APPLICATION OF MÖSSBAUER SPECTROSCOPY IN THE STUDY OF METEORITES.

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Introduction: Mössbauer spectroscopy is a powerful physical technique which provides the unique information about the ^{57}Fe state and hyperfine splitting of the ground and excited nuclear states due to extremely low energy resolution (about 10^{-9} eV). Mössbauer parameters such as isomer shift, δ, quadrupole splitting, ΔE_Q, magnetic hyperfine field, H_{eff} (B_{eff}), line width (full width at a half maximum), Γ, relative area of spectral component, A, provide an important knowledge about the iron valence/spin state, the iron electronic and magnetic structure, local iron microenvironment and effect of its variations, the ^{57}Fe dynamic properties, composition and qualitative variations of iron-containing phases, etc. Various iron, stony-iron and stony meteorites consist of iron-bearing phases such as Fe-Ni-Co alloy, olivine $(Fe, Mg)_2SiO_4$, orthopyroxene $(Fe, Mg)SiO_3$, clinopyroxene $(Fe, Mg, Ca)SiO_3$, troilite FeS, chromite $FeCr_2O_4$, hercynite $FeAl_2O_4$, daubréelite $FeCr_2S_4$, ilmenite $FeTiO_3$, schreibersite $(Fe, Ni)_3P$, etc. Therefore, ^{57}Fe Mössbauer spectroscopy appeared to be a useful probe to study various meteorites over than fifty five years. The first review in this field was published in 1964 [1] while the latest ones appeared in 2013–2015 [2, 3]. In the present review we consider briefly the results obtained using Mössbauer spectroscopy in the numerous studies of iron, stony-iron and stony meteorites during the last decade mainly.

Iron Meteorites: Fe-Ni-Co alloy in iron meteorites consists of different contents of b.c.c. α-Fe(Ni, Co) and α_2-Fe(Ni, Co) phases and f.c.c. γ-Fe(Ni, Co) and γ-FeNi phases with possible variations of Ni and Co concentrations within the phase. Metallic matrix may contain some inclusions (i.e., schreibersite, troilite, daubréelite). Using the ranges of H_{eff} it is possible to distinguish different Fe(Ni, Co) phases and evaluate phase composition. For example, α-Fe(Ni, Co) phase with some Ni variations was found in Sikhote-Alin IIAB and Anyujskij IIAB while α-Fe(Ni, Co), α_2-Fe(Ni, Co) and γ-Fe(Ni, Co) phases with some Ni variations were revealed from the Mössbauer spectra of Sterlitamak IIIAB, Aliskerovo IIIE-an, Chinga IVB and Dronino iron-ung.

Stony-Iron Meteorites: Pallasites which are stony-iron meteorites consists of Fe-Ni-Co alloy matrix with the phase composition similar to that in iron meteorites and stony part contained silicate minerals, troilite, chromite, etc. Mössbauer spectroscopy demonstrated some differences in the ^{57}Fe microenvironments in olivines extracted from two main group pallasites Omolon and Seymchan and showed olivine variations in two different Seymchan PMG fragments. The Fe^{2+} occupations of the M1 and M2 sites in olivines and the temperatures of equilibrium cation distribution were evaluated and showed some differences for olivines from different Seymchan fragments. Mössbauer spectroscopy of Fe-Ni-Co alloy matrix extracted from Seymchan PMG demonstrated the presence of α-Fe(Ni, Co), α_2-Fe(Ni, Co) and γ-Fe(Ni, Co) phases with possible variations in Ni and Co in local iron microenvironment.

Stony Meteorites: The main part of meteorites Mössbauer studies is related to investigation of various ordinary chondrites. These results showed the possibility of technique to reveal iron-bearing phase composition and relative iron contant in these phases, variations of the ^{57}Fe hyperfine parameters for the same phases in different ordinary chondrites related to small variations in the local iron microenvironments. It was possible to reveal Mössbauer spectral components related to the ^{57}Fe in the M1 and M2 sites in olivine, orthopyroxene and clinopyroxene with further evaluation of Fe^{2+} partitioning between two sites and the temperatures of equilibrium cation distribution for olivines and orthopyroxenes. Approaches for H, L and LL ordinary chondrites classification using Mössbauer parameters have been also developed.

Fusion Crust and Weathering Products: Mössbauer spectroscopy appeared to be useful for study of iron-bearing phases in the meteorites fusion crust as well as in its weathering products. For example, Mössbauer study of the fusion crust from Chelyabinsk LL5 fragment demonstrated the presence of magnesioferrite $MgFe_2O_4$ instead of magnetite Fe_3O_4 as earlier considered iron oxide in the fusion crust. Some iron oxides were observed in the bulk ordinary chondrites while in case of Dronino iron-ung meteorite the investigation of surface weathering products demonstrated the presence of iron oxides and hydrous oxides and their transfer in soil with concretions formation.

Acknowledgements: This work was supported by the Ministry of Education and Science of the Russian Federation (the Project # 3.1959.2017/4.6) and Act 211 of the Government of the Russian Federation, contract № 02.A03.21.0006.

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