
**Introduction:** It was shown recently that compositionally zoned metal grains (Ø: ~10−400 µm) (wt% throughout) (5-10% Ni, 0.25-0.4% Co, 0.3-0.8% Cr, ~0.07% Si) in CH and Bencubbin-like chondrites [1, 2] formed by condensation from a gas of solar composition, and subsequently escaped chondrule formation and thermal metamorphism [3]. Here we report further observations of metal grains in CH chondrites (PAT91546, PCA91467, RKP92435, ALH85085, EET96238, and Acfer 182) and in the Bencubbin-like chondrite QUE94411 [2]. We find compositionally zoned FeNi metal grains with a wide range of Ni concentrations (~5-60% Ni). We suggest that metal in CH and Bencubbin-like chondrites can be used to constrain the total pressure ($P_{tot}$), oxygen fugacity, and cooling rates of the nebula regions, where these metal grains condensed, and the rate of grain growth. We infer that these metal grains formed by gas-solid condensation from a gas with variable redox conditions in rapidly and localized thermal episodes in the solar nebula.

**Results:** Metal grains in CH and Bencubbin-like (QUE 94411) chondrites can be divided into three categories: 1. Concentrically zoned metal grains (type 1) with Ni concentrations decreasing from the center (9-14%) to the edge (3-7%) [1]. Cobalt (0.2-0.5%) is positively correlated with Ni with a solar Co/Ni ratio (~0.045), whereas Cr (0.2-0.8%) is negatively correlated with Ni. Phosphorous and Si concentrations are 0.1-0.3% and 0.05-0.15%, respectively. 2. Compositionally homogeneous low-Ni (5-7% Ni) metal grains (type 2), with a $\sim$ solar Ni/Fe ratio (~0.055), 0.6-0.8% Cr, a solar Co/Ni ratio (0.2-0.3% Co), and 0.3-0.4% P; Si <0.02%. 3. High-Ni metal grains with Ni concentrations ranging from 25% to 60% (type 3) and $\sim$ solar Co/Ni ratios. Chromium and P concentrations are near the detection limit (~0.05%); Si <0.02%. Some of the high-Ni (~53-58% Ni) grains are concentrically zoned in a way similar to type 1 grains.

**Discussion:** Meibom et al. [1] showed that type 1 metal grains are the result of equilibrium condensation from a gas of solar composition at 1400 to 1300 K at $P_{tot}$=10$^4$ bars [3]. Assumming spherical geometry of the growing grains and grain growth by bombardment of Fe and Ni atoms (sticking coefficient = 0.5) from a gas of solar composition, $P_{tot}$ 10$^4$ bars, and temperatures around 1400 K, we calculate that it takes a few days to grow metal grains several hundred microme-

The composition of type 2 (low-Ni, homogeneous) metal grains is generally consistent with equilibrium condensation from a gas of solar composition at temperatures below 1250 K [3], when the Ni/Fe ratio of the condensing metal is $\sim$ solar (~0.055).

High-Ni metal grains (type 3), some of which are compositionally zoned similarly to grains of type 1, might also have formed by gas-solid condensation. However, because the first metal to condense from a gas of solar composition and total pressure between 10$^{-2}$-10$^{-3}$ bars is expected to have $<28$% Ni, condensation of metal with higher Ni concentrations requires more oxidizing conditions. This could be achieved by evaporation and subsequent cooling of a gas-parcel with an initial dust/gas ratio 10-100 x solar, or by removal of H$_2$. We infer that the high-Ni metal grains in CHs provide evidence for variable redox conditions in the regions of metal condensation.

In order to further explore the origin of metal in CH and Bencubbin-like chondrites, we are undertaking a multi-faceted study that includes: a. Detailed thermodynamic and physical modeling of metal condensation under various redox conditions. b. ICP-MS and X-ray microprobe analyses of moderately volatile elements (Ga, Ge, As, Au etc.) and PGEs in type 1 metal grains to constrain the behavior of these elements during condensation. c. High-magnification SEM and Mössbauer spectroscopy to determine the degree of metal decomposition and constrain the growth mechanism and subsequent thermal history of the metal grains. d. Ion-probe measurements of Ni and Cr isotope compositions to search for anomalies that might be related to early nebula mixing/evaporation processes. e. Measurements of the magnetic properties of the metal grains to constrain the magnetic field around the young Sun.

**References**