

Laser Raman characterization and 3D mapping of chromite crystal from Asurabandha mines of Bhuban ultramafic complex, Odisha (India)

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ABSTRACT

The Asurabandha chromite deposits are hosted in the Bhuban Ultramafic Complex (BUC), which is located in the Dhenkanal district of Odisha. The BUC forms part of the transition domain between the Singhbhum Craton and the Eastern Ghats Mobile Belt (EGMB). Highly altered chromitite rocks are found as isolated, irregular and sporadic orebodies located on the southern side of the Sukinda Ultramafic Complex (SUC) accompanied by the granite-charnockite association. Petrographic studies inferred the existence of heteradcumulate texture in the chromitite rock, which indicates early crystallization during the cooling of an ultramafic magma. Chromite begins to crystallize at a high temperature and accumulates to growth of crystal framework, subsequently crystallizing to form silicate minerals (olivine or pyroxene), that later altered to serpentine. Occurrences of euhedral chromite crystal indicates inherent crystal growth during the crystallization of magma. The Laser Raman Micro Spectroscopy (LRMS) analysis, displays four characteristics Raman Shift at 454, 559, 736 and 1437 cm^{-1} for chromite and five diagnostic Raman Shift at 127, 206, 397, 465 and 1166 cm^{-1} for serpentine. Laser Raman-SNOM scanning, 2D and 3D mapping of euhedral hexagonal chromite crystal, suggests its heterogenous internal crystal structure in the ultramafic rocks. In the chromite crystal, internal heterogeneity may appear because of trace element substitution during the magmatic crystallization or secondary alteration processes like serpentinization and carbonation. The Asurabandha chromite deposits are characterized by metasomatic alteration, serpentinization and carbonation, where original silicate minerals have been replaced by serpentine, presenting challenges for mineral exploration due to the extent beyond lateritic overburden.

Keywords: Laser Raman, Chromite, Serpentine, Ultramafic Rocks, Asurabandha, Bhuban Ultramafic Complex, Singhbhum craton.

INTRODUCTION

The Laser Raman Micro Spectroscopy (LRMS) is an in-situ scientific technique that uses inelastic scattering of light from a laser to provide a chemical 'fingerprint' of a sample's vibrational, rotational, and other low-frequency vibrational modes (Raman, 1922; Hope et al., 2001). By measuring the Raman Shift (the difference in frequency between the scattered and incident light), one can identify molecules, analyse their structure, and determine their composition in various forms, including solids, liquids, and gases (Raman, 1923). The technique requires a laser beam for excitation, a sample interface, and a spectrometer to disperse and detect the scattered light (Raman, 1942, 1947). The LRMS technique is applied to identify minerals by analysing light scattering, which creates a unique "spectral fingerprint" from a mineral's atomic vibrations (McMillan, 1989; Keresztury, 2006). This non-destructive method requires little to minimum sample preparation, complementing other techniques like Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) to provide detailed chemical and structural information. This Laser Raman technique is valuable for fieldwork and identifying difficult-to-discern minerals like light-coloured silicates. A mineral sample is exposed to a monochromatic light beam, usually a laser. The light interacts with the mineral's chemical bonds, causing some of the light to scatter inelastically (Raman, 1927, 1928; Raman and Krishnan, 1928). The scattered light has a unique energy shift or Raman Shift depending on the mineral's crystal structure, atomic masses, bond-lengths, and bond-angles (Raman, 1929, 1945). A spectrometer captures this scattered light and analyses the

energy shifts to produce a unique spectrum or Raman Shift or "fingerprint," for that mineral.

The LRMS's ability to provide rapid identification of mineral phases is beneficial for exploration, especially for minerals that are hard to identify optically using a polarising microscope (Rodgers, 1993; Bersani and Lottici, 2016). This method helps to differentiate between minerals with similar appearance but different chemical compositions, such as various silicate, sulphide and carbonate groups (Pandit, 2024). It is also useful for identifying opaque or weathered grains that are difficult to analyse with traditional optical microscopy (Singh and Pandit, 2025). This is a non-destructive technique and does not alter or destroy the sample. Minimal sample preparation is required for the LRMS studies, which means samples often require no specific preparation. It can be used on a wide variety of sample types and sizes, from small powders to large piece of samples. The LRMS is a valuable tool when simultaneously used with microscopy and X-ray diffraction to identify minerals.

The objective of this study is emphases on phase recognition in the mineralized ultramafic rocks by analysing a mineral's physical and optical properties, crystalline structure, size, shape, and textural position to identify their petrogenetic implications. The characterization of mineral phases in the ultramafic rock involving the LRMS technique with the help of 532 nm wavelength excitation. In general, the essential minerals found in ultramafic rocks are olivine and pyroxene, with smaller amounts of garnet and spinel. Chromite is an important economic mineral found predominantly in ultramafic rocks, which include peridotite, dunite, and serpentine.