METALLOGRAPHIC COOLING RATES ESTIMATION IN DIFFERENT LITHOLOGIES OF THE CHELYABINSK LL5 METEORITE

E. V. Brusnitsyna, R. F. Muftakhetdinova and V. I. Grokhovsky, Institute of Physics and Technology, Ural Federal University, Ekaterinburg, 620002, Russian Federation, e-mail: jeka_bru@list.ru.

Introduction: The Chelyabinsk LL5 S4 W0 meteorite has different lithologies [1, 2]. It is supposed that the macrostructure of the meteoroids body was formed by the formation mechanism of suevite structure. In the present work, we determined metallographic cooling rates of the Chelyabinsk chondrite in the various lithology.

Experimental: We studied both small fragments with monolithology and large pieces with a suevite structure. The meteorite fragments with dark and light lithology were prepared for optical and scanning electron microscopy studies using the standard metallographic procedure. Sample were etched with 2% Nital. Then, the microstructure of the meteoritic metal was examined with the Zeiss Axiovert 40 MAT inverted microscope and FE-SEM ∑IGMA VP electron microscope with the EDS.

Results and Discussion: In the areas of light lithology the metal particles have a structure of zoned taenite. This zone is formed during very slow cooling of the meteoroid body (about several °C/Myr.). In these zones we observed both tetrataenite and zoned taenite [3]. The cloudy zone consists of two phases ($\alpha_2 + \gamma$') of concentration 40–42 wt.% Ni. This area is formed as result by spinodal decomposition at low temperatures (below 400 °C) [4]. Tetrataenite in the cloudy zone has a spherical shape and a lighter appearance on the BSD images. It's size depends on cooling rate. In the high-nickel part of the cloudy zone the average size of spherical phase is 146 nm. Using dependence for ordinary chondrites [3] the cooling rate of light lithology fragments of the meteorite Chelyabinsk is about 6°C/Myr. This value is in the range of other LL5 chondrites.

The gray zone contains a significant amount of vugs and pores. They were formed as a result of shrinkage phenomena during crystallization of the melt. Previously, we found dendritic crystal within vugs consisting mainly of taenite γ-Fe(Ni, Co) [5].

It was shown in experimental studies [6-8] that the distance between the secondary arms of dendritic crystals is inversely proportional to the cooling rate (V) in the crystallization range. The following relationship between V (°C/sec) and the distance d (μm) is proposed in [9]: $V= 5.3 \times 10^5 d^{-2.9}$.

There is other relationship in a wide range of cooling rate for Fe-Ni and Fe-P alloys. The plot is linear in the double logarithmic coordinates [8]: $L=60\cdot V^{-0.32}$, where L (μm) is the distance between the secondary dendrite arms or the cell size, V (°C/sec) is the cooling rate in the crystallization range.

We used both formulas to estimate cooling rate. The cooling rate estimation based on the dendritic structure of dark lithology grey zone in the Chelyabinsk LL5 chondrite was performed by using two different formulas. The mean distance between dendrite secondary arms is 28 μm. Consequently, the cooling rate is 33 °C/sec and 10 °C/sec by using formulas [9] and [8], respectively. The calculated rates are within one order. Perhaps, different Ni content range discussed in [7] and [8] is a reason of difference. The obtained results of cooling rates are consistent with the previously known data for other meteorites.

In this work we obtained two metallographic cooling rates in different zones of the meteorite Chelyabinsk: the first one by slow cooling during creation parent body and the second one as a result melting crystallization after shock event.

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