Radiation Damage of LaMgAl$_{11}$O$_{19}$ and CeMgAl$_{11}$O$_{19}$ Magnetoplumbite

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Studies of radiation damage in magnetoplumbite-type LaMgAl$_{11}$O$_{19}$ and CeMgAl$_{11}$O$_{19}$ are reported. Ion irradiation was conducted on ceramic composites containing a LaMgAl$_{11}$O$_{19}$ phase at 500°C with 10 MeV Au$^+$ ions and on ceramic composites containing CeMgAl$_{11}$O$_{19}$ phase at 800°C with 92 MeV Xe$^+$ ions. The radiation response of these similar LaMgAl$_{11}$O$_{19}$ (Ln = La and Ce) hexaaluminate magnetoplumbite phases was evaluated using transmission electron microscopy (TEM) and X-ray diffraction (XRD). LaMgAl$_{11}$O$_{19}$ was amorphized by 10 MeV Au$^+$ ions with swelling of the structure within an approximate 2 μm radiation depth from the irradiation surface. CeMgAl$_{11}$O$_{19}$ did not amorphize after 92 MeV Xe$^+$ ion irradiation, but ion track damage contrast is seen in approximately 5 μm of the irradiated depth. SRIM Monte-Carlo simulations of nuclear displacements correlate with the experimental results.

I. Introduction

Inert matrix nuclear fuels with both fissile and nonfissile phases can be designed to offer (1) increased thermal conductivity, (2) second phases that can accommodate fission byproducts while they are being created, and (3) decreased microstructural evolution by providing alternative interfaces that can be more efficient sinks for defects. Recently, four-phase ceramic composites of 3Y-TZP–Al$_2$O$_3$–MgAl$_2$O$_4$–LaPO$_4$ were developed to serve as models for the ceramic fuel concept. Under certain process conditions, a fifth phase, LaMgAl$_{11}$O$_{19}$, could be formed by solid-state reaction during sintering. In a related study, CeMgAl$_{11}$O$_{19}$ was observed to form using an initial model composite of composition CeO$_2$–Al$_2$O$_3$–MgAl$_2$O$_4$. These two phases can be classified as magnetoplumbite-type LnMAl$_{11}$O$_{19}$ (Ln = lanthanide, M = divalent spinel-forming ion), a hexagonal crystal structure with a space group of $P6_3/mmc$ (Space Group No. 194).

Magnetoplumbite is a naturally occurring mineral with the general chemical formula PbM$_3$O$_{19}$, where M has a +3 valence. The crystal lattice of Ln-magnetoplumbite consists of close-packed oxygen in spinel blocks separated by perovskite-like layers that contain lanthanide cations (Fig. 1). These materials are also known as hexaaluminates, a broader class that includes not only the alumina-rich magnetoplumbites in which large cations are 12-fold coordinated but also β-alumina (NaAl$_{11}$O$_{19}$), a structure with similar spinel blocks but with ninefold coordination of the large cations. In magnetoplumbite-type structures, the layers containing the large cations (such as lanthanides) are mirror planes, so the unit cell in the c-direction is twice that for β-alumina.

The radiation damage of magnetoplumbite is of considerable interest as it has been proposed as a potential component in nuclear waste due to its ability to incorporate an extraordinary variety of fission products (including the high yield nuclides of Sr, Ba, Cs, La, and Ce) and actinide elements. It is also structurally similar to other ionic materials with close-packed oxygen that resist radiation damage. Morgan et al. demonstrated that Al$_2$O$_3$ added to radioactive waste could form a solid solution magnetoplumbite structure, with multiple large ions in the waste accommodated in the magnetoplumbite crystalline lattice sites. Excess Al$_2$O$_3$ can form insoluble spinel and remain asă-alumina, phases that microstructurally isolate radionuclides in the magnetoplumbite phase to help to prevent leaching and increase the thermal conductivity. Although these studies have suggested that Ln-containing magnetoplumbite phases should be considered for fission product immobilization in nuclear waste forms, to date there are scant data from published radiation studies to support such proposals.

Despite the lack of information on swift heavy-ion irradiation behavior of Ln-magnetoplumbites, studies conducted in similar crystal systems may be relevant. Hibonite, a mineral of nominal composition CaAl$_{12}$O$_{19}$, has a similar structure to magnetoplumbite and also has a lathlike grain morphology. Hibonite is found in meteorites formed from presolar star dust and despite containing fission tracks for Pu$^{234}$ from natural fission, the hibonite grains remain crystalline, indicating that this material is fairly robust against radiation damage. Vance et al. followed up with a study on synthetic CaAl$_{12}$O$_{19}$ irradiated with 3 MeV Ar ions at room temperature and found superior damage resistance against amorphization when compared with other crystal structures including monazite. Plans close to the basal plane orientation, however, showed damage with the (008) X-ray diffraction (XRD) reflections disappearing after 10$^{12}$ ions/cm$^2$ irradiation whereas (110) reflections remained unchanged and a 1% lattice expansion along the c-axis for 3 × 10$^{17}$ ions/cm$^2$ irradiation. Hexagonal ferrite BaFe$_2$O$_{19}$, used for permanent magnets, also has a magnetoplumbite-related crystal structure. Studies with highly energetic heavy ions (Ar and Kr > 1 GeV and fluxes of 10$^{13}$ and 10$^{14}$) in BaFe$_2$O$_{19}$ created disordered and amorphized zones in some regions and defects including stacking faults and a loss of periodicity.

