Degassing is a critical heat treatment process in aluminum powder metallurgy, where powders are subjected to high temperature in vacuum to remove volatile gaseous species absorbed in and adsorbed on powders. For cryomilled aluminum alloy powders with nanoscale features, degassing can cause accelerated microstructural and chemical changes including removal of volatiles, grain growth, dislocation annihilation, and formation of dispersoids. These changes can significantly alter the mechanical behavior of consolidated components based on their contributions to strength. In this study, cryomilled AA5083 (0.4 wt.% Mn; 4.5 wt.% Mg; minor Si, Fe, Cu, Cr, Zn, Ti; balance Al) powders were degassed at 200, 300, 350, 410 and 500°C at a ramp rate of 68.3 °C hr⁻¹ for a soak time of 8 hours with a vacuum at or below 6.5 x 10⁻³ Pa. Grain size, dislocation density and dispersoid phase constituents were examined as a function of degassing temperature by X-ray diffraction, scanning electron microscopy and transmission electron microscopy, equipped with high angle annular dark field detector and X-ray energy dispersive spectroscopy. Inert gas fusion and thermal conductivity analysis were employed to determine the oxygen, nitrogen and hydrogen concentrations as a function of degassing temperature. Grain size in as-cryomilled powders (21 ~ 34 nm) increased as a function of degassing temperature, and reached a maximum value of 70 ~ 80 nm for powders degassed at 500°C for 8 hours. The dislocation density of 1.11 x 10¹⁵ m⁻² in as-cryomilled powders decreased to 1.56 x 10¹⁴ m⁻² for powders degassed at 500°C for 8 hours. The Al₆(MnFeCr) phase was the most commonly observed dispersoid, mostly on samples degassed at or above 300°C. Volume fraction increased with degassing temperature up to 5 vol.% and the size of the dispersoids grew up to ~ 280 nm. Oxygen and nitrogen content after cryomilling were unaffected by the change in degassing temperature, but the hydrogen content decreased and reached a minimum of 45 ± 3.16 ppm for cryomilled powders degassed at 500°C for 8 hours. Grain growth was quantitatively analyzed based on the general grain growth formula and Burke’s model in the presence of pinning forces. Degassing occurred in two different kinetic regimes: Harrison A kinetics at higher temperatures and Harrison B in the lower with a transition temperature of about 287°C. Burke’s model exhibited a poor fit to the experimental results in higher temperature regime suggesting that pinning forces did not inhibit the grain growth. Desorption of impurities during degassing was analyzed using Fickian diffusion in a spherical coordinate system and an empirical expression based on the exponential decay of average concentration. The activation energy for degassing was estimated to be 16.2 ± 1.5 kJ mol⁻¹. Evolutions in composition and microstructure in cryomilled powders as a function of degassing temperature were further analyzed and quantitatively correlated to the strengthening mechanisms of solid solution, grain size reduction (i.e., Hall-Petch), dislocation forest and Orowan. For consolidated AA5083 derived from cryomilled powders, strengthening by grain size reduction was the dominant mechanism of strengthening.

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The public is welcome to attend.