

IRON OXIDATION STATES OF MATRIX IN CARBONACEOUS CHONDRITES ACFER 094 AND MIL 07687.

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Introduction: Primitive chondrites are among the most pristine material available to us and preserve in the matrix primordial dust from the protoplanetary disk [1]. Studying the matrix is important as it records solar nebula and parent body processes, which can be constrained by chemical composition and Fe-oxidation states [2]. Unaltered carbonaceous chondrite (CC) matrix is a mixture of fine-grained material, composed largely of amorphous silicate, sub-micron forsterite and enstatite grains and micrometre sized aggregates of such crystals [3]. Due to its minute size requires high resolution techniques. In this study we used STXM to investigate Fe-oxidation state in the matrix of ungrouped Acfer 094 and MIL 07687 which are characterized by a different styles of alteration. MIL 07687 exhibits localized aqueous alteration with poorly crystalline Fe-oxides occurring in the matrix and absence of phyllosilicates, whilst Acfer 094 shows the presence of Fe-oxides occurring prevalently in the pre-existing cracks.

Methods: Soft X-ray spectroscopy methods such as STXM and XPEEM have been shown to be appropriate for characterizing oxidation states in meteorites [4,5]. In this study STXM at beamline I08, Diamond Light Source, UK has been used to analyse ~70 nm thick FIB sections extracted from matrix areas in Acfer 094 and MIL 07687 that were previously characterised using an FEI Quanta SEM [6]. Spectra were extracted from selected areas of energy-dependent image stacks collected with a spatial resolution of ~50 nm, an energy resolution of 0.1 eV over the Fe L₃ (708 – 715 eV) and Fe L₂ (718 – 725 eV) edges and a dwell time per pixel of 5 ms. A method adapted from that of [7] using relative peak heights for the Fe²⁺ and Fe³⁺ components of both the L₃ and L₂ edges has been used to estimate the Fe³⁺/ΣFe ratio. A linear background was subtracted across the whole spectra and an arctangent function was subsequently fitted at the L₃ and L₂ edges. A preliminary calibration curve based upon mineral standards is being developed, and from this Fe³⁺/ΣFe estimates have been calculated from spectra extracted from specific grains/regions within the energy stacks ranging between 50 and 500 nm in size.

Results: MIL 07687 is characterized by Fe³⁺ throughout the foils investigated. This likely reflects parent body and/or terrestrial processes which have produced Fe³⁺ bearing minerals. One Fe-rich grain is clearly Fe²⁺ bearing. The oxidation state of the Fe in the matrix constituents of Acfer 094 matrix grains also exhibit mainly Fe³⁺ (consistent with previous works [8]), however some ROIs within separate foils display lower Fe³⁺/ΣFe ratios. The element map of these grains indicates that are Al-rich, with irregular shape. They appear to be condensates, and may have a genetic relationship to CAIs.

Discussion and Conclusions: There are two competing models for the the formation of amorphous material in Acfer 094: either it formed as a nebular oxidation product [8] or as the result of flash heating of hydrated silicates [9]. The oxidised form of iron may then be a feature of either the nebular environment or parent body processing. MIL 07687, which contains both aqueously altered and pristine regions, may hold a clue to help distinguish between these possibilities. This meteorite has similarly high Fe³⁺/ΣFe ratio in the matrix of both regions, with just one isolated Fe²⁺ grain identified. The similarity between both regions suggests that aqueous processing has not caused substantial changes to the oxidation state of the amorphous component. This in turn would suggest that the Fe³⁺ in both MIL 07687 and Acfer 094 is likely to be a primordial nebular signature. The effects of terrestrial weathering cannot be completely ruled out, but are unlikely to have a pervasive effect throughout both entire meteorites.

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