**In-situ** chromium isotope measurement of chromium-rich fine grains in the Murchison CM2 chondrite

W. FUJIYA,* N. SUGIURA, N. TAKAHATA and H. HIYAGON

1Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
2Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa-shi, Chiba 277-8568, Japan

(Received April 2, 2010; Accepted February 9, 2011)

Isotopic anomalies of $^{54}$Cr have been reported in bulk chondrites. Stepwise dissolution experiments have suggested the presence of a carrier of the $^{54}$Cr anomaly, probably of presolar origin. Although stepwise dissolution experiments and ion microprobe studies of Cr-rich grains have revealed, to some extent, the carrier of anomalous $^{54}$Cr, the nature of the carrier is not yet well understood. In this study, we attempted to detect the carrier phases. We performed an **in-situ** measurement of Cr isotopic compositions of small (~1 μm or less in size) Cr-bearing grains in the Murchison CM2 chondrite using a NanoSIMS 30 ion microprobe. $^{54}$Cr has an isobaric interference of $^{54}$Fe, which makes the measurement of $^{54}$Cr/$^{52}$Cr isotopic ratios difficult. In order to evaluate the contribution of $^{54}$Fe, the abundance of $^{56}$Fe was measured. Even after large corrections for $^{54}$Fe, $\delta^{54}$Cr values of Cr-rich grains were determined with a precision of ~30‰.

No grain out of ~200 Cr-rich grains was confirmed to be a presolar grain with a large $^{54}$Cr anomaly. If the carrier of the $^{54}$Cr anomaly is Cr-rich, this result implies a low abundance and a huge isotopic anomaly of the carrier, and/or its extremely fine grain size. In the former case, the maximum abundance of the presolar Cr-rich grains is roughly estimated to be ~1 ppm. In that case the minimum isotopic anomaly would be ~90‰.

Keywords: 54-chromium, isotopic anomaly, presolar grain, NanoSIMS, isobaric interference

**INTRODUCTION**

Isotopic anomalies found in meteorites have been one of the important issues when considering mixing processes of materials in the early solar system. They are also crucial for chronological studies of solar system objects using radioactive nuclides because they are based on homogeneities of the parent and daughter nuclides (Lugmair and Shukolyukov, 1998; Bizzarro et al., 2005; Villeneuve et al., 2009). Refractory inclusions in CV3 carbonaceous chondrites (Ca, Al-rich Inclusions; CAIs) have been known to display isotopic anomalies in the iron group elements such as Ca, Ti, Cr and Ni (summarized in Birck, 2004). Moreover, previous studies reported isotopic anomalies of Ti, Ni, Cu, Mo, Nd, Zr, Ba, Os, etc. in bulk samples and acid residues of chondrites and achondrites taking advantage of recent high precision (10 to 1 ppm level) isotope measurements (e.g., Yin et al., 2001, 2002; Dauphas et al., 2002a, b; Luck et al., 2003; Ranen and Jacobsen, 2006; Carlson et al., 2007; Yokoyama and Jacobsen, 2007; Regelous et al., 2008; Trinquier et al., 2009). These isotopic anomalies are generally interpreted as implying nucleosynthetic signatures, hence, incomplete mixing of diverse nucleosynthetic components in the early solar nebula.

