MICRO-RAMAN SPECTROSCOPY OF NWA 4560 CHONDRITE. M. Szurgot[1], K. Kisiel[2] and R. Kisiel[2], [1]Lodz University of Technology, Center of Mathematics and Physics, Al. Politechniki 11, 90 924 Lodz, Poland, (mszurgot@p.lodz.pl), [2]Lodz University of Technology, Department of Molecular Physics, Żeromskiego 116, 90 924 Lodz, Poland.

Introduction: NWA 4560 meteorite is one of hot desert chondrites found in Morocco in 2006. It was established that the NWA 4560 belongs to LL3.2 chondrites [1]. Elemental composition, mineral composition and microstructure of NWA 4560 meteorite were recently studied by analytical electron microscopy [2]. The aim of this paper was to identify meteorite minerals, and to determine pyroxene and olivine composition by micro-Raman-spectroscopy.

Experimental: Raman spectra were recorded at room temperature in back scattering geometry using confocal Raman micro-spectrometer T-64000 (Jobin-Yvon) equipped with the BX-40 microscope (Olympus). To excite the sample minerals Ar laser was applied (514.5 nm Ar line, the beam diameter about 1 μm), and acquisition time and laser power were adjusted to obtain spectra of sufficient quality. To identify minerals the Raman spectra were compared with the literature data, and chemical composition of olivine, pyroxenes and the feldspar group were determined on the basis of literature data on Raman spectra features and calibration of spectral peak positions [3-7]. The accuracy in determining forsterite content in olivines, and enstatite content in pyroxenes from Raman peak positions is about 0.06.

Results and discussion: Figure 1 shows an optical image of NWA 4560. The image reveals major characteristics of the chondrite: the presence and domination of olivine, pyroxene and plagioclase crystals, and the texture typical of ordinary chondrite.

Fig. 1. Optical image of NWA 4560 meteorite. Chondrules and matrix are seen. Olivine crystals are yellowish and rusty, pyroxene crystals are greenish and blackish (augite), and plagioclase are white.

Figures 2, 3, and 4 present Raman spectra from various parts of NWA 4560 meteorite. Different minerals have been identified in the chondrite: olivine (Figs. 2,3,4), orthopyroxene (Figs. 2,3), clinopyroxene (Fig. 4), and HT plagioclase (Figs. 2,4).

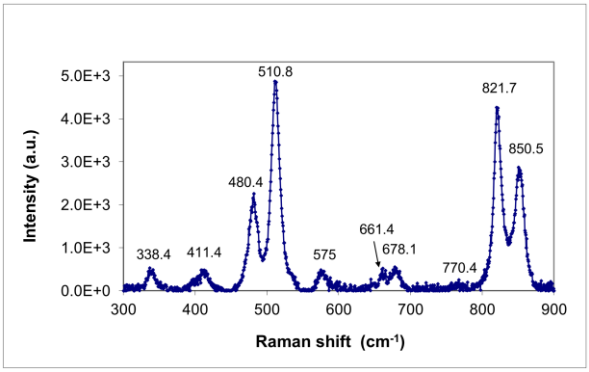

Fig. 2. Raman spectrum revealing coexisting minerals: olivine Fo84Fa16 (821.7, 850.5 cm^{-1} are DB1 and DB2 peaks), orthopyroxene En77Fs23 (338.4, 661.4, and 678.1 cm^{-1} peaks), HT plagioclase (andesine, 480.4 and 510.8 cm^{-1}).

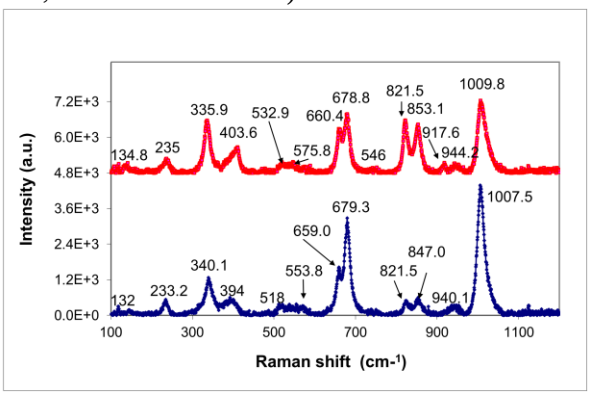

Fig. 3. Raman spectra revealing: i) orthopyroxene En75Fs25 (upper spectrum) and En80Fs20 (lower spectrum), ii) olivine Fo85Fa15 (upper spectrum) and Fo79Fa21 (lower spectrum).

Raman spectra features: multiplicity of peak groups, peak positions, and peak widths give the possibility to distinguish members within the feldspar group [5,6]. An analysis of the 180 cm^{-1} and 500 cm^{-1} Raman peaks positions indicates that NWA 4560 feldspar must be HT plagioclase (andesine An33, Figs. 2,4,5).

Figure 6 shows that the range of Mg/(Mg+Fe+Ca) values (values of enstatite En content) in NWA 4560 pyroxenes is between 0.43 and 0.80. The Raman data indicate that two clinopyroxenes are present in NWA

4560: pigeonite (En53Fs32Wo15, Fig. 4) and augite (En43Fs22Wo35), and orthopyroxene is represented by bronzite (En75-80Fs20-25, Figs. 2,3).

