

It should be understood that the hydrogel of the gel-in-matrix will also contain the micropores normally found in such hydrogels. References to gel fracture channels in this disclosure do not refer to such micropores, since the size of the fracture channels is substantially larger than that of the hydrogel's micropores.

The fracture channels of the gel-in-matrix have a mean characteristic dimension of from about 0.1  $\mu\text{m}$  to about 1000  $\mu\text{m}$ . This characteristic dimension, an indicator of the channels width or diameter, is preferably in the range of from about 1–100  $\mu\text{m}$ . The fracture channel network of the gel-in-matrix significantly increases the available surface area of the hydrogel, as compared to conventional slab hydrogels. The support provided by the matrix structure also ensures the continued viability of the fracture channel network throughout the hydrogel, during use of the gel-in-matrix.

The fracture channels in the gel-in-matrix of this invention are created by mechanical means. This is ordinarily accomplished by first forming a hydrogel within the matrix structure and thereafter treating the hydrogel in situ, by the preferred mechanical method, to fracture the gel. Formation of a hydrogel within the matrix is typically accomplished, in a conventional manner, by saturating the matrix with an aqueous solution containing the gel-forming component and thereafter inducing formation of a hydrogel, by cooling or otherwise. This results in a hydrogel that completely fills the void spaces, cavities, and/or interstices within the three dimensional matrix structure.

Mechanical treatment of this intact hydrogel within the matrix structure is the means employed for creating the network of fracture channels within the hydrogel of the gel-in-matrix. It should be evident that the matrix structure's porosity characteristics place an upper limit on the size of the fracture channels that can be created within the hydrogel. For example, the fracture channels in a gel-in-matrix employing reticulated open-cell foam as the matrix structure cannot exceed the size of the cells in the foam.

The preferred mechanical treatment method for creating the fracture channel network in the gel-in-matrix is partial dewatering of the hydrogel in situ.

The partially-dewatered gel-in-matrix of this invention is based on the unexpected discovery that when an intact hydrogel formed within a three dimensional porous matrix structure is compressed or squeezed, only water is expressed. One would have expected that pieces of the hydrogel itself would be expressed by such squeezing treatment since an intact hydrogel, absent a matrix structure supporting the gel, ordinarily breaks into pieces and fragments of gel when subjected to squeezing. It should be understood that the inventors do not wish to be bound by this theory since the physical basis of this invention is still not fully understood.

The partial dewatering treatment is preferably carried out as the mechanical means for forming fracture channels but may also be accomplished in conjunction with other mechanical treatments that create the fracture channels, some of which are described below. Likewise, these alternative mechanical treatment methods may also be the sole means used to form the fracture channel network.

The mechanical dewatering treatment is desirably sufficient to create a dewatered, fractured hydrogel that contains from about 10 to 90% of its original gel weight, i.e., prior to dewatering. Preferably, the fractured, dewatered hydrogel contains from 15 to 50% of its origi-

nal weight, as compared with the hydrogel weight prior to dewatering.

The partial dewatering may readily be accomplished by compression of an intact hydrogel contained within a flexible, resilient matrix, followed by decompression, which yields a network of fracture channels within the hydrogel. Centrifugal force is also an effective mechanical means for partially dewatering a matrix structure containing a gel. This technique is especially useful with rigid matrix structures which cannot be readily treated by the compression/decompression procedure.

It must be stressed that this partial dewatering treatment to form fracture channels in the hydrogel must be accomplished via mechanical means, such as compression/decompression or one of the other mechanical procedures described above. When a hydrogel contained within a matrix is dehydrated by conventional drying, at ambient or elevated temperatures, the resultant partially-dehydrated gel will not exhibit the favorable characteristics of the gel-in-matrix of this invention, e.g., rapid rehydration when exposed to water.

The partially dewatered, fractured gel-in-matrix of this invention may be exposed to an aqueous medium and will exhibit partial rehydration of the gel, within a relatively short period of time. Such rehydration, however, is not total so it does not cause a complete loss of porosity for the gel-in-matrix; the fracture channels are not closed or healed via such hydration.

This ability of a fractured, partially-dewatered gel-in-matrix to rehydrate itself when exposed to an aqueous medium, without losing its desirable porosity characteristics, is one aspect that creates numerous end-use applications for gel-in-matrix, e.g., in chromatographic separations. Rehydration of the partially-dewatered, fractured gel typically results in a rehydrated gel containing at least 80 to 90% (but less than 100%) of the original gel weight prior to dewatering.

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These other mechanical means used to form the fracture channels in the gel-in-matrix may include freezing and thawing of the hydrogel in situ, in one or more freeze-thaw cycles. Another technique, useful with resilient matrix structures such as flexible foamed plastics, involves stretching of the matrix structure containing an intact hydrogel. Yet another procedure that gives satisfactory results is exposure of the hydrogel in situ to a gas under pressure, to induce diffusion of the gas into the gel within the matrix structure, and thereafter rapidly releasing the gas pressure to cause fracturing of the gel. The initial gas diffusion may take place either before or after gelling of the hydrogel within the matrix structure.

The hydrogel employed in the gel-in-matrix of this invention may be selected from a wide variety of known hydrogel materials.

The hydrogel is desirably thermally-reversible. The hydrogel may alternatively be a gel that is not readily reversed from its gel state. Gels obtained by cross-linking of water soluble polymers, e.g., cross-linked polyacrylamide gels, are examples of the latter.