ORIGIN AND HOMOGENEITY OF ^{60}FE IN THE SOLAR SYSTEM: EVIDENCE FROM ACHONDRITES AND UNEQUILIBRATED ORDINARY CHONDRITES. H. Tang[1] and N. Dauphas[1], [1]Origins Lab, Department of the Geophysical Sciences and Enrico Fermi Institute, The University of Chicago, 5734 South Ellis Avenue, Chicago, IL 60637 (cafetang@uchicago.edu).

Introduction: Extinct radionuclides can provide constraints on the timescale and astrophysical context of solar system birth [1]. Among these nuclides, ^{60}Fe ($t_{1/2}$=2.62 Myr [2]) could play an important role as a chronometer and a heat source in early-formed planetary bodies [3]. However, the issues of the abundance and homogeneity of ^{60}Fe in the early solar system (ESS) are still not resolved. The first evidence for the presence of ^{60}Fe in solar system material was found in eucrites in the form of excess ^{60}Ni, defining internal isochrones [4,5]. However, the closure time for the Fe-Ni system was not well known, hindering a reliable estimate of the initial ^{60}Fe/^{56}Fe ratio at solar system formation. The initial ratio was constrained more precisely by *in situ* analyses of high Fe/Ni phases in chondrites [6-10]. Initial ^{60}Fe/^{56}Fe ratios of (2.2-3.7)×10^{-7} in chondrules correspond to an initial ratio of (6.3±2.0)×10^{-7} at the time of condensation of CAIs. Recently, the initial ratio was constrained using bulk and mineral analyses of angrites with high Fe/Ni ratios [11,12]. A solar system initial ratio of (7.47±3.05)×10^{-9} at the time of CAI formation was obtained based on the initial ^{60}Fe/^{56}Fe ratio of (3.12±0.78)×10^{-9} at the time of angrite formation. Such discrepancies could reflect heterogeneous distribution of ^{60}Fe in the early solar nebula or the possible presence of unresolved interferences on Ni isotopes [13].

To address this question, we developed a new method for high precision nickel isotopic measurement by MC-ICPMS and analyzed a diverse suite of achondrites and components from unequilibrated ordinary chondrites. In angrites and eucrites parent bodies (APB and EPB, respectively), high Fe/Ni ratio was produced by core formation and mantle differentiation, which have taken place within the first 4 Myr after the formation of the solar system [14-16]. Therefore, ^{60}Fe was expected to be present at the time of Fe-Ni fractionation in the different mantle reservoirs of the APB and EPB.

NWA5717 is an ungrouped ordinary chondrite characterized by a low metamorphic grade of 3.05 [17]. Multiple magnetic and size fractions were separated using a hand magnet and sieves. Chondrules from NWA5717 and Semarkona (LL3.00) were also measured in this study. Although Fe/Ni ratios in the chondritic components are relative low (12~80), our precision would still allow to resolve ^{60}Ni excess from ^{60}Fe decay, if the ^{60}Fe/^{56}Fe initial ratio is assumed to be 2×10^{-7}.

Fe-Ni systematics in achondrites and UOC: Terrestrial standards passed through the same column chemistry procedure as well as achondrites with relative low Fe/Ni ratios (such as aubrites and ureilites) exhibit terrestrial nickel isotopic composition (εNi=0). Four of six angrites show resolvable ^{60}Ni excesses correlated with their Fe/Ni ratios, defining a whole-rock isochron in APB. The ^{60}Fe/^{56}Fe ratio at the time of mantle differentiation in the APB is estimated to be ~3.5×10^{-9} and $\varepsilon^{60}Ni_0$ was 0 within uncertainties. According to Mn-Cr systematics in whole-rock angrites [18,19], the initial ^{60}Fe/^{56}Fe in ESS could be back calculated as ~1.4×10^{-8}, consistent with the abundance obtained in previous studies [20,21].

