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This Week's Citation Classic

Butler E P & Thomas G Structure and properties of spinodally decomposed Cu-Ni-Fe alloys. *Acta Metall.* **18**:347-65, 1970.
[Inorganic Materials Res. Div., Lawrence Radiation Lab., and Dept. Materials Sci. and Engineering, Coll. Engineering, Univ. Calif., Berkeley, CA]

The key structural elements of spinodal decomposition are identified in this experimental study of the aging response of a fast-quenched Cu-Ni-Fe alloy, Microstructural, crystallographic, and compositional parameters are characterized and related to the mechanical property changes accompanying decomposition. [The *SCI*® indicates that this paper has been cited over 100 times since 1970.]

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"In October 1967, after completing my graduate studies in physical metallurgy at Leeds University, I accepted a postdoctoral position at the University of California, Berkeley. Structure/property relationships in metals and alloys with the transmission electron microscope providing the important structural link was at that time, and still is, my principal interest, and I was keen to work with Gareth Thomas who headed one of the premier research groups in this technique of materials characterization.

"My initial impressions of Berkeley were vivid, in common no doubt with those of many people arriving in the Bay Area for the first time. The beauty of the campus in the strong Californian sunshine, the breathtaking views across blue water to the distant city, the scent of groves of eucalyptus, which made walking to work each morning a delight, all acted in those early weeks as a heady cocktail to my senses.

"Gareth had suggested that we look at spinodal decomposition —a phase transformation involving phase separation on a fine scale and thus amenable to electron microscopical study. Although there was considerable interest in the potential manipulation of this transformation to achieve strong microstructures from the solid state, it had received only scant experimental attention. There was even controversy concerning the alloy systems in which the transformation occurred, and a systematic characterization of the microstructural changes during decomposition in an alloy that everyone agreed decomposed spinodally was needed. For this reason, a Cu-Ni-Fe alloy was chosen, whose composition lay at the centre of the miscibility gap. Decomposition of the fast-quenched alloy was then undertaken as a function of those two stalwarts of metallurgical variability, aging time and temperature. Wavelength measurements were determined directly by TEM examination; compositional amplitude measurements by monitoring the Curie temperature of the Ni/Fe-rich decomposition product. It only remained to relate these structural parameters to the mechanical properties to complete the picture.

"The experimental problems encountered were exclusively related to alloy and specimen preparation. The production of the alloy in sheet form was difficult, necessitating hot rolling in a narrow temperature range to avoid cracking. The production of thin foil specimens for TEM by the sorcery euphemistically termed electropolishing necessitated the usual correct incantations in order to be successful.

"The published paper stressed the essential structural simplicity of the transformation and the key components by which it could be identified. It demonstrated for the first time the application of satellite spacing measurement from electron diffraction patterns of periodic microstructures. It identified the mechanism of spinodal strengthening and showed how dislocations could be trapped at the spinodal interfaces. It enabled the term spinodal decomposition, and its elegant theoretical modeling, to be translated via the microstructural approach into terms the metallurgist could more readily understand. It is for these reasons that I believe the paper has been so frequently cited."