Experimental and numerical study of the accretion of chondrule rims. A. Carballido[1], R. Hanna[2], C. Xiang[1], L. S. Matthews[1], and T. W. Hyde[1]. [1]Center for Astrophysics, Space Physics and Engineering Research, One Bear Place #97283, Baylor University, Waco, TX, 76798-7283, USA. [2]Jackson School of Geosciences, University of Texas, Austin, TX, 78712, USA.

Introduction: Fine-grained dust rims (FGRs) around sub-millimeter-sized chondrules act as the "glue" that enables chondrules to stick together [1]. In turn, centimeter-sized objects formed by agglomerates of rimmed chondrules may constitute the building blocks of asteroid parent bodies [2]. FGR fabrics contain critical information regarding the local dynamics of the solar nebula, particularly the strength of nebular turbulence and the electrical charge of dust grains. Current experimental techniques have advanced to the point that FGR porosity, thickness and grain alignment in meteorite samples can be used to infer FGR morphology at the time of rim accretion [e.g., 3-5]. Numerical modeling of the growth of FGRs can then be used to link measurements of fabric and porosity of primitive FGRs to the statistics of turbulent dust-chondrule collisions, taking into account the effect of possible surface electrical charges. Here, we present an approach for examination of the nebular formation of FGRs through a combination of numerical modeling and laboratory measurements of chondrule FGRs.

Methods: ***Numerical***. The porosity of newly formed FGRs, the size distribution of dust components, and the preferred alignment of ellipsoidal grains in such rims can be determined from numerical modeling of FGR accretion. The collision of spherical, micron-sized dust grains onto sub-mm-sized chondrules is performed using a well-tested, discrete-element, dust coagulation code called Aggregate_Builder (AB) [6]. The model accounts for sticking, restructuring, and bouncing of accreting dust grains where fragmentation is assumed negligible for particles of sub-mm sizes [7]. The initial dust grain monomer size distribution employs an interstellar-medium power law [8], with radii between 0.5 and 10 µm.

Collision velocities between dust grains and chondrules are determined through simulations of solid particle dynamics in isotropic turbulence using the ATHENA astrophysical fluid dynamics code [9]. In these simulations, both dust (with spherical or ellipsoidal shapes) and spherical chondrules are subject to gas drag. The resulting particle relative velocity distributions, which can be shown to be non-Gaussian [7], are used as input to AB.

Experimental. FGR structure within unaltered and unheated carbonaceous chondrites can be characterized by quantitative measurements of FGR grain alignment, porosity and thickness. This allows determination of turbulent gas velocities and grain charge in the solar nebula during FGR formation as well as insight into structural modifications occurring after initial FGR formation.

In order to analyze the FGR fabric of primitive CV, CO, and CR chondrites, we employ electron backscatter diffraction (EBSD), which measures the orientation of crystalline phases such as olivine [e.g., 3].

Results: ***Numerical***. The characteristics of the FGRs depend on the nebular environment: high relative velocities due to turbulence can lead to compact rims, while radiative or plasma environments which produce charged dust can change both the porosity of the rims and the size of the dust grains incorporated into the rims [10] (Fig. 1). Results using spherical monomers show greater rim compaction for strong turbulence (as measured by the dimensionless parameter α of accretion disk theory) than for weak turbulence (Fig. 1 a,b). In weak turbulence, the electrostatic interaction of charged grains leads to highly porous rims containing very few small dust grains (see Fig. 1 c).

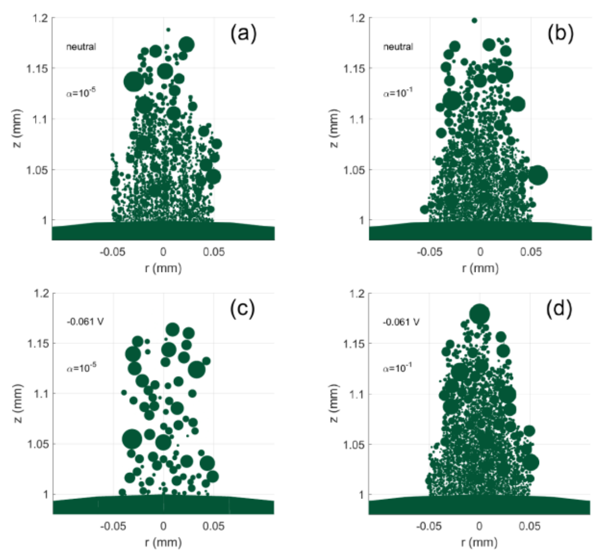

Figure 1: Cutaway view of rim growth on a 100 µm-diameter patch on the surface of a chondrule with a radius of 1000 µm, formed in (*top row*) neutral and (*bottom row*) charged environments (dust surface potential of -0.061V). The turbulence strength α is 10^{-5} for (a, c) and 10^{-1} for (b,d).

