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This Week's Citation Classic

Li J C M. Petch relation and grain boundary sources.
Trans. Metall. Soc. AIME 277:239-47, 1963.
[Edgar C. Bain Laboratory for Fundamental Research, US Steel Corp., Research Center, Monroeville, PA]

The relation between flow stress and grain size, now known as the Hall-Petch relationship, is derived from a consideration of grain boundary sources of dislocations. These sources are identified as ledges (or adsorbed dislocations) in the grain boundary. The effects of impurities and annealing temperature on the ledge structure are analyzed. Some critical experiments are suggested. [The *SCI*® indicates that this paper has been cited over 135 times since 1963.]

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"Working on fundamental problems in an industrial laboratory is any scientist's dream. We had a good time at the Edgar C. Bain Laboratory for Fundamental Research of the US Steel Corporation. We worked graduate student hours, including evenings, weekends, and holidays. Somehow we also had understanding young wives (my wife, Lily, included) with small kids. A lot of original work was done and the Bain Laboratory was well known among the workers in the field.

"In the beginning of the 1960s we were feeling the impact of dislocation theory. Any paper with no dislocations mentioned was considered out of date. Many of us did not know anything about dislocations. So we organized a study group in which each of us studied a chapter in books by W.T. Read, Jr.,[1] or A.H. Cottrell,[2] and then explained it to the others. I still remember the excitement when our first paper on dislocations was accepted for publication.

"One of the concerns at the time was the source of dislocations. The Frank-Read source[3] was generally accepted but was not generally observed. Instead, dislocations were frequently found near grain boundaries. Another concern was the flow stress-grain size relationship whose proposed mechanism depended on the existence of dislocation pileups. A.S. Keh, who was a co-worker at the time, did not observe any dislocation pileups in iron. So, one day I was thinking about these discrepancies and discovered that the grain size effect could be understood by assuming grain boundary sources without dislocation pileups. Then I worked out the details of impurity and temperature effects and searched the literature to compare experimental facts with theoretical expectations. They were surprisingly consistent. The manuscript was reviewed by three people in the Bain Laboratory before it was submitted for publication. There were arguments about some details but not about the main proposal.

"The paper received some attention, probably because it satisfied the two needs mentioned, namely, the lack of general observation of both the Frank-Read sources and dislocation pileups in iron. It has stimulated some experiments on the grain boundary ledge structures and their ability to emit dislocations. I want to emphasize the interaction we had at the Bain Laboratory. Without the experimental work of Keh and others, I would not be involved in such studies.

"This problem was later reviewed by myself and Y.T. Chou[4] as an invited contribution and more recently at the Acta-Scripta Metallurgica International Conference."[5]

1. **Read W** T, J**r.** *Dislocations in crystals.* New York: McGraw-Hill, 1953. 228 p.
2. **Cottrell A H.** *Dislocations and plastic flow in crystals.* Oxford: Clarendon Press, 1953. 223 p.
3. **Frank F C & Read W** T, J**r.** Multiplication processes for slow moving dislocations. *Phys. Rev.* 79:722-3, 1950.
4. **Li J** C **M** & **Chou Y T.** The role of dislocations in the flow stress grain size relationships. *Metall. Trans.* 1:1145-59, 1970.
5. Li J C M. Dislocation sources. (Ashby M F, Bullough R, Hartley C S & Hirth J P. eds.) *Dislocation modelling of physical systems.* Oxford: Pergamon Press, 1981. p. 498-518.