

LASER MICRO-RAMAN SPECTROSCOPIC STUDIES OF HIGH-PRESSURE AND HIGH TEMPERATURE MINERALOGY OF KAMARGAON (L6) CHONDRITE. Bhaskar J. Saikia¹, G. Parthasarathy² and R.R. Borah³, ¹Anandaram Dhekial Phookan College, Nagaon, India, ²School of Natural and Engineering Science (IISc Campus), Bengaluru, India, ³Nowgong College, Nagaon, India.

Introduction: Shock metamorphism in meteorites provides essential information of impacts which can be used to determine the impact histories of meteorite parent bodies. The high-pressure polymorphs of silica are becoming a new clue for clarifying a dynamic event occurred in the solar system. The existences of high-pressure polymorphs of silica (seifertite, coesite and stishovite) allow us to infer that intense planetary collisions (like LHB scenario) occurred on the moon until at least about 2.7 Ga ago [1]. The high-pressure polymorphs of rock-forming minerals in shocked meteorites are of imposing interest because they provide minerals that is assumed to occur in the in the deep Earth. The pioneer of high-pressure mineral in meteorites was olivine polymorph with an inverse-spinel structure (or ringwoodite) in Tenham L6 chondrite [2]. It is found as a rare mineral in shocked meteorites and in impact craters by transformation from olivine, and is considered to be the major constituent of the lower part of the mantle transition zone [2-4]. The presence of high-pressure mineral in LL and H chondrites are quite few. The study of NWA 757(LL6), Chelyabinsk (LL5) and Yamato (75110 and 75267) (H6) chondrite are the only reports of high-pressure mineral in LL and H chondrite.

The crystalline state of silica permits assessing the intensity of the shock. Among the conventional techniques, X-ray diffraction and Raman spectroscopy are more convenient technique to for determining the shock phases. Mason et al. first introduced the study of meteoritic high-pressure minerals using conventional powder X-ray diffraction [5]. Laser micro-Raman spectroscopy is also very commonly utilized to determine the high-pressure mineralogy of shocked meteorites. This technique allows precise identification of high-pressure mineral in shocked meteorites. We confine our interest in this article to characterize the high-pressure minerals present in the Kamargaon L6 chondrite using Raman spectroscopy.

Experimental: The Raman spectra were obtained for minerals and the high-pressure polymorphs using a Jobin-Yvon Horiba LabRam-HR Raman microspectrometer equipped with an Olympus

microscope with 50X objectives and a motorized x-y stage and using 1800 grooves /mm grating and the spectral resolution is around 0.1 cm^{-1} in the range from 100 to 3000 cm^{-1} . Ar ion excitation laser beam of 488 nm is used to focus a $2 \mu\text{m}$ spot and to collect the Raman signal in the backscattered direction. Accumulations lasted from 60 to 180 sec. The laser power was restricted from 10 to 40 mW to avoid deterioration of the sample. Collected spectra of sample were compared against spectra from standard materials, primarily from the RRUFF database. X-ray diffraction pattern was produced using an automated powder diffractometer (40 mA, 40 kV) and monochromated $\text{CuK}\alpha$ -radiation ($\lambda_{\text{K}\alpha 1} = 1.5406 \text{ \AA}$, $\lambda_{\text{K}\alpha 2} = 1.54439 \text{ \AA}$). The data were collected in step scans at room temperature in the 2θ -range between 15° to 70° , the step width and counting time being 0.02° and 5 sec, respectively, divergence slit = 0.5 mm, and receiving slit = 0.3 mm.

Result and Discussion: Comparative Raman spectral pattern of end-member chromite with RRUFF R060796 exhibits of a major broad peak near 685 cm^{-1} and a shoulder near 650 cm^{-1} (Figure 1). The strongest peak at 685 cm^{-1} is assigned to the A_{1g} mode and this feature presumably is generated by the bonds in $(\text{Cr}^{3+}, \text{Fe}^{3+}, \text{Al}^{3+})\text{O}_6$ octahedra. The trivalent ions lead to a more compact structure and a higher degree of covalency than those in Fe^{2+}O_4 tetrahedra. Minor peaks in the range $400\text{--}600 \text{ cm}^{-1}$ also assist in identification [49]. The strong fluorescence at $\sim 500\text{--}600 \text{ cm}^{-1}$ could hide the intense feldspars Raman bands at around 500 cm^{-1} .

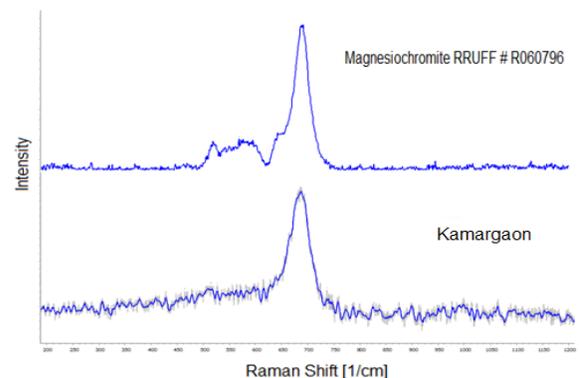


Fig.1. Raman spectrum of chromite of Kamargaon ordinary chondrite compared with RRUFF data taken as a reference.

