ECN

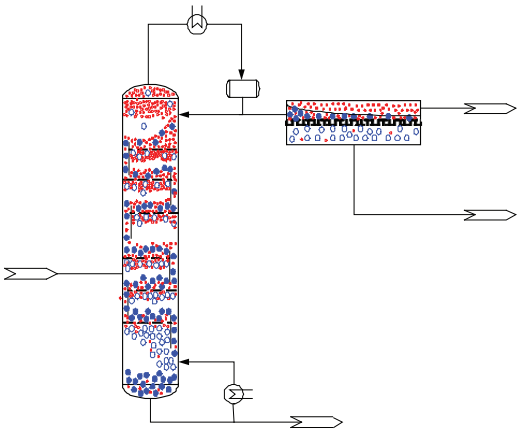
Energy research Centre of the Netherlands

Pervaporation with HybSi® membranes

HybSi®
Pervaporation Membranes

What is pervaporation?
Pervaporation is the selective evaporation of one of the components of a liquid mixture using a membrane. The word pervaporation itself is a combination of the words permeation, the transport through a membrane, and evaporation, the phase transition from the liquid to the vapor phase. It is not a pressure driven process such as several filtration processes and reverse osmosis. Instead, the driving force is due to the fact that on the feed side the chemical potential is higher than on the permeate side, similar to what is found in gas separation membranes. The gradient in chemical potential is maximized by using high feed temperatures and low pressures on the permeate side. Alternatively to pervaporation, membranes can often be used in vapor permeation mode as well. In this case the feed is fully vaporized. Often a detailed analysis of the full process is required to determine which option offers the highest benefits to the end user. These kinds of membrane processes are beneficial for the separation of e.g. azeotropes. In distillation the complete liquid feed is evaporated leading to high energy demands. By replacing distillation by the pervaporation membranes or combining the two processes large energy savings are possible.

Why is pervaporation still not the dominant separation technology?
The state-of-the art polymer membranes have a limited application window in terms of temperature (up to ~100°C), resistance against organic solvents and acids. The alternative, an all ceramic membrane, has a low hydrothermal and acid stability.

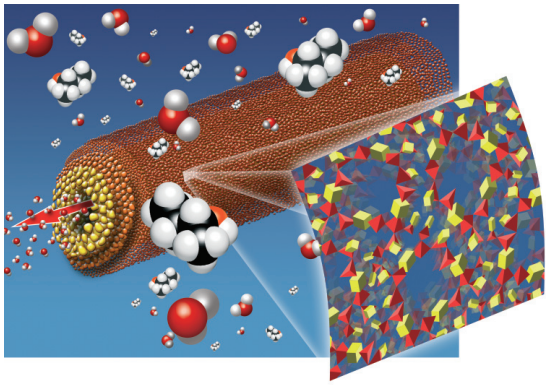


Combination of distillation and membrane: pervaporation or vapor permeation to break the azeotrope

The eight advantages of HybSi® membranes
- Energy saving of up to 50% possible
- Azeotrope separation is perfectly possible
- Decrease usage of cooling water
- Enhanced product quality also through milder conditions
- Reduced formation of side products
- Higher plant availability
- Chemical resistant
- Stable up to high temperatures

HybSi®: ECN's Answer
ECN has removed these limitations through the development of a revolutionary organic-inorganic hybrid membrane. De separating layer is deposited on a robust support tube. This membrane is stable in water at high temperatures, in (a)protic solvents, and in the presence of acids. The application window of pervaporation membranes is expanded with separation processes in reactors, aggressive feeds and at high temperature. The membrane has survived a number of extended tests (up to 3 years) under demanding conditions (at 150°).

Better products with less energy consumption: possibilities for your company?
The applicability of HybSi® membrane in a number of dehydration processes of organic solvents has already been proven. A selection of these is given on the reverse side. In close collaboration with the client ECN will assess the suitability of HybSi® membranes and confirm this by small scale lab tests. An on-site pilot test would be a logical continuation for the successful cases. For this purpose ECN has a complete demo skid unit available, that has passed a number of HAZOP analyses and is explosive proof. This unit can run batchwise as stand alone equipment using a 1000 liter feed vessel, or in line using a continuous feed.