While CAIs show isotopic anomalies in iron group elements including Cr (Birck and Allègre, 1984), isotopic anomalies of $^{54}$Cr have also been reported in bulk meteorites (Shukolyukov and Lugmair, 2006; Trinquier et al., 2007) and leachates in stepwise dissolution experiments of carbonaceous chondrites (Rotaru et al., 1992; Podosek et al., 1997; Trinquier et al., 2007). According to these studies, chondrites (Shukolyukov and Lugmair, 2006; Trinquier et al., 2007) and achondrites (Trinquier et al., 2007) are found to be characterized by their unique $^{54}$Cr/$^{52}$Cr ratios. In stepwise dissolution experiments (Rotaru et al., 1992; Podosek et al., 1997; Trinquier et al., 2007), all leachates of bulk carbonaceous chondrites show $^{54}$Cr excesses or deficits relative to Earth. Rotaru et al. (1992) and Trinquier et al. (2007) showed that large $^{54}$Cr enrichments in HCl + HF solutions of CI, CM2 and CR2 chondrites. Podosek et al. (1997) and Trinquier et al. (2007) also reported that fractions of the Orgueil CI chondrite treated with HCl show the strongest positive anomalies of $^{54}$Cr in the stepwise dissolution experiments. On the other hand, HCl + HF solutions of CV3 and CO3 chondrites do not display such large $^{54}$Cr anomalies. Recently, Qin et al. (2010) reported Cr isotopic composi-
tions of HCl leachates of the insoluble organic-rich residues extracted from various chondrites. They prepared the organic residue using the CsF-HF demineralization technique (Cody et al., 2002). While HCl leachates of the organic residues of CI, CM2 and CR2 show large excesses of $^{54}$Cr, those of CV chondrites show smaller excesses. A possible explanation of these results is that a chemically refractory mineral with the $^{54}$Cr anomaly in primitive meteorites was modified into a more readily dissolved phase in thermally metamorphosed meteorites. The Allende CV3 chondrite has the very low concentration of presolar SiC grains relative to Orgueil (Huss and Lewis, 1995), supporting this assumption. Therefore, stepwise dissolution experiments suggest the presence of a $^{54}$Cr anomaly probably of presolar origin, i.e., a nucleosynthetic component. Indeed, several Cr rich grains with enrichments of $^{54}$Cr up to 1500‰, most likely chromite and Cr-rich spinel, were found in acid residues extracted from Orgueil (Ott et al., 1997; Qin et al., 2009; Dauphas et al., 2010; Nittler et al., 2010). However, the nature of these grains is not yet well understood. The carrier of the $^{54}$Cr excess is (at least partly) soluble in HCl + HF. Hence, such a mineral is likely dissolved in conventional preparation procedures of presolar grains with harsh acids (Amari et al., 1994). Such nucleosynthetic components seem to be initially homogeneously distributed within the inner protoplanetary disk, inferred by the evidence from Ti isotopes of chondritic and differentiated materials (Trinquier et al., 2009). However, the observed isotopic heterogeneities of Cr, Ti and other elements among main meteorite groups require the existence of a secondary process imparting selective loss of these objects before the formation of solar system solids and accretion of planetary bodies. Spatial dimensions of the isotope heterogeneity of the protosolar nebula should be comparable to the source regions of their parent bodies.

For a better understanding of the relationship between planetary and mineral scale isotopic heterogeneities, there is a need for more investigations of the nature of the isotopically anomalous phases, including the chemical and isotopic composition, size, physical property and texture. These studies impose a new constraint on the models of planetary formation. Chromium-54 shows an isotopic anomaly larger than any other heavy elements in bulk meteorites. Therefore, it is the most suitable tracer to search for the mineral scale isotopic heterogeneity by an in-situ measurement with an ion microprobe. Here we report $^{54}$Cr/$^{52}$Cr ratios of approximately 200 Cr-rich grains in an organic residue of the Murchison CM2 chondrite.

**EXPERIMENTAL**

We extracted an organic residue from approximately 4 g of the Murchison CM2 chondrite by the CsF technique (Cody et al., 2002; Alexander et al., 2007) at room
Cr isotope measurement of Cr-rich grains in Murchison 277

temperature. Most of the silicates in the bulk sample were removed except chemically refractory phases, such as chromite, spinel and Cr₂O₃. A Scanning Electron microscope (SEM) image of the organic residue with chemically refractory phases is shown in Fig. 1. A terrestrial chromite was used for a standard to normalize measured meteoritic ⁵⁴Cr/⁵²Cr ratios. The chromite standard was powdered so that the condition of the isotope measurement was identical for both standard and meteoritic samples. The organic residue and the powdered standard were deposited on high-purity silicon wafers.

The isotope measurement was performed with the NanoSIMS 50 at Atmosphere and Ocean Research Institute, the University of Tokyo. A primary beam of O⁻ with a diameter of ~0.2–0.3 µm and a beam current of ~10 pA was used. Four Electron Multipliers (EMs) were used to analyze ⁵⁰Cr⁺, ⁵²Cr⁺, ⁵⁴Cr⁺ and ⁵⁶Fe⁺ ions simultaneously by ion imaging. Typical count rates for ⁵²Cr⁺ and ⁵⁶Fe⁺ are ~15,000 and ~2500 cps, respectively. At first, the primary beam was rastered over 50 × 50 µm² areas and Cr-bearing grains were located by real-time imaging of ⁵²Cr⁺ ions. Then, the primary beam was rastered over 2 × 2–5 × 5 µm² areas around the grains to measure their elemental and isotopic ratios. The acquisition time was ~5 minutes and the number of pixels was 32 × 32. Irradiation time per pixel was 0.3 seconds. The dead time of each EM was 44 ns and was corrected for the calculation of isotopic compositions. The abundance of each isotope was obtained by integrating ion signals from the grain.

