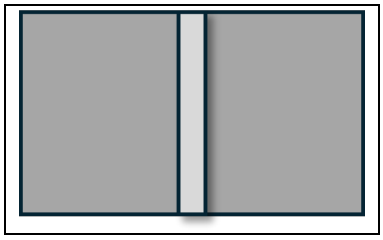
Chemical kinetics for microelectronics

A. Consider a thin slab of material sandwiched between two large regions of the same crystalline solid. Let us assume the thin slab has significantly larger diffusivity for chemical species compared to the larger adjacent regions. Let the entire exposed surface have a *fixed* concentration of the diffusing species and *negligible variation in composition* across the slab.



   - Write down the flux equation for concentration in the slab
   - Write down the temporal variation for concentration outside the slab
   - Write down an expression for the concentration outside the slab assuming an error function solution
   - If the temporal variation in concentration in the slab is much greater than that outside, derive an expression for the concentration. This expression represents a x, y variation in concentration with time.
   - Read the Hoffman-Turnbull paper we have discussed and compare your analysis so far against their results on silver diffusion as well as their fitting to the Fisher model. This is one of the early studies showing a critical comparison of lattice versus grain boundary diffusion kinetics.

B. Moving on from self-diffusion, in the contemporary microelectronics setting, numerous memory (e.g. ECRAM, CBRAM) and neuromorphic device concepts involve silver and silver ion diffusion / drift across dielectrics for function as artificial synapse or neurons. In this context, electronic properties can influence chemical kinetics.
   - Read the 1986 Sigman *et al* paper on silver diffusion in SiO_2 and explain in your words the reasons for why metal diffusivity depends on the annealing environment. Here we will be primarily concerned with the nature of electronic trap states in the dielectric medium that can influence the diffusion phenomena.
   - Besides heat or electric fields, there are growing efforts to co-integrate optically active materials with electronics for emerging fields such as machine vision, autonomous vehicles and optical computing. Read the paper posted in Canvas on photo-diffusion of silver into chalcogenide glasses. Note that the band gap in these systems is substantially less than in silica. Following the previous question, let us consider the nature of electronic properties in the glass that can lead to silver migration. Particularly, critically examine the argument that we are creating tiny solar cells inside the glass that essentially drives the silver ion diffusion. Draw an approximate band diagram for this argument and explain under what scenario this could be a likely explanation for the observed kinetics. Suggest an experiment to test this hypothesis.
   - Study the Valov-Kozicki review paper to look at nanoscale effects on cation diffusion in similar systems. Here the diffusion effects are indirectly probed by electrical measurements across the medium in which the cations are diffusing. Focus on the section discussing the nature of interfacial energy between the metal particles and the dielectric medium (Gibbs-Thomson effect, this was not considered in the previous questions explicitly). This has a direct consequence on the spatial profile of the metal particle clusters and therefore the memory characteristics of a device built with such a heterogeneous medium.