Microstructure investigations of iron meteorites by EBSD and EDS analyses

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Meteorites are a unique and inspiring material for microstructural studies because if their very specific genesis. Iron meteorites have been formed under unimaginable cooling rates of a few ten Kelvins per million years so that the observable transformation of the formerly huge Fe-Ni single crystals of taenite occurred under nearly-equilibrium conditions. Octahedrites (meteorites having a Ni content between 6...15%) are characterized by ribbons of the low-temperature Fe-Ni phase kamacite separated by rims of residual taenite. This very specific feature is known as Widmanstaetten structure and has been investigated by synchrotron radiation in order to cover a higher volume fraction for a statistically relevant description of orientation relationships [1]. However, plessite – a microstructure mainly consisting of the same phases – reflects the orientation relationship between kamacite and taenite as well [2]. For their characterization, a scanning electron microscope is very suitable in order to investigate crystal orientations or identify phases. Despite the apparently ideal formation circumstances of iron meteorites, Ni concentration profiles prove non-equilibrium conditions [3]. Combined EDS (energy dispersive spectroscopy) and EBSD (electron backscatter diffraction) measurements at a selected plessitic region of the Cape York iron shows that a correlation exists between Ni-concentration and the locally detected orientation relationship.

At higher Ni-contents (>18%), the typical Widmanstaetten structure is no longer developed. The structural classification refers to these meteorites as ataxites. If the Ni concentration of an ataxite is comparatively poor, a duplex microstructure of small kamacite grains separated by taenite lamellae is formed, see Fig. 1 (right part in the left image). However, one of the highest Ni-containing ataxite – the Dermbach, with more than 42% Ni – consists of coarse-grained taenite crystals, cf. Fig.1 (right image, left part), covering sulfide and phosphide precipitates. Despite the high Ni-content, both meteorites show strong corrosion, which has taken as occasion for further investigations since this is a general problem of meteorite conservation.

It is well-known that high orientation variations around brittle phases like schreibersite or rhabdite - $(Fe,Ni)_3P$ - are the result of high-speed collisions occurring in the asteroid belt. Nearly all meteorites show shattered crystals of brittle phases. Both, the Dermbach but also the Dronino iron contain besides voids in between the shattered phases also local networks of microcracks (veins) within the metallic matrix. In both meteorites, troilite (FeS) filled voids and veins although it is often partly or completely substituted by nano-crystalline weathering products like akaganeite (β-FeOOH) [4]. Thus, the microcracks seem to be one reason for the occasionally observed dramatic corrosion of meteoritic iron, because they offer free surfaces also within the metallic body. Moreover, they seem to be interconnected between the shattered precipitates so that an inner corrosion is explainable.

At the beginning, the Cl-bearing lawrencite ($FeCl_2$) was assumed to be an original cosmic mineral and the origin of the observed corrosion, but it could be shown by light microscopy that the real mineral seems to be hibbingite β-$Fe_2(OH)_3Cl$ [4] and the corrosion is terrestrially based. Unfortunately, for identification by conventional X-ray diffractometry in those days the phase fraction was too small. The reason is that Cl ions are continuously attacking the metal and form hibbingite in a very thin layer only. With an increasing stream of O_2 or H_2O, it immediately transforms into partially X-ray amorphous oxides and/or hydroxides. Applying the electron backscattered coefficient η for the imaging (Z-contrast), hibbingite reflects the weakest signal of all phases so that it appears in Fig.1 as black areas. In many cases the corrosion is still ongoing and hibbingite as crystalline phase can be clearly confirmed by EBSD and EDS. The intensity simulation using dynamical theory

[5] and experimental EBSD pattern in Fig.2 shows a very good agreement. Especially, the very thin line in the nearly horizontal band close to the lower edge of the EBSD pattern is extremely characteristic and a rare phenomenon in EBSD pattern formation.
Further investigations shall show whether and how the observed substitution of schreibersite by troilite can be interpreted. In Dermbach many of the schreibersites are partly or fully resorbed by troilite. A few selected examples will be presented.

