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This Week's Citation Classic

Herring C. Diffusional viscosity of a polycrystalline solid. *J. Appl. Phys.* **21**:437-45, 1950. [Bell Telephone Laboratories, Murray Hill, NJ]

A crystal grain acted on by surface tractions too weak to disrupt its lattice structure can still change its shape by a volume diffusion of atoms (or vacancies) that removes materials from some faces and adds material to others. This paper described this process quantitatively, with applications to the creep of polycrystals, especially thin wires, at high temperatures and low stresses. [The *SCI*® indicates that this paper has been cited over 405 times since 1961.]

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"In the late 1940s, in the course of preparing a review article with M.H. Nichols on thermionic emission,[1] I became intrigued by the problem of the thermal etching of metal surfaces, and the possible role of anisotropy of surface energy in it. At a physical electronics conference I chanced to meet a powder metallurgist, G.C. Kuczynski, whose experiments on the fundamentals of sintering seemed to relate closely to the things I had been thinking about. I became very interested in sintering and related effects, and this paper was one of several that I wrote in this area over the next few years.

"A few years earlier, J. Frenkel, encouraged by the successes of his vacancy model of liquids, had proposed that a crystal, like a liquid, should display a viscous response to a small shearing stress, with a coefficient that could be related to its vacancy self-diffusion constant.[2] I was convinced that such a response should be impossible in the presence of crystalline long-range order. In such case, the creep observed in very lightly stressed wires at very high temperatures could only be explained by a diffusive migration of material between free surfaces and grain boundaries. This migration could be crudely described by an effective viscosity inversely proportional to the square of the crystal grain dimensions. It turned out to be possible to describe this process precisely in terms of thermodynamic concepts and an independently measurable diffusion coefficient.

"When my work was nearly finished, I discovered that this mode of deformation had already been described, although without the precise quantitative formulation in a paper by Nabarro.[3] So, in writing my paper, I tried to place emphasis on a precise and general formulation, on quantitative comparisons of theory and experiment, and on possible complicating factors. The latter include the question *of* whether dislocations in the interiors of the crystal grains can be made to absorb or emit vacancies under very weak stresses, and the distinction *of* the mass-transport diffusion coefficiency from that measured in diffusion of a radioactive tracer.

"Reflecting on this work, and on my other work of the time in the field of sintering, I find it a nice illustration of the value of chance informal personal contacts between scientists. Also, I am grateful that it has made me aware of the intellectual challenges that still remain in modern applications of classical physics, particularly thermodynamics, and taught me to appreciate the century-old foundations laid by J.W. Gibbs."

1. **Herring C & Nichols M H.** Thermionic emissions. *Rev. Mod. Phys.* **21**:185-270, 1949.
2. **Frenkel J.** Viscous flow of crystalline-bodies under the action of surface tension. *J. Phys.* (Moscow) **9**:385-91, 1945.
3. **Nabarro F R N.** in *Report of a conference on the strength of solids-* London: The Physical Society, 1948. 75p.