispersion through the PVAc matrix,  agglomeration prevention and to evaluate any change in gas separation performance | Colloidal silica, Aluminium isopropoxide, sodium hydroxide (NaOH), tetramethylammonium hydroxide solution (TMAOH), 3- Aminopropyl(diethoxy)methylsilane (APDEMS), Anhydrous toluene, Poly(vinyl acetate) (PVAc) beads, anhydrous dichloromethane (DCM), Anhydrous isopropanol and ethanol. | Solution, Calcination at 550 °C for 6hr, ultra sonication,  solution casting method | FESEM, DSC, TGA, XRD, FTIR, Solid state 29Si (59.9 MHz) and 13C (75 MHz) Cross Polarisation Magic-Angle Spinning (CPMAS) and 29Si Bloch Decay Magic-Angle Spinning (BDMAS), nuclear magnetic resonance (NMR) experiments were carried out to investigate the modified and unmodified zeolite nanoparticles. The Brunauer-Emmett-Teller (BET) surface area was obtained using a Micromeritics TriStar II 3020 | Zeolite 4A(15%wt) loaded PVAc permeate 5.8 barrer, H2/CO2 5.3 and H2/N2 117 |  | 4 |
| Modified Zeolite 4A(15%wt) loaded PVAc permeate 5.6 barrer H2, H2/CO2 6.1 and H2/N2 143 |
| 5. Mixed Matrix Membranes Based on 6FDA Polyimide with Silica and Zeolite Microsphere Dispersed Phases. |  |  |  |  |  |  | 5 |
| 6. Fluorine-free synthesis of all-silica STT zeolite membranes for H2/CH4 separation. | 1. To produce HF free STT(0.24 × 0.35 nm, 0.37 × 0.53 nm).  2. To check the stability of STT membrane. | N, N, N-trimethyl-1-adamantammonium hydroxide (TMAdaOH), colloidal silica, deionized water | Hydrothermal synthesis | powder X-ray diffraction, | 2.8 × 10−8 mol·m−2·s−1·Pa−1 H2/CH4 selectivity up to 49.6 at 0.2 MPa and 298 K. |  | 6 |
| 7. Ultrapermeable 2D-channeled graphene-wrapped zeolite molecular sieving membranes for hydrogen separation. | 1. To Introduce a new type of thermally stable Zeolite-based membrane that enables the rapid and selective separation of H2 from CH4 or other gas. | Graphene Oxide(GO), Silicalite-1(MFI zeolites), NH4Cl | Colloidal method | Thermogravimetric analysis (thermal reduction of GO and burning of the reduced Graphene), Raman Spectroscopy(Thermal stability of G-MFI membrane) , SEM(Crack free MFI membrane and intergranular mesoscale pores), TEM(Highly crystalline MFI turns into crack containg G-MFI membrane), XRD(Slight distortion of MFI lattice during the grapheme wrapping). | Permeability of H2 and 1.3 × 10-5 mol m-2 s-1 Pa-1  Selectivity of H2/CH4 245 |  | 7 |
| 8. Separation performance of Si-CHA zeolite membrane for a binary H2/CH4 mixture and ternary and quaternary mixtures containing impurities. | 1. To Separate H2/CH4 gases using a novel Si-CHA zeolite membrane.  2. The membrane displayed good stability in wet mixtures. | Fluoride-free all-silica gel, α-alumina tubes (200 nm average pore size) from Inopor Co, DI water, N,N,N trimethtyl-1- adamantammonium hydroxide (TMAdaOH), sodium hydroxide, colloidal silica. | Hydrothermal synthesis | XRD, FESEM, Adsorption Isotherm, GS-TDC, | Permeability of H2 1.44 × 10−6 mol/(m2 s Pa)and  Selectivity of H2/CH4 85 at 298 K and 0.2 MPa. |  | 8 |