References

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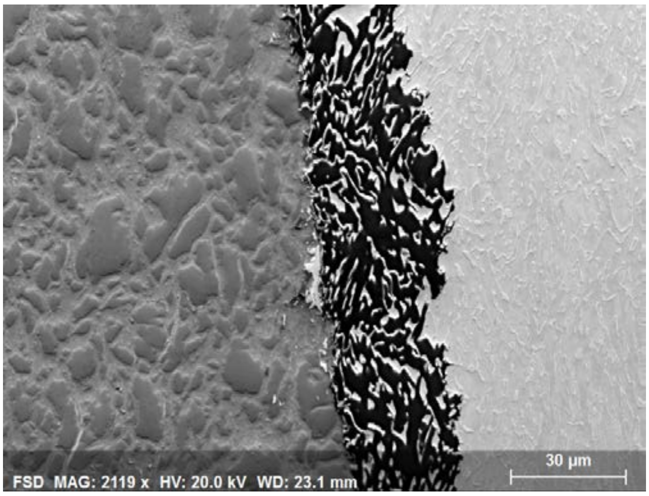
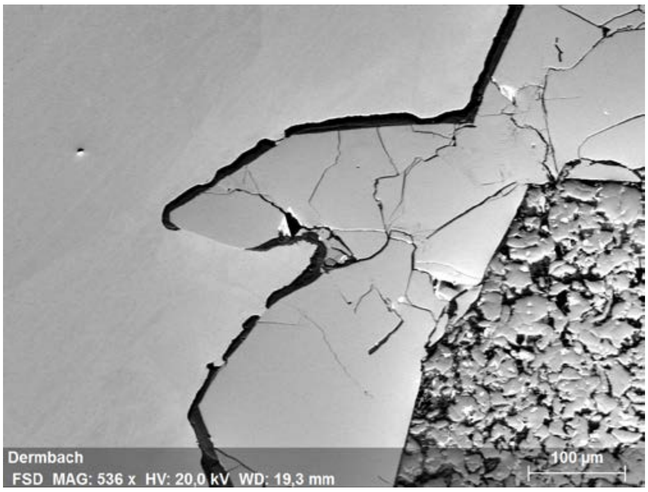
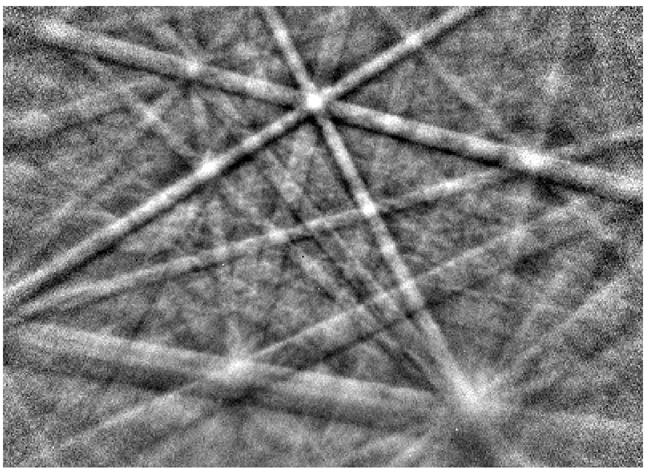




Dronino Dermbach

Figure 1. *BSE images (Z-contrast) of the microstructure of two ataxites. Both meteorites depict an ongoing weathering containing troilite (Dronino, left; Dermbach right). The black-colored phase is hibbingite. The shattered Phase in Dermbach is Schreibersite. (scale bar: left -30µm, right- 100µm)*



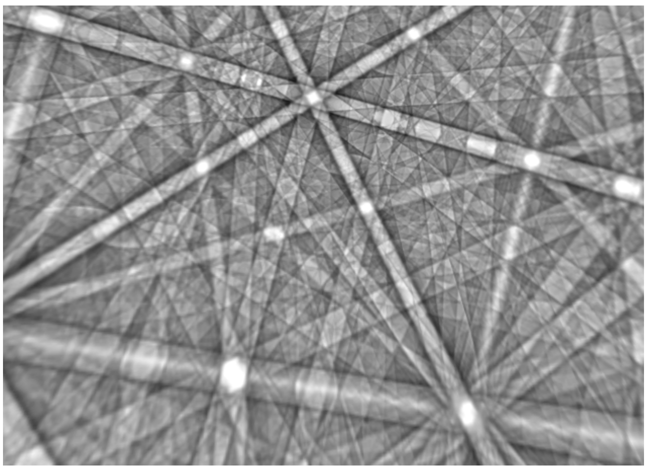


Figure 2. *Experimental (left) and simulated (right) EBSD pattern of hibbingite.*