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Raman spectroscopic signature of shock features in chondritic meteorites and its cosmogenic implications

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The shock features in meteorites are developed due to high impact collision of asteroids during the formation and evolution of the solar system. These features are important for constraining the shock P – T – t conditions [1]. The high pressure shock phases are developed due to hypervelocity impacts, formed by the process of solid state transformation, crystallization of shock melts and instantaneous shock deformation of the host rock and minerals. Six chondritic meteorites (i.e. Chainpur, Bori, Mirzapur, Ramnagar, Kuttippuram and Dhandepur) of varying chemical and petrologic types (LL3 – L5 – L6) with different shock grade (S5 – S6) [2] have been studied to characterise the relative amount of shock developed in these meteorites. These chondritic meteorites are essentially composed of olivine + orthopyroxene + Na-plagioclase ± clinopyroxene ± apatite ± merrillite + opaque minerals (including magnetite, chromite, troilite, Fe and Fe – Ni metal). Shock features include: fracturing of olivine and pyroxene phenocrysts (planar, irregular and radial fractures), undulose extinction of olivine, isotropic shock veins and melt pockets with development of anastomosing multiple opaque melt veins with relict and recrystallized olivine and pyroxene, and melting of plagioclase and pyroxene to glass due to high intensity impact induced shock deformation. Shock features in chondrites are also being constrained from the high pressure polymorphs of olivine and pyroxene.

Raman spectrum acquisition was undertaken using a Renishaw Invia Reflex Micro-Raman instrument with 514 nm edge Ar-laser and 785 nm edge laser, using ~ 1 µm beam diameter and focus energy ~ 15 – 18 mW to acquire the Raman signal. Raman spectrum measured from shocked olivine grains give the Raman fingerprint bands at 796, 797, 799 and 844, 845, 846 cm^{-1} respectively, corresponding to ringwoodite occurring as fine lamellae within the host olivine. Raman peak values for shocked olivine in different chondrites deviate from the standard Fermi double peak [3] of undeformed olivine (820 and 856 cm^{-1}) and ranges between 817 - 824 cm^{-1}, 843 - 844 cm^{-1} and 848 – 856 cm^{-1} respectively. The weak bands at 915, 916 and 917 cm^{-1} represent thin wadsleyite lamellae within host olivine. Olivine locally recrystallized and transformed to different high pressure polymorphs like wadsleyite and ringwoodite. The presence of ringwoodite in chondrites indicates escalation of impact pressure at about 18 - 20 GPa and temperatures range from 900 - 1100°C [4]. The highly deformed and disordered olivine structure had insufficient time to order due to post-collision rapid cooling [5]. Systematic variation in Raman peak positions with a shift towards lower values with decrease in $^{Ol}X_{Mg}$ for both major 820 and 856 cm^{-1} peaks and low intensity 915 cm^{-1} peak has been observed. Disordered olivine structure with doublet peak position shifts towards higher wavenumbers suggesting shock pressure at about 50 GPa [6]. Moreover, the presence of plagioclase melt glass occurring along the interstitial/intergranular spaces of olivine and pyroxene and within the matrix suggests shock pressures at above ~ 45 GPa [7]. The dark glassy phases within melt pockets have been identified as shocked mafic glass having pyroxene (orthopyroxene) composition associated with the barred olivine (BO) and such shock veins show characteristic Raman bands at 231, 337, 396, 660, 680 and 1008 cm^{-1} respectively. Despite these impacts/collisions lasting for a few second to milliseconds (ms) [1], the resultant shock features provide valuable information regarding meteorite evolution in the cosmochemical environment.

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