FORMATION OF THE LAMELLAR STRUCTURE IN GROUP IA AND IIICD IRON METEORITES; J. A. Kowalik, D. B. Williams and J. I. Goldstein, Department of Materials Science and Engineering, Lehigh University, Bethlehem, PA 18015

Iron meteorites are composed primarily of Fe and Ni with small amounts of carbon and phosphorus and have cooled slowly in their parent asteroidal bodies [1]. Upon cooling Kamacite precipitates in a Widmanstatten pattern on the (111) planes of the prior taenite single crystal. The residual taenite regions between the Widmanstatten pattern decompose into various morphologies called plessite. A unique lamellar plessite structure is found in carbon containing Group IA and Group IIICD irons. The purpose of this research is to characterize the lamellar structure and to determine the phase transformations responsible for its formation.

Representative meteorites studied from Group IA were: a) Canyon Diablo 7.1 wt% Ni, 0.26 wt% P; b) Odessa, 7.35 Wt% Ni, 0.25 wt% P; c) Toluca, 8.4 wt%, 0.16 wt% P and from Group IIICD, Dayton 17.6 wt% Ni, 0.4 wt% P. [2]. These meteorites were examined using light microscopy, scanning electron microscopy (SEM), and analytical electron microscopy (AEM). Convergent beam electron diffraction was used to determine orientation relationships.

The Group IA irons contain fine lamellae of kamacite and taenite (width of lamellae <1 μm) in the plessite field (Figure 1). The lamellar morphology develops in residual taenite regions containing $\geq$ 23% wt% Ni. No formational relation to carbide or phosphide inclusions is apparent. In contrast the lamellar morphology of group IIICD Dayton contains coarse lamellae of kamacite and taenite phases (width of lamellae >3 μm) (Figure 2). The lamellar structure develops in residual taenite regions containing ∿17.6 wt% Ni. The lamellae occur only in areas near large, (∿5mm) phosphides and abut directly on the Widmanstatten structure. Ni composition profiles across the fine lamellar morphology of group I plessite using AEM, reveal kamacite with ∿4 wt% Ni and Tetrataenite [3] with ∿48 wt% Ni (Figure 3). Concentration gradients across the lamellae in Dayton (group IIICD) reveal kamacite with ∿4 wt% Ni, and taenite consisting of clear taenite I (Tetrataenite) containing 45-52 wt% Ni and in some cases a cloudy zone containing ∿38 wt% Ni.

The kamacite/taenite interface of the lamellae of the Group IA irons forms with a Kurdjumov-Sachs orientation relationship. The lamellar plessite forms at less than 400°C, the temperature at which the residual taenite contains more than 23 wt% Ni. In some cases the lamellar plessite is intermixed with Haxonite indicating the presence of Carbon. The effect of carbon as a nucleation site, taenite stabilizer and/or reaction product is unclear. Two types of mechanisms may control the process, a eutectoid reaction involving carbon or a grain boundary discontinuous reaction. For the latter mechanism a high angle interface is required at the transformation front of the lamellar region. This type of interface is not observed nor do we expect an interface to be present in a plessite field. Therefore the formation mechanism of the lamellar morphology in Group IA remains unknown.

The kamacite/taenite interface of the lamellae of the Dayton IIICD iron forms as in Group IA irons with a Kurdjumov-Sachs orientation relationship. This relationship is 6° from the Nishiyama-Wassermann orientation of the kamacite/taenite interface in the Widmanstatten pattern. The formation mechanism for the lamellar structure is different from that of the Widmanstatten pattern. A discontinuous reaction between 500° and 400° C controls the formation of the lamellar plessite. The Widmanstatten plates act as high angle nucleation sites for the reaction. In addition, the lamellar

plessite forms in P depleted regions surrounding large phosphide precipitates which have grown at higher temperatures. These low P regions, which also contain carbon in solution, stabilize the high temperature taenite phase thereby inhibiting the nucleation of the more common Widmanstatten pattern. The much larger lamella size in the Dayton meteorite indicates a higher transformation temperature than for the IA irons.

References

[1] Narayan, C. and Goldstein, J.I. (1985) Geochim Cosmochim. Acta, 49, 397. [2] Buchwald, V. F. (1975) Handbook of Iron Meteorites, Univ. of California Press. [3] Clarke, R. S., Jr. and Scott, E. R. D. (1980) Am. Min. 65, 624.

Fig.1. SEM image of a lamellar plessite field in the Canyon Diablo meteorite.

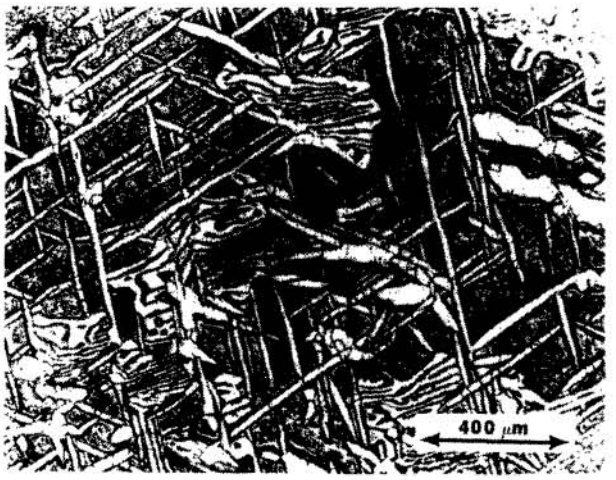

Fig. 2. Light micrograph exhibiting the Widmanstatten and Lamellar morphology.

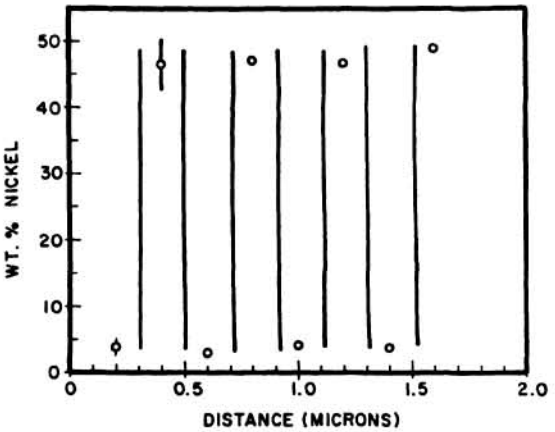

Fig. 3. AEM Ni concentration gradient across three lamellae in Odessa.

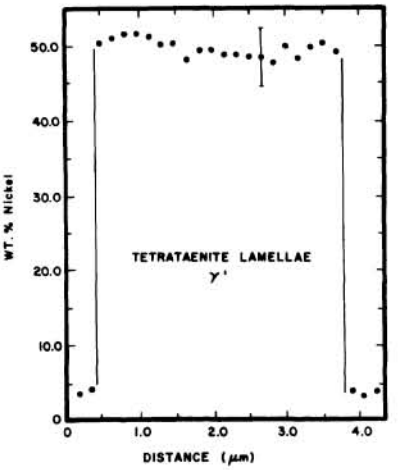

Fig. 4. AEM Ni concentration profile across a lamella in Dayton.