Typical ion images of analyzed grains are shown in Fig. 2. Grain outlines were defined according to the 60% level of individual maximum values of ⁵²Cr. No systematic change in the measured Cr isotopic ratios was observed across a single grain. The analyzed grains were observed with the SEM after the NanoSIMS analysis. Most grains were identified as spinel-chromite grains, which contained Mg, Al, Cr and Fe in varying proportions. Almost pure Cr₂O₃ grains were also found. These grains were typically submicron to a few microns in size.

⁵⁴Cr has an isobaric interference of ⁵⁴Fe, which cannot be resolved with mass resolving power of <73,000. It is difficult to measure the abundance of ⁵⁴Cr precisely by SIMS, and hence, a ⁵⁴Cr/⁵²Cr ratio cannot be determined easily with the analytical precision of several permil. However, because a presolar grain typically shows a large isotopic anomaly (e.g., >1500‰; Nittler et al., 2010), a precision of a few % may be sufficient to detect it.

⁵⁶Fe was used to correct for an isobaric interference of ⁵⁴Fe on mass 54 using the following equation.

![Fig. 3. ⁸⁸⁴Cr values of ~200 Cr-rich grains plotted against ⁵⁶Fe⁺/⁵²Cr⁺ ratios, indicating the magnitudes of corrections for an isobaric interference of ⁵⁴Fe. Error bars are 2σ. Isotopic anomalies of ⁵⁴Cr were not found in analyzed ~200 Cr-rich grains within errors.](image-url)
Table 1. Chromium Isotope Measurements

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{56}$Fe*2</th>
<th>$^{52}$Cr*2</th>
<th>$^{54}$Cr*1</th>
<th>$^{53}$Cr*1</th>
<th>$^{54}$Cr/$^{52}$Cr</th>
<th>$^{54}$Fe/$^{56}$Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinel-chromite grain #1</td>
<td>40891</td>
<td>16811</td>
<td>522641</td>
<td>28197</td>
<td>5884</td>
<td>0.02718 ± 0.00050</td>
</tr>
<tr>
<td>Spinel-chromite grain #2</td>
<td>2129028</td>
<td>195910</td>
<td>2254502</td>
<td>119207</td>
<td>12450</td>
<td>0.02674 ± 0.00040</td>
</tr>
<tr>
<td>Spinel-chromite grain #3</td>
<td>86939</td>
<td>26552</td>
<td>779963</td>
<td>41217</td>
<td>5490</td>
<td>0.02726 ± 0.00043</td>
</tr>
<tr>
<td>Spinel-chromite grain #4</td>
<td>125673</td>
<td>27041</td>
<td>703580</td>
<td>37972</td>
<td>7899</td>
<td>0.02705 ± 0.00048</td>
</tr>
<tr>
<td>Spinel-chromite grain #5</td>
<td>953101</td>
<td>88836</td>
<td>1064767</td>
<td>57004</td>
<td>4531</td>
<td>0.02641 ± 0.00057</td>
</tr>
<tr>
<td>Spinel-chromite grain #6</td>
<td>122974</td>
<td>19553</td>
<td>430255</td>
<td>22792</td>
<td>6026</td>
<td>0.02724 ± 0.00066</td>
</tr>
<tr>
<td>Spinel-chromite grain #7</td>
<td>7277</td>
<td>4487</td>
<td>146760</td>
<td>7791</td>
<td>5826</td>
<td>0.02742 ± 0.00093</td>
</tr>
<tr>
<td>Spinel-chromite grain #8</td>
<td>95902</td>
<td>16018</td>
<td>367643</td>
<td>19465</td>
<td>3042</td>
<td>0.02695 ± 0.00070</td>
</tr>
<tr>
<td>Spinel-chromite grain #9</td>
<td>52360</td>
<td>12024</td>
<td>122786</td>
<td>17242</td>
<td>8748</td>
<td>0.02692 ± 0.00069</td>
</tr>
<tr>
<td>Spinel-chromite grain #10</td>
<td>33072</td>
<td>17942</td>
<td>585560</td>
<td>32632</td>
<td>3707</td>
<td>0.02704 ± 0.00046</td>
</tr>
<tr>
<td>Spinel-chromite grain #11</td>
<td>63778</td>
<td>33991</td>
<td>1106568</td>
<td>59395</td>
<td>14841</td>
<td>0.02705 ± 0.00034</td>
</tr>
<tr>
<td>Spinel-chromite grain #12</td>
<td>14899</td>
<td>6406</td>
<td>204761</td>
<td>10934</td>
<td>10548</td>
<td>0.02665 ± 0.00079</td>
</tr>
<tr>
<td>Spinel-chromite grain #13</td>
<td>157655</td>
<td>38549</td>
<td>1072627</td>
<td>57524</td>
<td>26803</td>
<td>0.02658 ± 0.00037</td>
</tr>
<tr>
<td>Spinel-chromite grain #14</td>
<td>97402</td>
<td>12315</td>
<td>229249</td>
<td>12343</td>
<td>1568</td>
<td>0.02663 ± 0.00099</td>
</tr>
<tr>
<td>Spinel-chromite grain #15</td>
<td>16167</td>
<td>9958</td>
<td>326367</td>
<td>17278</td>
<td>3040</td>
<td>0.02736 ± 0.00062</td>
</tr>
<tr>
<td>Spinel-chromite grain #16</td>
<td>155757</td>
<td>28137</td>
<td>688947</td>
<td>37193</td>
<td>5502</td>
<td>0.02627 ± 0.00050</td>
</tr>
<tr>
<td>Spinel-chromite grain #17</td>
<td>28705</td>
<td>7284</td>
<td>197700</td>
<td>10318</td>
<td>2832</td>
<td>0.02760 ± 0.00088</td>
</tr>
<tr>
<td>Spinel-chromite grain #18</td>
<td>125641</td>
<td>48791</td>
<td>1504963</td>
<td>80955</td>
<td>33464</td>
<td>0.02710 ± 0.00030</td>
</tr>
<tr>
<td>Spinel-chromite grain #19</td>
<td>67953</td>
<td>28705</td>
<td>901944</td>
<td>48643</td>
<td>19440</td>
<td>0.02703 ± 0.00038</td>
</tr>
<tr>
<td>Spinel-chromite grain #20</td>
<td>86678</td>
<td>52648</td>
<td>1716091</td>
<td>91399</td>
<td>11601</td>
<td>0.02739 ± 0.00027</td>
</tr>
<tr>
<td>Spinel-chromite grain #21</td>
<td>202470</td>
<td>65443</td>
<td>1924073</td>
<td>102928</td>
<td>19380</td>
<td>0.02731 ± 0.00027</td>
</tr>
<tr>
<td>Spinel-chromite grain #22</td>
<td>14451</td>
<td>238780</td>
<td>8770585</td>
<td>471830</td>
<td>40726</td>
<td>0.02710 ± 0.00011</td>
</tr>
<tr>
<td>Spinel-chromite grain #23</td>
<td>171312</td>
<td>34428</td>
<td>1220209</td>
<td>65652</td>
<td>12948</td>
<td>0.02732 ± 0.00031</td>
</tr>
<tr>
<td>Terrestrial chromite standard #1</td>
<td>213773</td>
<td>49974</td>
<td>1344331</td>
<td>71780</td>
<td>5202</td>
<td>0.02704 ± 0.00034</td>
</tr>
<tr>
<td>Terrestrial chromite standard #2</td>
<td>175924</td>
<td>41637</td>
<td>1135145</td>
<td>60311</td>
<td>4795</td>
<td>0.02692 ± 0.00037</td>
</tr>
<tr>
<td>Terrestrial chromite standard #3</td>
<td>161579</td>
<td>39283</td>
<td>1050387</td>
<td>55147</td>
<td>4723</td>
<td>0.02717 ± 0.00038</td>
</tr>
</tbody>
</table>

Average of the standard: 0.02705 ± 0.00015

*a, b* Example of analytical results obtained in one day.

*54Cr*2: Total count of each ion, i.e., summation of several pixels.

*54Cr*1: Example of analytical results obtained in one day.

*54Cr*1 ratios are calculated using Eq. (1). Errors represent counting statistics (2σ).

*54Cr*2: Ratios of ion counts, not atomic ratios (see text).

*54Cr*1 ratios from the *54Cr*3/52Cr ratio of the terrestrial chromite standard (0.02705). The uncertainty of that value was propagated to errors of *54Cr*2 ratios of the sample.

\[
\left( \frac{54\text{Cr}}{52\text{Cr}} \right) = \frac{54M_{\text{Fe}} - 54\text{Fe}}{54\text{Cr}} = \frac{54M_{\text{Fe}} - 54\text{Fe}}{54\text{Cr}} \times \frac{54\text{Fe}/56\text{Fe}}{\text{ref.}}
\]

where *54M* is the total ion signal at mass 54 (sum of *54Cr and *54Fe) and (*54Fe/56Fe)*ref. represents the solar *54Fe/56Fe ratio of 0.063703 (Lodders, 2003). In this calculation, mass fractionation of Fe (irrespective of instrumental and intrinsic) was not considered for the reasons described below: 1) A presolar grain is likely to have a large isotopic anomaly of Cr according to previous results (e.g., Nittler et al., 2010), and as a result, the uncertainty of *54Fe/56Fe* ratio seems negligible; 2) The leach fractions with the greatest *54Cr anomalies in the stepwise dissolution experiment have no isotopic anomaly of other elements including Fe (Rotaru et al., 1992); 3) The presolar grains are likely enriched in Cr (Podosek et al., 1997). Obtained *54Cr/52Cr* ratios of analyzed samples are expressed as a deviation from that of the terrestrial standard in permil:

\[
\delta^{54}\text{Cr} = \left( \frac{54\text{Cr}}{52\text{Cr}} \right)_{\text{sample}} - \left( \frac{54\text{Cr}}{52\text{Cr}} \right)_{\text{std}} \times 1000
\]

where (*54Cr/52Cr)*sample and (*54Cr/52Cr)*std are *54Cr/52Cr...
results of a meteoritic sample and the terrestrial standard, respectively. The reproducibility of $^{54}\text{Cr}/^{52}\text{Cr}$ ratios of the terrestrial chromite standard ranged 6‰ to 25‰, which varied from day to day. The uncertainties of ($^{54}\text{Cr}/^{52}\text{Cr})_{\text{std}}$ were propagated to the errors of $\delta^{54}\text{Cr}$. $^{56}\text{Cr}$ also has irresolvable isobaric interferences of $^{50}\text{Ti}$ and $^{50}\text{V}$, and $^{56}\text{Fe}/^{52}\text{Cr}$ ratios could not be corrected for their contributions because other isotopes of Ti and V were not measured. Therefore, the $^{56}\text{Fe}/^{52}\text{Cr}$ ratios are not referred to in the following discussion.

RESULTS AND DISCUSSION

Data for approximately 200 Cr-rich grains are plotted in a $\delta^{54}\text{Cr}$ vs. $^{56}\text{Fe}/^{52}\text{Cr}$ diagram (Fig. 3) and some of the data obtained in one day are given in Table 1. $^{54}\text{Cr}/^{52}\text{Cr}$ ratios are also shown in a histogram (Fig. 4). The relative sensitivity factor for Fe/Cr is not fully understood. Therefore, $^{56}\text{Fe}/^{52}\text{Cr}$ values do not represent true $^{56}\text{Fe}/^{52}\text{Cr}$ atomic ratios. Data for grains with high $^{56}\text{Fe}/^{52}\text{Cr}$ ratios have large corrections for $^{54}\text{Fe}$; e.g., if $^{56}\text{Fe}/^{52}\text{Cr} = 1$, ions at mass 54 consists of ~70% $^{54}\text{Fe}$ and 30% $^{54}\text{Cr}$. As illustrated in Figs. 3 and 4, most grains show the terrestrial Cr isotopic composition within the 2 standard deviation of ~30‰. No grain was confirmed to have a presolar grain with a large $^{54}\text{Cr}$ anomaly expected from the results of previous studies (e.g., Qin et al., 2010). This result also indicates that if $^{56}\text{Fe}/^{52}\text{Cr}$ ratios of the grains are less than ~1, $\delta^{54}\text{Cr}$ values can be determined with uncertainties of ±30‰ in spite of the possible presence of (instrumental and/or intrinsic) mass fractionation of Cr and Fe. Although mass fractionation of Cr and Fe affects calculated $\delta^{54}\text{Cr}$ values, it is found to be negligible when large isotopic anomalies are searched for. However, it appears difficult to determine $\delta^{54}\text{Cr}$ values of grains with higher $^{56}\text{Fe}/^{52}\text{Cr}$ ratios (>1) with a precision of 30‰.

The CsF technique used for extraction of the organic residue removes silicates. Therefore it is unlikely that silicates are candidates for the carriers of $^{54}\text{Cr}$ anomalies in the organic residues of carbonaceous chondrites. Incomplete dissolution of presolar SiC grains may be a possible candidate for the $^{54}\text{Cr}$ anomaly, as suggested by Dauphas et al. (2002b) for the Mo isotopic anomaly in Orgueil. However, the measured $\delta^{54}\text{Cr}$ values of SiC grains were indistinguishable from the terrestrial value (Savina et al., 2010). Therefore, they concluded that incomplete dissolution of presolar SiC grains is not the source of the $^{54}\text{Cr}$ anomalies in leachates of carbonaceous chondrites. They also suggested that SiC doesn’t contain a significant amount of Cr (~1 ppm; Knight et al., 2008), so even if the SiC had a large anomaly of $^{54}\text{Cr}$ the effect of incomplete dissolution seems small. Isotope data on refractory inclusions (Birck, 2004) and nucleosynthetic calculations (Woosley et al., 2002) indicate that $^{54}\text{Cr}$ anomalies should be associated with detectable effects on the other heavy isotopes of the iron peak elements. However, no correlative anomaly of any other elements, including iron group elements, has yet been found in the fractions by the stepwise dissolution of bulk meteorites (e.g., no anomaly was found in Ni isotopes for the fractions with Cr isotopic anomalies; Rotaru et al., 1992). The absence of correlative anomalies in other elements suggests that the carriers of $^{54}\text{Cr}$ anomalies are chemically enriched in Cr (Podosek et al., 1997).

The number of grains analyzed in this study was about 200 and they are dominated by spinel-chromite and almost pure Cr$_2$O$_3$ grains. Although these phases are generally thought to be not sufficiently soluble in HCl, it is not impossible that due to their small grain sizes, these phases are soluble in HCl and are the carriers of $^{54}\text{Cr}$ excesses in the organic residues of carbonaceous chondrites. Qin et al. (2010) reported that both the HCl leachates and residues of the Murchison organic-rich separates show $^{54}\text{Cr}$ excesses, supporting the idea that there could be $^{54}\text{Cr}$-rich oxide grains in the organic residues of carbonaceous chondrites (at least Murchison). In fact, chrome and Cr-rich spinel grains of <200 nm with large $^{54}\text{Cr}$ enrichments were recently reported in the organic residue of Orgueil, although the nature of these grains is not yet well understood (Qin et al., 2009; Dauphas et al., 2010; Nittler et al., 2010). In a previous NanoSIMS analysis of an organic residue from Orgueil (Nittler et al., 2005), 5 presolar chromite grains and one Al$_2$O$_3$ grain of out ~2700 O-rich grains were identified based on oxygen isotopic anoma-
Simulations have suggested that 54Cr associated with other
isotopes are expected to form in the ejecta of supernovae as sug-
gested by Kozasa et al. (1991). If this is the case, an iso-
topic anomaly is ~90‰. Indeed, Qin et al. (2009) reported a few chromite
grains of ~200 nm with positive 54Cr/52Cr anomalies of 100‰ to 300‰. Astrophysical
simulations have suggested that 54Cr associated with other neutron-rich isotopes of the iron-group elements is pro-
duced in a neutron-rich environment at or near nuclear statistical equilibrium in massive stars prior to the super-
nova stage (Woosley et al., 2002). Fine grains of <10 µm in size) in a Murchison
organic residue is ~1 ppm. This means that the minimum iso-
topic anomaly is ~90‰. If (2) is the case, the maximum abundance of presolar Cr can be es-
timated to be ~1 ppm. This means that the minimum iso-
topic anomaly is ~90‰. In this study, the analyzed ~200 Cr-rich grains were all acid re-
sistant phases and showed the terrestrial 54Cr/52Cr ratio. Considering one previous report on the abundance of presolar oxide grains, however, it may be reasonable to
assume that no presolar grain was identified in the 200 grains analyzed in this study.

ACKNOWLEDGMENTS—The NanoSIMS 50 was made available
through the courtesy of Dr. Y. Sano at Atmosphere and Ocean Research Institute, the University of Tokyo. We are grateful to Dr. S. Nakai for constructive comments. We thank K. Ichimura for analytical support of the FE-SEM and assistance for chemi-
cal treatments to extract the organic residue from the Murchison meteorite. We are grateful to the GCOE program instructors of the University of Tokyo for proofreading/editing assistance.

REFERENCES


Birk, J. L. and Allègre, C. J. (1984) Chromium isotopic anomali-


Bizzarro, M., Baker, J. A., Haack, H. and Lundgaard, K. L.


Cr isotope measurement of Cr-rich grains in Murchison 281