Simulations also show that FGR porosity is roughly proportional to the ratio of the electrostatic potential energy, PE (measured at the point of collision) and the kinetic energy, KE, due to the relative velocity between colliding grains (Fig. 2).

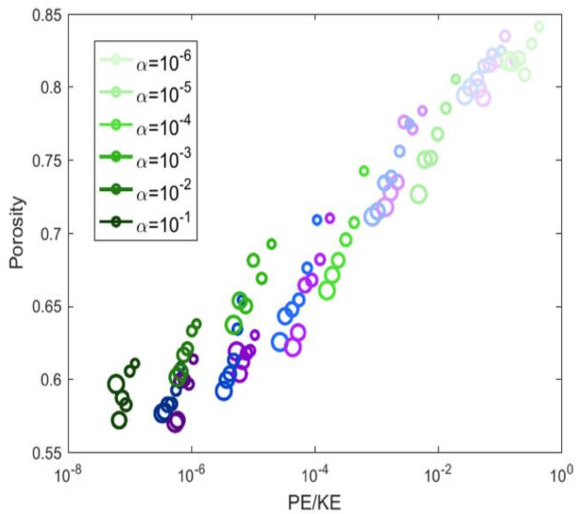

Figure 2: Relationship between FGR porosity and the ratio of the electrostatic potential energy (PE) to collision kinetic energy (KE). Results shown for different turbulent strengths α, dust surface potential (green: -0.020 V; blue: -0.048 V; purple: -0.061 V), and chondrule sizes (symbol size denotes chondrule radii from 500 – 1000 μm).

Experimental. Grain fabric from EBSD is typically quantified by calculating the density distribution of the crystallographic axis orientations and displaying it as multiples of uniform density (MUD) in a pole figure (Fig. 3). A MUD of approximately 1 is interpreted as a random fabric and values >> 1 are typically interpreted as a preferred alignment of grains. Preliminary FGR fabric results for CV Vigarano (Fig. 3) indicate a random orientation of olivine grains in this FGR area. MUD values of ≈ 3 are not spatially coherent and thus are not interpreted as a preferred alignment of grains, which is supported by $C = 0.14$ and 0.57, indicating a random fabric (e.g. < 1; [11]). Importantly, it is apparent that the FGR within this Vigarano sample is not affected by the compaction event recorded by another Vigarano sample [12].

Future Work: Future measurement efforts will characterize the porosity of the FGR for comparison to the numerical models. We are currently expanding our laboratory measurements of FGR grain alignment and porosity to a suite of COs, CVs, and CRs. In future numerical models, ellipsoidal dust grains will be used to approximate the shape of grains that would form an oriented fabric. Refinements to the numerical model will also incorporate non-spherical chondrule bodies.

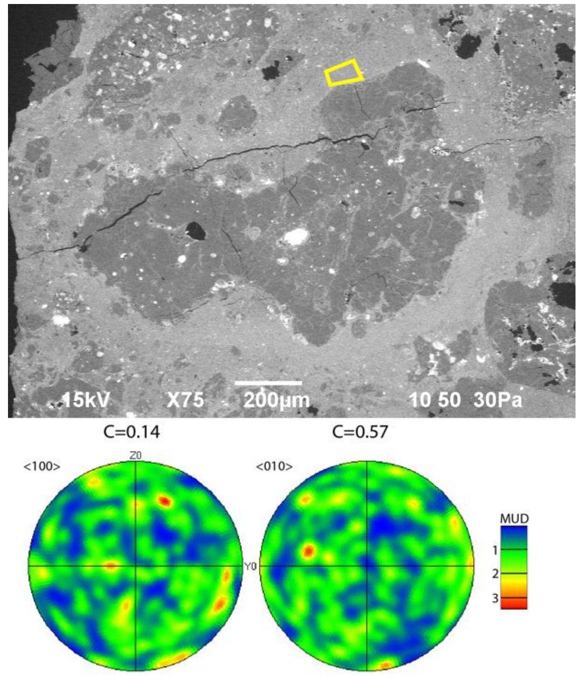

Figure 3: CV Vigarano FGR. (top) BSE image with yellow box showing location of EBSD map data. (bottom) Crystallographic orientations of 524 olivine grains in map area. Pole figures show crystallographic <100> and <010> directions of contoured data with calculated MUD values. The parameters $C = 0.14$ and 0.57 confirm a random fabric (<< 1.0) for both crystallographic axes and therefore a random orientation of olivine grains.

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