OVERLOOKED CHONDRULES: A HIGH RESOLUTION CATHODOLUMINESCENCE SURVEY. G. Libourel[1,3] and M. Portail[2], [1]Université Côte d'Azur, Observatoire de la Côte d'Azur, Lagrange, Nice, libou@oca.eu. Cedex 4, France, [2]Centre de Recherches sur l'Hétéro-Epitaxie et ses Applications, CRHEA-CNRS, Sophia Antipolis, [3]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu.

Chondrules, millimeter-sized igneous spherules making chondritic meteorites, formed during the Solar System's first few million years. They may provide powerful constraints on conditions in the solar protoplanetary disk only if the processes that led to their heating, melting and crystallization can be understood [1]. This problem remains unresolved yet, and the central question of whether the heating mechanism was an nebular or a planetary process is still debated. Tough heating by shock waves in the protoplanetary disk [2, 3] is currently one of the most favored mechanisms, chondrules generated by protoplanetary impacts is recently gaining interest [4].

Given the great diversity of chondrules, laboratory experiments are invaluable in i) yielding information on chondrule thermal history, and ii) judging a chondrule formation model viable or nonviable by their ability to meet these constraints. Experiments aimed at producing chondrule-like objects have moved from simply producing melt droplets, and then crystallizing them, to more complex scenarii by exploring melt-solid and melt-gas interaction [5, 6]. Owing to this approach, chondrule texture and chemistry, volatile element behavior (e.g., alkalis), oxygen isotope variations as well as chemical zoning profiles of olivine single crystals have provided some of the most crucial constraints on the thermal histories of chondrules, i.e., peak temperature, cooling rates, redox conditions and environment opacity, etc, that were then employed either as input or targeted parameters in astrophysical models of solar protoplanetary disk evolution [1-4].

Determining the main textural characteristic of chondrules together with the intimate structures of their constituting phases : olivine, pyroxene, metal, sulfide and glass, is therefore key to decipher the chondrule formation processes ; any mistinterpretations in these observations leading unavoidably to erroneous thermal histories and unreliable processes/scenarii for chondrule formation.

Cathodolumiscence theory, i.e., emission of photons after injection of high voltage electrons promotes valence electrons to conduction band, predicts that intrisic CL of minerals will be enhanced by defects and structural imperfections in the lattice and/or by substitutional or interstitial elements which distort the lattice. Few elements can perform the opposite role modifying the energy level arrangement so that the CL process does not operate or is diminished. These are "quenchers", with Fe^{2+} being the most common. As long as CL quenchers are low in concentrations, high resolution CL could be able to resolve very subtle changes of CL activators, which in turn should allow to resolve internal structures not seen by other techniques (including electron microscopy and both EDS or WDS X-ray imaging). In the more favorable cases, only a few ppm or tenth of ppb of an activator are enough for CL emission. The ferromagnesian silicates in Type I chondrules of unequilibrated chondrites exhibiting magnesian-rich compositions (mg# = Mg/(Mg + Fe >> 0.95) provide motivation for this high-resolution CL survey of chondrules. Both porphyritic and barred chondrules belonging to several representative carbonaceous and ordinary chondrite samples (CV, CR, CO and OC) have been surveyed for this study, using CL hyperspectral imaging acquired with high resolution CL facility mounted on FEG-SEM.

Comparison between back scattered electron (BSE) with our high resolution CL images of the same chondrules reveals unambiguously the quantum difference between these two observations. Our results show that CL panchromatic images and hyperspectral analyses on different types of chondrules of various chondrites reveal overlooked olivine internal structures at a hitherto unprecedented detail by resolving faint changes of CL activator concentrations of iron-poor olivines (e.g., Al^{3+}, Cr^{3+}, Mn^{2+}). These stunning features observed in all the studied magnesian chondrules so far tell a complex, but similar, record of dissolution and epitaxial growth episodes of olivines during chondrule formation events, at odds with classical and quiescent cooling history models inferred for chondrules. Implications of this finding on chondrule formation will be discussed.

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