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MEASUREMENT OF PERMEABILITY OF LOW POROUS MEMBRANES

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1 Key words

Transient method, porous media, low porous ceramic membrane, permeability, mass flow rate, pressure gradient, constant volume technique, free molecular regime, transitional regime.

2 Abstract

The determination of the permeability of low porous media like the micro and nano porous membrane or ultra-tight shale-gas reservoir is still a challenge up to now. The low porous membranes find a large application in medicine, biotechnology for separation and filtration. Gas permeability is an important parameter to understand the transport characteristics of the porous media. This characteristic can be obtained from the mass or volume flow rate through a media. For low permeability the transient techniques, "pulse-decay" or "draw-down" techniques, see [1], are suitable to determine low permeabilities. By using these techniques some authors underlined that it is not necessary to measure the mass flow rate because the permeability can be calculated from the changes of pressure in time. The main objective of the present work is to develop the transient (unsteady) method to measure the pressure evolution in time in high and low pressure tanks due to the gas flow through a porous membrane. This experimental methodology, based on the constant volume technique, was initially developed for the isothermal and non-isothermal measurements of the mass flow rate through the micro channels [2]. It is shown that the gas permeability can easily be obtained directly from the pressure evolution in time without calculation of the mass flow rate.

2.1 Experimental methodology

The experimental setup is a high vacuum system capable of measuring 5 decades of pressure ranging from $1,3$ Pa up to 133 kPa Fig.1. The reservoirs are connected only by a sample of micro porous ceramic membrane fixed with vacuum epoxy. This membrane sample has a cylindrical shape with radius $R = 475$ µm and length $L = 2.0$ mm.

3 Permeability

When an initial pressure drop is induced in one of the reservoirs, by shortly connecting the one of the reservoirs to the pump. It can be shown, that for the pressure evolution can be suitable fitted using and exponential decay model

$$p(t) = p_\mathrm{f} + (p_0 - p_\mathrm{f}) \exp(-t/\tau), \quad (1)$$

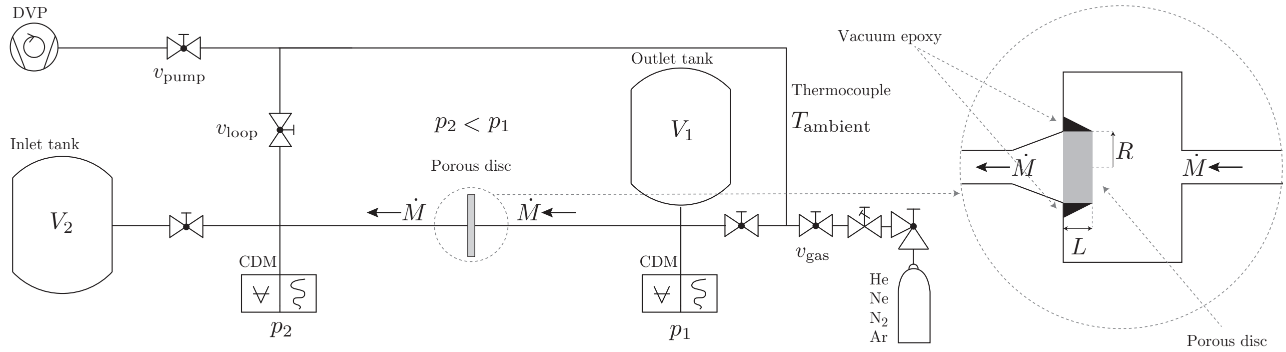

Figure 1: Schematic of the experimental setup.

where τ is the relaxations time of a gas and the only fitting parameter of the model. p_0,p_f are the initial and final pressure respectively. When the pressure evultion is determined, the mass flow rate can be calculated using the constant volume technique, previously used for the measurements of the mass flow rate through the micro channels [2]. Then, using the mass flow rate expression and the classical Darcy law, we can express the permeability as

$$K = \frac{V}{\tau}\frac{\mu L}{p_{\rm m} S}, \tag{2}$$

where V is volume, μ viscosity, L and S are the width and surface of the porous membrane, $p_{\rm m}$ the mean pressure. Therefore, when the relaxation time is obtained from the fitting of the pressure evolution, the permeability coefficient can be easily be determined using Eq.(2) as a function of gas mean pressure, see left Fig.2. We can observe the typical behavior of the permeability: it decreases linearly with the mean pressure increases demonstrating the well-known Klinkenberg effect. The influence of the gas nature is visible on left Fig.2, the permeability for Neon is higher compared to other gases. However, if we plot the permeability as a function of inverse gas mean free path all, gases are located on the same curve, see right Fig.2 .

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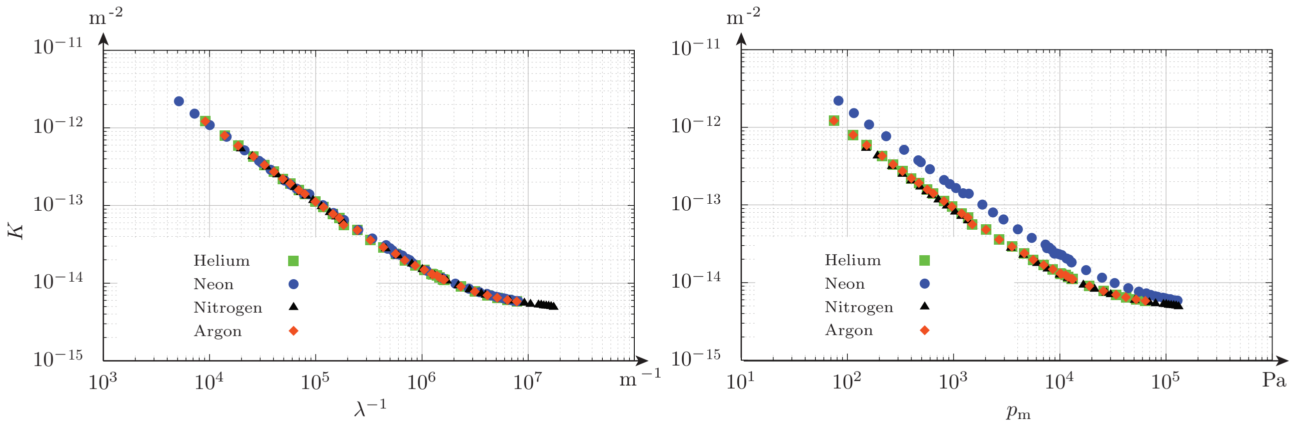

Figure 2: Membrane permeability.