
In the present work we have studied M-chondrules and spherules of the Fe,Ni-phase in Kainsaz CO chondrite and compared their structures and compositions with those for other chondrites. The following main types of metallic chondrules have been identified.

Type I. M-chondrules consisting of polycrystalline kamacite, taenite and troilite. Chondrule a, oval in shape (Fig.1a) and ~140μm in size, occurs in an isolated inclusion of the forsterite composition. High-Ni taenite in the form of separate inclusions: one in a troilite grain, another at the contact between metal and silicate. Sulphide associating with taenite is monocrystalline. Very fine chromite grains have been identified in the metal.

Type II. M-chondrules consisting of polycrystalline taenite and troilite with a small amount of kamacite. Chondrule b, ~200μm in size (Fig.1b), consists of a metallic core and two shells: a sulfide one ~40μm wide and an discontinuous metallic one. The chondrule occurs in a dark silicate matrix and has even edges. The chondrule core consists of high-Ni taenite of a slightly varying composition with a low Cr content. The sulfide shell consists of polycrystalline troilite and, possibly, mackinawite/deficit of S (33.1 mass %) and an increased Ni content (2.9 mass %). Kamacite principally occurs on the periphery of the chondrule in the form of a small sharp inclusion in taenite. The chondrule is rich in chromite inclusions forming a thin discontinuous rim around the chondrule and separate larger grains occurring in taenite. Chromites consist of FeO and Cr2O3 practically without admixture of other elements. The larger part of the chondrule surface has a fine sulfide shell. Inside the chondrule there occur silicate inclusions with fairly high contents of CaO and P2O5 (3 mass %). Some inclusions correspond to whitlockite (CaO/P2O5 ≈ 1), but have a high FeO content.

Type III. M-chondrules consisting of polycrystalline kamacite and troilite are most widespread. Chondrule c (Fig.1c) ~200μm in size, occurs in a dark silicate matrix and has clear boundaries. Over the boundaries of kamacite and troilite grains there occurs a phosphorus-containing phase of a variable composition enriched in FeO. In all cases an increase in the SiO2 and FeO contents is accompanied by a decrease of CaO and P2O5. The ratio CaO/P2O5 corresponds to whitlockite. Inclusions of fayalite and a phosphorus-containing phase were identified in kamacite. Discovered in this chondrule were kamacite grains with a very low content of Ni (~2.2 mass %) or Cr (~0.02 mass %). Other grains, on the contrary, are rich in Cr (up to 1.2 mass %).

Type IV. A unique concentrically-zonal chondrule-like metallic particle (Fig.1d). It consists of a metallic core...
of a subhedral shape (cube faces are visible) of the taenite composition (Ni - 54.2 mass %), two sulfide shells and a metallic rim of the kamacite composition with a very low Co content (Ni - 4.7, Co - 0.04 mass %). High-Ni taenite is in association with troilite. The surface zone of the particle contains fine chromite crystals.

Comparison of the structures and compositions of the investigated M-chondrules and spherules of the Fe,Ni-phase in Kainsaz C0 with similar literature data /1-3, etc./ for other chondrites has enabled us to identify the relics of the following main processes: (1) equilibrium condensation of metal under different P, T conditions; (2) fractionation of refractory and middle volatile elements; (3) evaporation and re-condensation of primary Fe,Ni particles; (4) partial oxidation and sulfurization of Fe,Ni,Ca,Cr,P condensates under different fO2 and O/S ratios; (5) partial decomposition of the products of these reactions down to metal; (6) reduction of dust-like Fe,Ni-particles in situ in olivine grains; (7) thermal metamorphism due to interaction with the gas phase and diffusion in a solid state under slow cooling at the rate of 1⁰C/10⁶ years within t ≤ 500⁰C range; (8) metasomatosis processes. The structure and morphology of M-chondrules point to eutectic metal-sulfide fusion and to their genesis in a single chondrule-forming process.


Fig. 1. Types of metallic chondrules in Kainsaz C0 chondrite: a - chondrule of type I; b - chondrule of type II; c - chondrule of type III; d - particle of type IV.