In typical Raman spectrum (RUFF database), coesite reveal the intense band at $\sim 521 \text{ cm}^{-1}$ with weak to medium intensity peaks at $\sim 206, 270, 327, 356, 427$ and 468 cm^{-1} ; stishovite exhibits characteristic bands at $231, 588, 655, 752,$ and 960 cm^{-1} ; (Figure 2) and the shock-induced silica glass exhibits broad bands at $\sim 500, 800,$ and 1000 cm^{-1} . The observed peaks at $234, 756$ and 948 cm^{-1} in Kamargaon sample (Figure 2) are agree with the literature values of crystalline stishovite. The peaks at $234, 756,$ and 948 cm^{-1} are assigned to the $B_{1g}, A_{1g},$ and B_{2g} fundamental vibrational modes respectively. The peaks at $480\text{-}580 \text{ cm}^{-1}$ is characteristic for high-pressure plagioclase glasses (diaplectic glass) or maskelynite, which indicates a disordered structure of stishovite or amorphized stishovite in Kamargaon. This region is characterized by the vibration of rings of tetrahedral in glass. The relative intensity of maskelynite glass peaks at 580 cm^{-1} to peak at 508 cm^{-1} is low, indicating a high equilibrium shock pressure. These Raman peak positions of the high-pressure glasses can be use as an indicator for identify cooling-decompression history. These are also inferred to be quenched from feldspar melt.

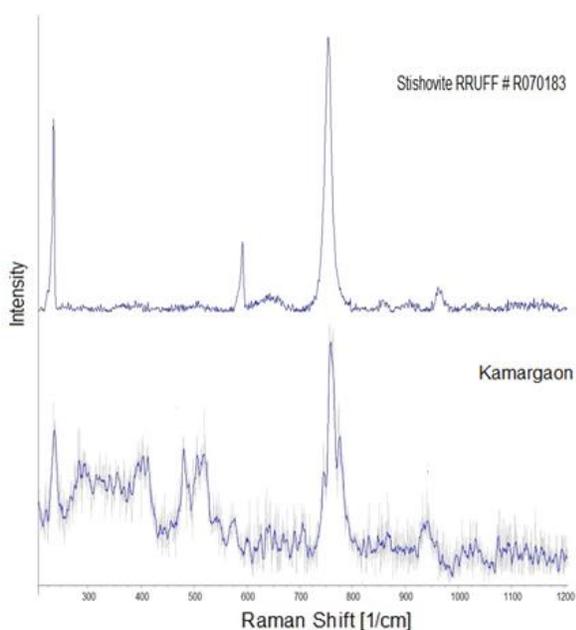


Fig. 2. Raman spectrum of stishovite of Kamargaon Kamargaon ordinary chondrite compared with RRUFF data taken as a reference.

The X-ray diffraction peaks are dominantly of olivine and appear more intense. It is because the olivines have become more singular in composition

upon recrystallization. Chromite peak position is similar to magnetite and would be masked by olivine. Some mineral phases such as: kamacite, taenite, troilite and chromite have been identified by X-ray diffraction technique.

Most of the plagioclase has been converted to the optically glassy or X-ray amorphous isotropic phases indicating the presence of high-pressure residual stress and irreversible transformation of plagioclase to amorphous as a result of shock metamorphism. The pyroxene fragments are commonly preserved metastably at high pressure because of the slow rates of transformation and it exhibits the nature of pressure. The doublet of olivine at $\sim 824 \text{ cm}^{-1}$ and $\sim 856 \text{ cm}^{-1}$ occur in all of the shocked meteorites, which suggest that some olivine has continue to exist after passage of the shock. The spectra of the studied sample also indicates the characteristic doublet at 821 cm^{-1} and 851 cm^{-1} which is a result of the coupling between the symmetric (ν_1) and anti symmetric (ν_3) stretching modes of Si-O_{nb} bonds in SiO_4 tetrahedra of olivine. The FWHM value of the ν_1 olivine band in the Raman spectra of L6 ordinary chondrites have been related to the degree of crystalstructural disorder resulting from shock deformation. The FWHM value $\sim 17 \text{ cm}^{-1}$ of this doublet is identical to that of the strongly shock stage [6]. Olivine-wadsleyite assemblages were found in several shocked chondrites and were produced in high-pressure synthetic samples. We have focused Raman spectroscopic data on the high-pressure polymorphs of silica in Kamargaon L6 chondrite. The results of Raman spectroscopy suggest the deformation microstructure system in highly deformed olivine grains, which is an evidence for high stage shock-metamorphism. Presence of high-pressure plagioclase glasses (diaplectic glass) or maskelynite indicates a disordered structure of stishovite or amorphized stishovite in Kamargaon. The presence of high-pressure polymorphs of silica should be addressed for the meaningful estimations of shock pressure conditions in Kamargaon L6 chondrite.

References: [1] Miyahara M.; Ohtani, E.; El Goresy, A.; Ozawa, S.; Gillet, P. (2016) *Phys. Earth Planet. Inter.* 259, 18–28. [2] Binns, R. A. (1967), *Nature*, 18, 1111-1112. [3] Ringwood, A.E. (1975) McGraw-Hill, London. [4] Rull, F.; Martinez-Frias, J.; Rodríguez-Losada, J.A. (2007), *J. Raman Spectros.* 38, 239–244. [5] Mason, B.; Nelen, J.; White, J. S. Jr. (1968) *Science*, 160, 66–67. [6] Saikia, B. J., Parthasarathy, G., Borah, R. R., Satyanarayanan, M., Borthakur, R., Chetia, P. (2017) *PINSA*, 83, 941-948.