Artist impression of the HybSi® membrane

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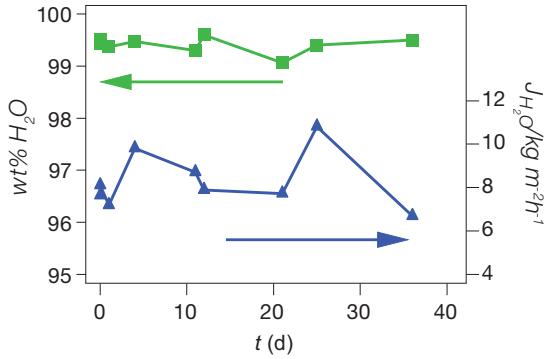
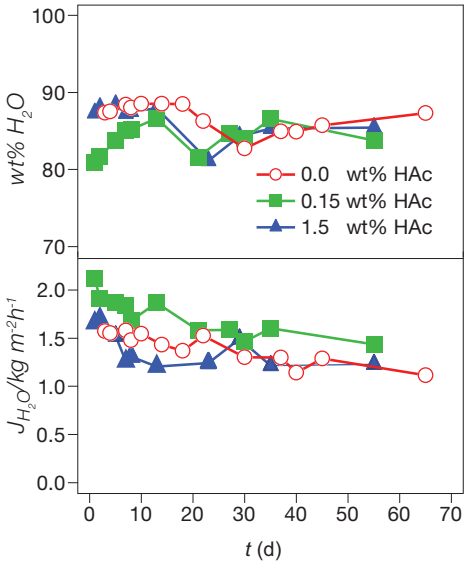
b-09-011

These tests would allow for an unambiguous assessment of the value of the HybSi® membrane system in your process.
Would you like to know more about this technology, it's utilization, or possibilities to perform tests please contact Jaap Vente.
Please visit www.hybsi.com

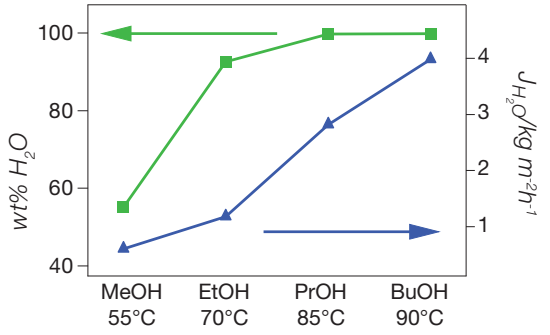
Some experimental results of the HybSi® membrane



Dehydration of 5 wt.% water in nBuOH vs. time at 190°C: permeate composition > 99% water



Dehydration of ethanol vs. time in the presence of acidic acid with HybSi® (bottom the water flux en top water concentration in the permeate at 5% water in the feed.



Dehydration of 5 wt.% water in MeOH, EtOH, PrOH en BuOH determined at various temperatures: water flux and water concentration in permeate

The membrane functions perfectly in the presence of acids up to a temperature of at least 190°C. The long term performance is far superior over any other existing pervaporation membrane used for dehydrations.
The application window is much broader than what has been conceivable to date. The flux through the membrane and the purity of the water in the permeate is dependent on the specific application and process conditions. First indications can be provided upon request.

Examples of Azeotropes that can be separated with HybSi® membrane technology

Permeating species	Retained species	Azeotrope (wt% of retained species)
Water	Acetonitrile	83.7
Water	Ethanol	95.5
Water	n-Propanol	71.7
Water	t-Butanol	88.3
Water	Methyl acetate	95.0
Water	Methyl ethylketone	89.0
Water	Tetrahydrofuran	95.0
Methanol	Toluene	31.0
Methanol	Methyl acetate	81.3
Methanol	Tetrahydrofuran	69.0

Other examples where HybSi® can be used include complex distillations and processes like:
- Acetone/phenol in e.g. the oxidation of. cumene
- Acrylates
- Bisphenol A
- Carbonates
- Diols
- EDC/VCM/PVC
- Isocyanates
- Propylene oxide
- Terephthalate compounds and terephthalic acid

Specifications of the pilot test unit
The ex-proof demo skid mounted unit can be operated in both pervaporation and vapor permeation modes:
- 1m^3 liquid feed vessel, feed flow 0.5 m^3/hr
- T_{max} = 150°C, P_{max} = 10 bar
- Membrane surface area = 1m^2

Pervaporation pilot test unit