Five non-cumulate bulk eucrites investigated here show significant ^{60}Ni excesses reaching ~+2 ε for a Fe/Ni ratio of ~20,000, yielding an isochron with an initial ^{60}Fe/^{56}Fe ratio of ~3.5×10^{-9} and $\varepsilon^{60}Ni_0$ of 0 within uncertainties. Given the timescale of mantle differentiation based on ^{53}Mn-^{53}Cr chronometer (3.5±1.3Myr) [19,22], the initial ^{60}Fe/^{56}Fe in ESS could be constrained as ~9.0×10^{-9}, identical with the estimation from bulk angrites within uncertainties.

In contrast to the ^{60}Fe-^{60}Ni whole-rock isochron, the process of mantle differentiation in APB, ^{60}Fe may also be alive in early-formed quenched angrites at the time of their crystallization. Here we also report ^{60}Fe/^{56}Fe ratio of 3.53×10^{-9} in D'Orbigny at the time of its crystallization from the mineral internal isochron. This ratio indicates that D'Orbigny crystallized in 3.3±0.3 Myr after CAI condensation, consistent with the age of D'Orbigny inferred from other chronometers (^{53}Mn-^{53}Cr and ^{182}Hf-^{182}W) [23,24] and suggests the initial ^{60}Fe/^{56}Fe in ESS to be ~1.5×10^{-8}.

Diverse components from NWA5717 as well as two chondrules from Semarkona were analyzed to determine the reason of the systematic discrepancies in ^{60}Fe abundance between achondrite MC-ICPMS analyses and chondrule SIMS measurements. No ^{60}Ni excesses were found in any components from UOC in this study, supporting the initial ratio constrained from achondrites instead of the ratio from *in situ* analysis.

^{60}Fe homogeneity in ESS: Lack of ^{60}Ni excesses in ureilites was explained as heterogeneous distribution of ^{60}Fe in the solar nebula [10]. In order to address this question, ^{58}Fe isotopic compositions of achondrites as well as components from UOC were obtained. ^{58}Fe, the most neutron-rich stable isotope of iron is produced together with ^{60}Fe in AGB-stars and supernovae by neutron capture reactions. If ^{60}Fe was heterogeneously distributed in the early solar system, such heterogeneity should be accompanied by ^{58}Fe variations in different reservoirs. If achondrites are missing some ^{60}Fe compared to chondrites due to heterogeneous distribution of that extinct radionuclide, ^{58}Fe deficits in achondrites should be observed [25].

No ^{58}Fe anomalies are found in any types of meteorites within the uncertainty (±0.5ε). This dispersion only allows ~15% heterogeneity for the initial ^{60}Fe/^{56}Fe in ESS. These data support our conclusion from nickel isotopic measurement and are consistent with rapid mixing of ^{60}Fe in the early solar nebula. Our study reveals that ^{60}Fe abundances estimated from APB and EPB are identical within uncertainties, implying ^{60}Fe homogeneous distribution in the reservoirs from which APB and EPB accreted. Lack of evidence of ^{60}Fe presence by MC-ICPMS in chondrites and achondrites with low Fe/Ni (<300) is due to the limited achievable precision rather than ^{60}Fe heterogeneity in ESS.

Conclusion: Fe-Ni systematics in achondrites and chondritic components from UOC was studied, demonstrating that ^{60}Fe was distributed homogeneously in inner solar system with an initial ^{60}Fe/^{56}Fe ratio of $\sim 1.2\times 10^{-8}$.

These new constraints have far-reaching implications for the source of ^{60}Fe in the inner solar system and the heat source of early-formed planetary bodies. Unlike ^{26}Al, our estimation of the abundance of ^{60}Fe in the ESS is consistent with inheritance from the galactic background, with no nearby injection needed.

The decay of ^{60}Fe in early-formed planetary bodies was thought to be an important heat source contributing to global melting and differentiation after most ^{26}Al had decayed into ^{26}Mg [26]. However, based on the ^{60}Fe initial abundance obtained in this study, ^{60}Fe played a negligible role in the heat budget of planetesimals.

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