Mailvaganam Memorial Oration – 2014

2014 lecture was delivered by

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Uphill Diffusion of hydrogen in metals

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Summary:

Hydrogen dissolves in many metals and occupies interstitial sites which results in an expansion of the metal lattice. The process that is responsible for the interaction between the dissolved hydrogen atoms is not yet fully understood but has been considered to be associated with lattice expansion. Expansion of the metal lattice results in the creation of an elastic field which is in turn responsible for changes in many physical properties. In this lecture I shall demonstrate changes occurring due to diffusion of hydrogen in metal lattices by considering thin slab diffusion membranes.

If the diffusion flux of hydrogen at any point in a diffusion membrane is proportional to the hydrogen concentration gradient at that point then the diffusion process is said to obey Fick's law and the diffusion is called Fickian diffusion. The steady state in Fickian diffusion is characterized by hydrogen concentration- independent flux and linear variation of hydrogen concentration across the thin slab membrane. But the stress field developed in a metal lattice due to the presence of hydrogen in the lattice affects the diffusion process and the diffusion process losses its Fickian character. The stress field developed during the hydrogen diffusion in a metal is time dependent due to the time dependence of hydrogen concentration in the metal lattice. This results in the hydrogen concentration variation at the steady state becoming non-linear and the diffusion flux becoming dependent on the hydrogen concentration in the membrane.

A series of experiments with tubular shaped membranes of Palladium and two of its alloys ($Pd_{77}Ag_{23}$ and $Pd_{81}Pt_{19}$) exhibited diffusion of hydrogen at the initial stage of the experimentation in the direction opposite to that of hydrogen concentration gradient imposed experimentally(2). This is referred to as "Uphill diffusion" of hydrogen. The physical process responsible for this non Fickian diffusion will be presented in this lecture. Further a theoretical analysis leading to an estimation of the diffusion coefficient of hydrogen in a membrane under the influence of a stress field induced by the hydrogen diffusion will also be presented.