

This Week's Citation Classic

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Hart E W. On the role of dislocations in bulk diffusion.
Acta Metall. 5:597, 1957. [General Electric Research
Lab., Schenectady, NY]

This paper presented a calculation for the contribution of dislocations to the measured self-diffusion coefficient of metals. The resultant enhancement of the diffusion is important principally at low temperatures and accounts for the low temperature anomalies observed for the self-diffusion activation energy. [The SC[®] indicates that this paper has been cited over 135 times since 1961.]

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"This paper was written during a period when I was associated with D. Turnbull and R. E. Hoffman in a variety of interesting problems in solid state diffusion. The principal stimulation for this work was the quantity of high quality experimental results that were then being generated at the General Electric Research Laboratory and elsewhere with the use of techniques that were then relatively new. There was considerable interest in understanding the mechanisms involved in diffusion and other point defect phenomena. One such area of interest was the difference of diffusivity in crystal grain matrix and in grain boundaries. The low angle tilt boundaries, that could be easily modeled as dislocation arrays, were of special interest, since data obtained for such boundaries implied measurement of diffusivities in dislocations themselves¹—the so-called 'pipe diffusion.' It was in that atmosphere that it occurred to me that there might be a sizable contribution to the measured matrix diffusion coefficient

from the random dislocation networks that populated even very well annealed single crystals. I then proceeded to a calculation of the effect and found that the contribution was indeed significant. Furthermore, the effect was increasingly significant at low temperatures and was able to account for some rather puzzling anomalies in the plots of measured diffusion coefficients at low temperatures. Turnbull thought this was an important result and suggested that I publish it. I prepared a short note on the calculation, but, since it seemed so simple to me, I hesitated to submit it for publication. Some time after that Turnbull again prompted me to submit it, and so I sent it to *Acta Metallurgica* where it soon appeared as a one page paper. To my surprise, it was immediately received with strong interest and continued to be cited long after my interest in the field had ceased.

"The idea behind the calculation was rather simple. Any atom in the crystal could be considered, in the course of its diffusion history, to spend a fraction of its time as part of a dislocation core and the remainder of its time in regular lattice sites. Since there is only one atomic species involved, the fraction of time spent in a dislocation is the same as the fraction of atoms of the crystal that are in dislocation cores. Since there is no statistical correlation between migrations in dislocations and in matrix, an application of random walk theory was sufficient to compute the resultant atomic diffusion coefficient.

"The theory was later extended by Mortlock² to the case of diffusing solute species. There does not seem to have been improvement in the method of calculation since the initial paper."

1. **Turnbull D & Hoffman R E.** The effect of relative crystal and boundary orientations on grain boundary diffusion rates. *Acta Metall.* 2:419-26, 1954.
2. **Mortlock A J.** The effect of segregation on the solute diffusion enhancement due to the presence of dislocations. *Acta Metall.* 8:132-4, 1960.