| 9. Efficient scale-up synthesis and hydrogen separation of hollow fiber DD3R (0.36 × 0.44 nm) zeolite membranes. | 1. To improve the membrane quality by controlling the alkalinity of synthesis solution.  2. To improve membrane stability | SiO2 , 1-Adamantanamine, Ethylenediamine, Na2O, H2O, NaOH | Hydrothermal synthesis | FESEM, EDX, XRD, Gas adsorption isotherms, | The single component permeance of H2 is 1.8 × 10− 8 mol m− 2 s − 1 Pa− 1 and ideal selectivity of 124 for H2/CH4 at at 303 K and feed pressure of 0.4 MPa. DD3R zeolite membranes pave the way to H2 separation from ethylene industry. |  | 9 |
| 10. Facile synthesis of zeolite FAU ( 0.74 nm in diameter) ,molecular sieve membranes on bio-adhesive polydopamine modified Al2O3 tubes. | 1. To develop a simple, versatile and powerful synthesis strategy to prepare highly reproducible molecular sieve membranes.  2. To extend and develop this concept for in-situ growth of dense zeolite FAU molecular sieve membranes on PDA-modified α-Al2O3 tubes. | LUDOX AS-40 colloidal silica, aluminum foil, sodium hydroxide, Dopamine, tris(hydroxymethyl) Aminomethane, Porous α-Al2O3 tubes | Hydrothermal synthesis | XRD, FESEM, EDXS, FTIR | H2 permeance of about 1.9x10-7 mol m-2 s-1 Pa-1 For binary mixtures at 50 °C and 1 bar, the mixture separation factors of H2/CH4 and H2/C3H8 are 9.9 and 127.7, respectively. |  | 10 |
| 11. Effect of the membrane quality on gas permeation and chemical vapor deposition (CVD) modification of MFI-type zeolite (0.54 nm × 0.56 nm) and (0.51 nmx0.55nm) membranes. | 1. To evaluate the quality of MFI zeolite membranes on the basis of the H2/CO2 separation factor at room temperature.  2. To investigate the The permeation and diffusion properties of some small gas molecules, such as He, H2, and CO2 (SF6 for comparison) through unmodified and CVD modified membranes in a wide temperature range with consideration of gas molecular weight and size. | R-Alumina porous supports made of alumina powder (Alcoa, A-16) with a thickness of 2 mm and a diameter of 20 mm (average pore diameter, ∼0.2 µm; porosity, ∼45%), fumed silica, 1 M TPAOH, NaOH | Since the R-alumina porous supports were prepared by sintering at 1150 °C for about 30 h. | GC for the calculation of H2/CO2 separation factor, XRD, SEM, | The H2/CO2 separation factor for the CVD modified membrane at 450 °C is about 8.2. The H2 permeance 1.1 × 10-7 mol ·m-2 ·s-1 at 450°C. |  | 11 |
| Autoclave at 180 °C for 4 hr, Hydrothermal synthesis |
| 12. Molecular layer deposition (MLD) modified SSZ-13(0.38 nm) membrane for greatly enhanced H2 separation. | 1. SSZ-13 (crystalline pore size: 0.38 nm) membrane was modified by MLD in an attempt to narrow the crystal pore mouth to the size close to H2.  2. To reduce flow through non-selective defects/inter-crystalline pores.  3. Binary mixture separation properties of H2/N2 and H2/CH4 were also evaluated for both pristine and modified membranes. | Colloidal silica, NaOH, titanium tetrachloride, ethylene glycol,  N,N,N-trimethyl-1-adamant ammonium hydroxide, | Teflon-lined autoclave for synthesis at at 433 K for 96 h. | FESEM, XRD, Soap film flowmeter, | At the optimum MLD cycles of 30, a H2 permeance of 4.27 × 10− 8 mol m− 2 s − 1 ⋅Pa− 1 with H2/N2 and H2/CH4 ideal selectivities of 35.6 and 427, respectively, were obtained on SSZ-13+30M. |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |