OSMIUM ISOTOPE ANOMALIES IN CHONDRITE COMPONENTS: REFRACTORY INCLUSIONS, CHONDRULES, METAL AND PRESOLAR GRAINS. T. Yokoyama[1, 2], R. J. Walker[2], C. M. O'D. Alexander[3] and G. J. MacPherson[4], [1]Dept. of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo 152-8551, Japan (tetsuya.yoko@geo.titech.ac.jp), [2]Dept. of Geology, Univ. of Maryland, College Park, MD 20742, USA, [3]Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, DC 20015, USA, [4]Dept. of Mineral Sciences, US National Museum of Natural History, Smithsonian Institution, Washington DC 20560 USA

Introduction: Primitive chondrites are mineralogically, chemically and isotopically unequilibrated. Isotopic anomalies are common for bulk chondrites and components within them [1-5]. There are multiple causes for the isotopic anomalies. For example, extremely large isotopic anomalies that deviate by orders of magnitude from solar ratios are present in presolar grains, and have been attributed to multiple stellar nucleosynthetic processes [6,7]. Very precise isotopic measurements of chondrites have raised questions as to whether presolar grains of diverse provenance were homogeneously distributed in the early solar nebula, and whether the timing of homogenization processes pre- or postdates formation of major chondrite components (e.g., CAIs, chondrules, metals) and chondrite parent bodies.

We have previously reported that acid resistant fractions (IOM: insoluble organic matter) of some carbonaceous chondrites and their acid leachates possess nucleosynthetic Os isotope anomalies, while bulk chondrites have uniform $^{186,188,190}Os/^{189}Os$ ratios [4,5]. Most recently, sequential acid leaching of the Murchison meteorite revealed the presence of internal Os isotope anomalies of nucleosynthetic origin [8]. All of these anomalies suggest the existence of multiple phases in the chondrites that are enriched in s- or r-process nucleosynthesis products (e.g., presolar SiC), although the actual carriers of individual anomalies are poorly constrained. Further, Os isotope measurements with ultra high-precision mass spectrometry have not previously been performed for other chondrite components. In this study, we present precise Os isotope data for chondrite components including CAIs, chondrules and metal grains, as well as IOMs and their acid leachates. Our objective is to develop a better understanding of stellar nucleosynthetic contributions to our solar system, and the subsequent processes that acted on these diverse materials in the early solar system.

Experimental: Two CAIs were prepared from the carbonaceous chondrite Allende at the Smithsonian Institution. USNM 3529-Z and 3529-41 are coarse-grained CAIs with group I and III REE patterns, respectively. All CAIs are enriched in Os (7-10 ppm) [9]. Approximately 10 mg of the CAI was placed in a Pyrex Carius tube and digested at 260^{o}C with a 2:1 mixture of HNO_3 and HCl for four days. The Os was then extracted by CCl_4 and purified by a microdistillation technique. Ferromagnesian chondrules (USNM 3529-20) were also separated from Allende at the Smithsonian Institution. Eight chondrules (totaling 119 mg) were ground into fine powder. Coarse metal grains (totaling 23 mg) from a CR2 chondrite GRA95229 were separated using a hand magnet. These samples were digested by the same method as for the CAIs. In addition to eight IOMs examined in [5], we analyzed newly prepared IOM fractions separated from two carbonaceous chondrites (GRA95229 and Adelaide). Further, we performed new leaching experiments on three IOMs (Orgueil, Adelaide and Leoville) with hot 6M HCl (80^{o}C for two days).

Osmium isotope analyses were carried out by TIMS (Thermo-Fisher TRITON) at the University of Maryland for which the details of the analytical performance are described in [5]. The Os isotope ratios, normalized to ^{189}Os, are reported in εOs units ($\varepsilon^{186}Os^i$, $\varepsilon^{188}Os$ and $\varepsilon^{190}Os$) which represent relative deviation from the average of seventeen bulk chondrite analyses ('solar values') [4,5]. The $^{186}Os/^{189}Os$ ratio of each sample was time-corrected for ^{190}Pt decay using measured Pt/Os.

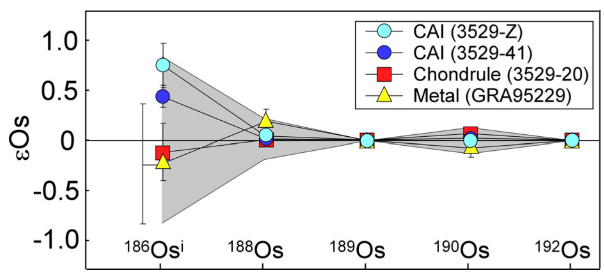

Fig. 1 εOs values for CAIs, chondrule and metal. $\varepsilon^xOs=\{(^xOs/^{189}Os)_{sample}/(^xOs/^{189}Os)_{solar}-1\}\times10^4$. *Errors are* $\pm2\sigma_m$. *Gray zone is the ±2σ reproducibilities of seventeen bulk carbonaceous chondrites.*

Results and Discussion: None of the CAIs, chondrule or metal samples show Os isotopic anomalies that are resolvable from the solar values (Fig. 1). This indicates that the melted portions of the chondrites have solar Os isotopic compositions. The Os isotope anomalies previously reported for chondrites evidently reside in low-temperature components (i.e. matrix). Thus, CAI and chondrule formation, and metal condensation must postdate the time at which the solar nebula became well mixed with respect to Os isotopes. This reinforces our previous conclusion that disparate nucleosynthetic components were, at least for Os, thoroughly mixed within the solar nebula at the time of the initiation of planetesimal accretion [4].

Osmium isotope data for IOMs and their acid leachates (HHLL: hot hydrochloric-acid leaching leachate) are presented in $\varepsilon^{186}Os^{i}$–$\varepsilon^{188}Os$ and $\varepsilon^{190}Os$–$\varepsilon^{188}Os$ diagrams together with IOM and HHLL data of [5] and Murchison leachates of [8] (Fig. 2). Bold and dashed lines are mixing trends between the solar value and an s-process component predicted in [8] using Maxwellian averaged cross sections (MACS) for Os isotopes in refs. [10] and [11], respectively. New IOM data for GRA95229 (CR2) and Adelaide (C2/3-ung) show positive εOs anomalies that plot on the mixing trend based on the MACS data of [10]. As previously reported in [5], the magnitude of Os isotope anomalies for IOMs is in the order of the petrologic grade of host chondrites, indicating a presolar origin for the s-process Os carrier in the chondrite matrix.

In contrast, Os isotope data for HHLLs are much more complicated. HHLLs from Murchison and Allende have negative εOs values while Leoville HHLL shows enrichments in s-process Os that are greater than the original IOM before leaching. The HHLLs are known to have ^{54}Cr anomalies [12]. However, there are no correlations between the extent of Cr and Os isotope anomalies. This simply indicates that the carriers of isotopically anomalous Cr and Os are different in the IOMs. It is intriguing that most of HHLLs and some Murchison leachates of [5] deviate from the main trend of IOMs in Fig. 2a, but plot on the mixing trend with the MACS values of [11], while a straight line is obtained for all IOMs and HHLLs in Fig. 2b. The mismatch cannot be explained by possible mass interferences in TIMS measurements, uncertainties in ^{190}Pt decay corrections, or contribution from p-process Os.

Overall, chondrite IOMs contain multiple presolar components enriched in s/r-process Os. One dominant component is strongly acid resistant and enriched in s-process Os. It is most likely mainstream presolar SiC. Because most IOMs plot on a single mixing trend in Fig. 2, this phase is likely common for all chondrites. The other carriers in the IOMs, leachable with hot HCl, are enriched both in s- and r-process Os. Mass balance calculations reveal that these phases are minor (<15% for Os) in the IOM, excluding Adelaide HHLL which liberated 30% Os and does not plot on the HHLL trend in Fig. 2a. Taken together, it is conceivable that there exist minor but distinct presolar phases that have been produced in different stellar environments. As proposed in [8], minerals generated in AGB stars with C/O <1 may be the carrier of acid leachable components enriched in s-process Os. Likewise, at least two different phases enriched in r-process Os are required. The different proportions of presolar phases in IOMs from different chondrites could be associated with metamorphic processes on individual parent bodies that ultimately controlled the abundances of presolar grains surviving in the chondrites.

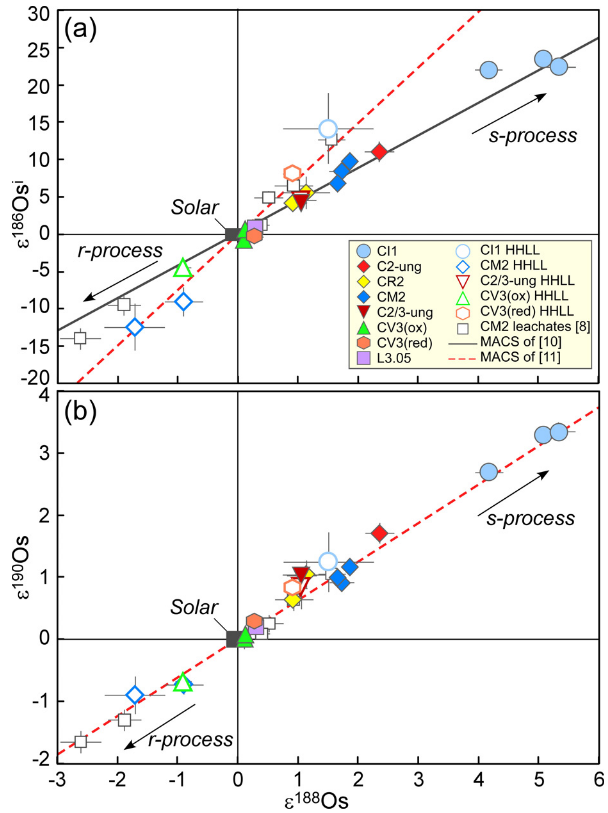

Fig. 2. (a) $\varepsilon^{186}Os^{i}$-$\varepsilon^{188}Os$ and (b) $\varepsilon^{190}Os$-$\varepsilon^{188}Os$ plots for IOMs and HHLLs. Also plotted are IOMs and HHLLs of [9] and Murchison leachates of [10]. Bold and dashed lines are mixing trends of the solar and an s-process component using the Os MACS values in [13] and [14], respectively. Because of the absence of ^{190}Os MACS data in [13], only the trend base on [14] is shown in (b).

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