MARTENSITE MORPHOLOGY IN DIFFERENT TYPES OF METEORITES

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Introduction: Martensite is a feature of polymorphous metals. It is formed by a diffusionless shear mechanism. There are four morphological types of martensitic structure: lath (packet); butterfly; lenticular and thin plate martensite[1]. Many materials other than steel are now known to exhibit the same type of solid-state phase transformation, known as martensitic transformation, frequently also called a shear or displacive transformation. It is observed in Fe-Ni artificial and meteorite alloys. In the iron and stone meteorites martensite is formed from taenite: γ (fcc) $\rightarrow$ α_2(bcc)+γ(fcc) $\rightarrow$ α(bcc)+γ(fcc) at different temperature and Ni concentration in accordance with Fe-Ni phase diagram [2].

Experimental: In the present work martensite morphology in the fragments of several meteorites were studied: Chelyabinsk LL5 chondrite (light lithology [3]); Seymchan pallasite PMG, Odessa Iron IAB-MG and of 5 Ataxites: Hoba, Iquique, Cape of Good Hope, Gebel Kamil, Chinga. The meteorite fragments were prepared for optical and scanning electron microscopy studies by standard metallographic procedures: grinding, polishing and etching with 2% Nital. The meteoritic metal microstructure was examined using Zeiss Axiovert 40 MAT inverted microscope and FE-SEM ∑IGMA VP electron microscope with EBSD and EDS units.

Results and Discussion: Chelyabinsk chondrite fragment demonstrates large metallic particle 350 μm wide and 1000 μm long within light lithology. Kamacite and troilite are associated with this taenite particle. The taenite particle has zoned structure. Previously haxonite was observed within this particle [4]. The surprising feature was the presence of lenticular martensite within taenite. The plates width and length are varied from 4 to 12,5 μm and from 16 to 200 μm respectively. The crystals form acute-angled connections. This martensite type is a characteristic of high-carbon and high-alloy steels and alloys and it may be formed at temperatures below 300 °C [1]. In meteorites this morphology of martensite indicates the presence of carbon.

Typical martensitic transformation signatures for irons were observed in Seymchan and Odessa meteorites. Zoned taenite part (400 μm size wide and 1500 μm long) within the kamacite phase were studied. The plessite (α+γ) present within zoned taenite. The plessitic structure is something similar to packet/lath martensite in steels. Usually, it is observed in low-carbon low-alloy steels and Fe-Ni alloys with Ni content less than 28% [1]. The authors [5] name this martensite martensitic plessite and assume that it is formed from taenite during cooling from 350 to 30 °C.

The most pronounced signatures of martensitic transformation are observed in the ataxites with 15-25 wt.% Ni. The formation of highly dispersed needle-shaped structure (black plessite [6]) is a result of $\gamma \rightarrow \alpha_2$+$\gamma$ decomposition with the formation of lath-morphology. EBSD method applied to individual fragments of Hoba, Iquique, Cape of Good Hope, Gebel Kamil and Chinga IVB ataxites demonstrated that plessite consists of a submicron irregular mixture of bcc (80-90 %) and fcc (20-10 %) phases. Each ataxite demonstrates a set of three main bcc orientations which retained in the neighboring Schlieren bands while the dominant bcc orientation in these bands was different. The orientation of fcc phase in all ataxites is the same in both Schieren bands and near the kamacite spindles. Therefore, the origin of the Schlieren bands in the ataxites is stated to be the shift of bcc crystal grains during martensitic transformation with formation of lath martensite. When inreached by P, Cr and S near the inclusions of daubréelite, chromite and troilite the plessite structure becomes more coarse, subgrains of bcc-phase become larger and its directions are visualized clearly forming squares or triangulars in the section. Pole figures in this areas are very close to the theoretical models showing dominant crystal orientations same as in the plessite away from the inclusions.

In this study, two different types of martensite were observed: lenticular (Chelyabinsk LL5, Odessa IAB) and packet/lath (IVB and ungrouped ataxites, Seymchan PMG). These structures are formed at different temperatures and nickel content. Further study of the martensite morphological features in meteorites will define the temperature and shock conditions of its formation.

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