NUMBER 9
FEBRUARY 26, 1979

This Week's Citation Classic

Tiller W A, Jackson K A, Rutter J W & Chalmers B. The redistribution of solute atoms during the solidification of metals. *Acta Metallurgica* **1**:428-37, 1953.

A quantitative analysis of solute partitioning at a freezing interface was given for steady state transient cases. Solute distribution in solid and liquid were given for both constant **and** abrupt changes in freezing rate and a quantitative criterion for the onset of constitutional supercooling calculated. [The *SCI*® indicates that this paper has been cited 206 times since 1961.]

William A. Tiller
Dept. of Materials Science and Engineering
Stanford University
Stanford, CA 94305

June 21, 1978

Of my coauthors, B. Chalmers was the professor, J Rutter was a postdoc and K Jackson, like myself, was a lowly Masters Degree candidate. This particular paper became the central item in my M.A. Sc thesis at the University of Toronto in 1953.

"The work evolved out of a series of blackboard discussions that the four of us had on consecutive mornings during our usual coffee sessions. John Rutter had recently completed his Ph.D. thesis on a prismatic substructure, presently called cells, which developed during dilute alloy solidification and was known to involve the interaction between the temperature distribution and the solute distribution in the liquid at the freezing interface. He and Bruce Chalmers had previously proposed the concept of 'constitutional supercooling' to rationalize the existence of this phenomenon. Ken Jackson had been set to work on the investigation of the origins of the dislocations leading to another substructure called 'striations. ' I had been set to work to understand the origins of the phenomenon called "banding " which involved the appearance of an almost o-function of solute excess in the crystal, located parallel to the interface, either regularly or randomly along the length of the crystal. The fine hand of Bruce Chalmers stimulated and guided us all.

"Our initial discussions centered about a qualitative understanding of these phenomena and, after several days, we had reached the point where we thought that we could give an acceptable qualitative explanation for the banding and the cell formation phenomena. Central to both of these explanations was the actual distribution of solute in a liquid ahead of an interface moving at constant velocity. Our qualitative discussions had led us to realize the importance of the steady-state distribution. Being somewhat mathematically inclined, I tried to set up the problem in a moving coordinate system and was successful in solving for the steady-state solution. The results predicted, surprisingly to many at the time, a very thin layer of highly solute-rich liquid at the interface. Very quickly thereafter, approximate solutions were gained for the initial transient and the rate change regions. With these in hand, it was then very easy to write down a quantitative criterion for the onset of constitutional supercooling and, thus the onset of cell development for metallic systems. Being excited about it all and fairly articulate with words, I wrote the paper (my first) the following weekend and, with a minimum of haggling and polishing, Bruce Chalmers accepted it for publication in *Acta Metallurgica.*

"Our accomplishment was primarily a matter of being at the right place at the right time with the right tools. The world seemed poised and ready for this new contribution. The quantitative understanding expanded the dimension of our qualitative appreciation allowing us to begin to explain a whole host of solidification and casting phenomena in a precise way at a time when the semiconductor industry was just beginning to depend greatly on freezing processes for controlled materials preparation. Success in that field spilled over into the empirical field of casting and foundry technology and the beginnings of a science-based technology of the freezing process began to form which is still continuing to grow today "