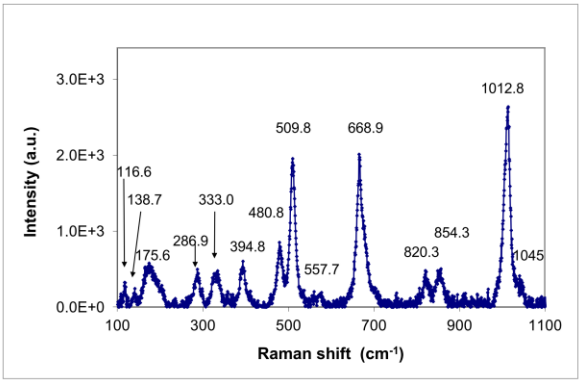

Fig. 4. Raman spectrum revealing: i) pigeonite En53Fs32Wo15 (peaks at 333, 668.9, 1012.8 cm^{-1}), ii) HT plagioclase (andesine Ab66An33Or1, peaks at 175.6, 286.9, 480.8 and 509.8 cm^{-1}), iii) olivine Fo79Fa21 (peaks at 820.3, 854.3 cm^{-1}).

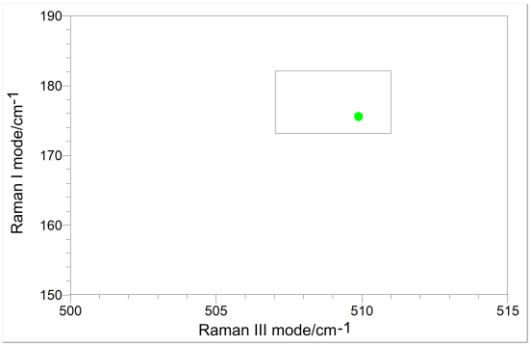

Fig. 5. Correlation of Raman I mode to Raman III mode for NWA 4560 feldspar. It is seen that the two characteristic Raman peaks indicate HT plagioclase region. The rectangle shows the high temperature plagioclase range established for feldspars by Freeman and coworkers [5,6].

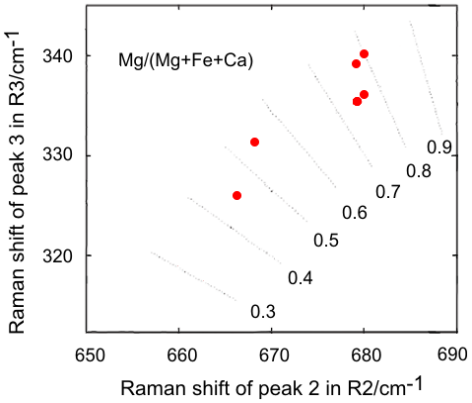

Fig. 6. Position of Raman peak 3 relative to position of peak 2 for NWA 4560 pyroxenes. Dashed lines mark values of Mg/(Mg+Fe+Ca) molar ratio (=En content) established by Wang et al. for pyroxenes [4].

Figure 7 presents distribution of Fs content in pyroxenes and distribution of Fa content in olivines of NWA 4560 meteorite. Raman data indicate that pyroxenes reveal the range of composition En43-80Fs20-32Wo0-35, and mean composition is En68±16Fs24±4 Wo8±14, where En = Mg/(Mg+Fe+Ca) is enstatite, Fs =Fe/(Mg+Fe+Ca) is ferrosilite and Wo = Ca/(Mg+Fe+Ca) is wollastonite content. Olivines exhibit composition range Fo77-99Fa1-23, and the mean compostion Fo86±6Fa14±6. It can seen that Fs content is in the range of LL chondrites, and Fa content is lower than that established for this group.

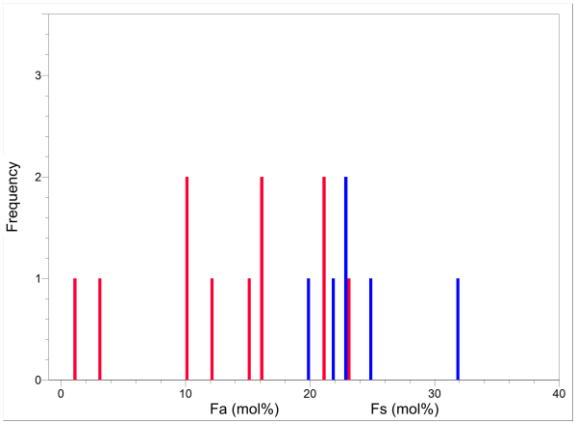

Fig. 7. Distribution of Fs content in pyroxenes (navy blue) and of Fa content in olivines (red) of NWA 4560 meteorite.

Data on FWHM's values for Raman peaks (OL: 7-20 cm^{-1}, Opx: 12-17 cm^{-1}, Cpx: 15-22 cm^{-1}, HT Plagioclase: 12-42 cm^{-1}) indicate relatively high structural order in chondrite minerals.

Conclusion: The main chondrite minerals have been identified in the NWA 4560 meteorite by micro-Raman spectroscopy. Most of them are the same minerals which were identified by analytical electron microscopy. Ferrosilite content in pyroxenes is in the range of LL chondrites, and Fa content in olivines is lower than that established by analytical electron microscopy. Feldspar is represented by HT plagioclase.

References: [1] Weisberg M.K. et al. (2010) *Meteoritics & Planet. Sci., 45(3),* 449-493. [2] Szurgot M. and Polański K. (2013) *Acta Soc. Metheor. Polon., 4,* 90-107. [3] Huang E. et al. (2000) *Amer. Mineral. 85*, 473-479. [4] Wang A. et al. (2001) *Amer. Mineral. 86*, 790-806. [5] Freeman et al. (2003) *LPS XXXIV*, Abstract #1676. [6] Freeman J.J. et al. (2008) *Can. Mineral. 46*, 1477-1500. [7] Kuebler K.E. et al. (2006) *Geochim. Cosmochim. Acta, 70,* 6201-6222.