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This Week's Citation Classic

Brandon D G, Ralph B, Ranganathan S & Wald M S. A field ion microscope study of atomic configuration at grain boundaries. *Acta Metallurgica* **12**:813-21, 1964. [Dept. Metallurgy, Univ. Cambridge, Cambridge, England]

A number of grain boundaries in tungsten and tungsten-rhenium alloys were examined by field-ion microscopy. The width of the high-angle boundaries was observed to be very narrow. The observations were correlated with a model for high-angle grain boundaries derived from coincidence site lattice theory. [The *SCI*® indicates that this paper has been cited over 210 times since 1964.]

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"In the summer of 1958 Erwin Müller gave the first international presentation of his beautiful helium field-ion micrographs taken at 21°K.[1] A few months later my then research supervisor, Jack Nutting, asked me if I would be willing to stay on in Cambridge after completing my doctorate and start a field-ion microscope group in the department of metallurgy.

"We set up shop the following October, under the aegis of Professor (now Sir Alan) Cottrell. The group consisted of myself, two research students (Mike Southon and Mike Wald), and a technician (joe Reich). By the spring of 1960 we were getting rather fuzzy images of oxide-contaminated field-ion tips.

"Brian Ralph and Srinivasa Ranganathan (Rangu) joined the group the following October. By this time we were imaging moiybdenum and tungsten field-ion tips in helium at temperatures down to about 60°K. We had decided early that our objective was to study lattice defects and that we did not wish to compete with Müller and his group at Penn State University in developing the field-ion technique. Since the United Kingdom Atomic Energy Authority was sponsoring the work, the emphasis was placed on radiation damage.

"In the summer of 1961 I gave a paper at the annual Field Emission Symposium (held in Williamstown, MA) and had my first opportunity to meet Erwin Müller and other FIM enthusiasts. By that time we had already identified several grain boundaries, although the small tip radius (typically 50-100 nm) reduced the chances of finding a boundary in any given tip to something like 1 in 10.

"The first grain boundary we were able to analyse in detail was in molybdenum, but irregular field-evaporation, especially around the {111} planes, made molybdenum an unattractive candidate for high resolution field-ion microscopy. Thereafter we concentrated on tungsten and tungsten-rhenium alloys.

"By late 1962 we had accumulated images from field-evaporation sequences of at least a dozen different grain boundaries and had finally begun to ask the obvious question — why does the atomic fit between two grains of completely different orientation appear so remarkably good?

"The 'flash of inspiration' came during an afternoon brain-storming session of all the group members on the subject of errors in determining the angular misorientation between grains: a large proportion of lattice sites at the boundary must be common to both grains.

"Actually, although we didn't know it at the time, the idea wasn't all that original. In 1959 C.G. Dunn (at an AIME meeting in San Francisco) had already reported on the geometry of some simple coincidence lattices, while as early as 1949 Kronberg and Wilson had noted the odd behaviour of grain boundaries exhibiting a 'special relationship.'[2]

"I suppose our real and unique contribution lay in the visual impact of the field-ion images, which provided the first direct hard evidence for good atomic fit at grain boundaries—that and the tables of high density coincidence lattice relations painstakingly prepared by Rangu!"

1. **Müller E W.** *4th International Conference on Electron Microscopy.* Berlin: Springer-Verlag, 1958. 820 p.
2. **Kronberg M L & Wilson F H.** Secondary recrystallization in copper. *Trans. AIME* **185**:501-14, 1949.