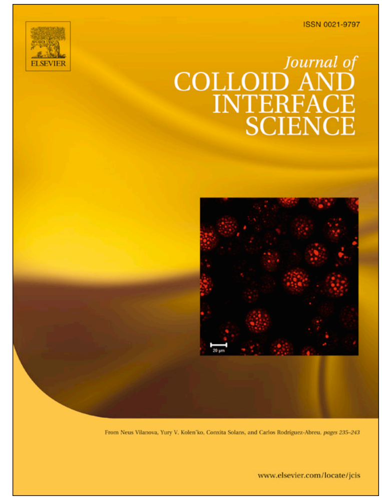

A method for quantifying in plane permeability of porous thin films

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A method for quantifying in plane permeability of porous thin films

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Abstract

The in-plane permeability of porous thin films is an important fluid mechanical property that determines wicking and pressure-driven flow behavior in such materials. This property has so far been challenging to measure directly due to the small sidewall cross-sectional area of thin films available for flow. In this work, we propose and experimentally demonstrate a novel technique for directly measuring in-plane permeability of porous thin films of arbitrary thicknesses, in situ, using a manifold pressed to the top surface of the film. We both measure and simulate the influence of the two dimensional flow field produced in a film by the manifold and extract the permeability from measurements of pressure drop at fixed flow rates. Permeability values measured using the technique for a periodic array of channels are comparable to theoretical predictions. We also determine in-plane permeability of arrays of pillars and electrodeposited porous copper films. This technique is a robust tool to characterize permeability of thin films of arbitrary thicknesses on a variety of substrates. In Supplementary material, we provide a solid model, which is useful in three-dimensional printer reproductions of our device.

1 Introduction

Darcy's Law [1–3] accurately describes flow through porous media under a wide range of relevant conditions, with permeability characterizing the resistance to flow. Permeability is an essential characteristic of porous materials for many applications, e.g. hydrocarbon transport in porous rocks,[4] membrane transport,[5] and biological systems.[6] In anti-corrosion protection by organic coatings, permeability of thin films is important for oxygen and water uptake by the coatings. [8]

The numerous applications of Darcy's Law give rise to many corresponding methods of permeability characterization.[7] For example, in petroleum engineering, an established measurement technique is the so-called "perm-plug method" (standard APZ Code No. 27).[8] Measurement methods have also been developed for a variety of applications including water treatment, where permeability of filter membranes is key to understanding the transport of water, oxygen and bacteria through the membrane [9] and biomedicine, where e.g. researchers are interested in measuring the permeability of the cornea [10] in order to study its function.

Permeability is in general a three-dimensional (3D) tensor [11]. For thin porous layers there are two in-plane permeability components and one component through-plane. There exist standards for measurement of the permeability of thin layers such as clothing and technical textiles (ASTM D737: air flow; ISO 15496: water vapor flow) and compressed geotextiles (ASTM D5493: water