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along the c-axis for other regions, the latter similar to the basal plane damage reported for CaAl$_2$O$_4$.24

To evaluate the potential of lanthanide magnetoplumbites for either use in inert matrix fuel or as a waste form for lanthanide fission product retention, it is important to understand their specific irradiation response. Thus in the experiments detailed here, the microstructural response of LaMgAl$_{11}$O$_{19}$ and CeMgAl$_{11}$O$_{19}$ phases at the surface of a composite under irradiation by energetic heavy ions is evaluated. These two magnetoplumbite phases have the same crystal structure and similar lattice parameters. La and Ce are next to each other in the periodic table, and have similar cation outer electron shell configuration and ionic sizes (1.36 Å for La$^{3+}$ and 1.34 Å for Ce$^{3+}$),5,25 so it is expected that the radiation damage behavior of one phase should be a fairly good predictor for the other. Two different types of irradiation were deliberately used to show the differences that can result.

II. Experimental Procedures

(1) Sample Fabrication

Five-phase and three-phase ceramic composites were fabricated consisting of LaMgAl$_{11}$O$_{19}$–3Y-TZP–Al$_2$O$_3$–MgAl$_2$O$_4$–LaPO$_4$ (“LaMgAl$_{11}$O$_{19}$ composite”) and CeMgAl$_{11}$O$_{19}$–MgAl$_2$O$_4$–CeO$_2$ (“CeMgAl$_{11}$O$_{19}$ composite”). Ceramic powder mixtures were sintered at 1773–1873 K (1500°C–1600°C) for 3 h. The formation of magnetoplumbite can be identified on the XRD patterns by the (114) characteristic peak for the magnetoplumbite structure (Fig. 2). The solid-state reactions were as follows:

\[ 9\text{Al}_2\text{O}_3 + 2\text{MgAl}_2\text{O}_4 + 2\text{LaPO}_4 \rightarrow 2\text{LaMgAl}_{11}\text{O}_{19} + \text{P}_2\text{O}_5 \]

\[ 9\text{Al}_2\text{O}_3 + 2\text{MgAl}_2\text{O}_4 + 2\text{CeO}_2 \rightarrow 2\text{CeMgAl}_{11}\text{O}_{19} \]

Samples were cut into disks of 1 mm in thickness, with a diameter of 10 mm. The surfaces of the samples were polished with 60 nm colloidal silica for later microscopy observation and ion irradiation. The morphology of LaMgAl$_{11}$O$_{19}$ grains shown in Fig. 3 indicates exaggerated and anisotropic grain growth in the presence of a liquid phase. It is important to note that the magnetoplumbite grains form at the surface so they can be directly exposed to irradiation.

(2) Ion Irradiation and SRIM Monte-Carlo Simulations

Two sets of ion irradiation experiments were performed on the samples to evaluate the response of magnetoplumbite to different types of radiation damage sources. The LaMgAl$_{11}$O$_{19}$ composite was irradiated with 10 MeV Au ions to a fluence of $1 \times 10^{16}$ ions/cm$^2$ at 773 K (500°C),26 which at the end of the range simulate the damage caused by primary knock-on atoms (PKA) created by neutrons. The CeMgAl$_{11}$O$_{19}$ composite was irradiated with 92 MeV Xe ions at 1073 K (800°C) with fluences ranging from $10^{12}$ ions/cm$^2$ to $10^{13}$ ions/cm$^2$ to simulate the damage caused by fission fragments. Ion beams usually cause accumulated damage at a rate faster than that by irradiation in a reactor or in a nuclear waste, hence the use of higher temperature allows one to slowdown the rate of damage and also create near to realistic modifications. Figure 4–show SRIM Monte-Carlo simulated ion irradiation characteristics for the specific ion energy and material types in this study.27,28 The densities for different phases used for the SRIM calculation are listed in Table I. These experiments do generate more damage (~20 dpa) in LaMgAl$_{11}$O$_{19}$ comparing with natural damage accumulation in waste forms within 1000 yr (~10 dpa). However, as the half-life of some of the minor actinides is $1 \times 10^5$ yr, hundreds of dpa's damage is expected to accumulate in waste forms from radionuclides, so there is
scientific relevance to using ion beams for simulating damage by radionuclides.

The five phases present in the LaMgAl\textsubscript{11}O\textsubscript{19} composite (3Y-TZP, Al\textsubscript{2}O\textsubscript{3}, LaPO\textsubscript{4}, MgAl\textsubscript{2}O\textsubscript{4}, and LaMgAl\textsubscript{11}O\textsubscript{19}) exhibit different ion penetration depth and peak damage doses due to the difference in ion stopping power (Fig. 4). For 92 MeV Xe ion irradiation, the displacement damage is greater at larger depths than near the surface. Figure 5 shows the comparison of estimated energy loss partitioned between nuclear ($S_n$) and electronic stopping ($S_e$) for 10 MeV Au ions in the LaMgAl\textsubscript{11}O\textsubscript{19} composite and 92 MeV Xe ions in the CeMgAl\textsubscript{11}O\textsubscript{19} composite as a function of target depth. The dominating role of $S_e$ is more important in 92 MeV Xe ion irradiation comparing with that in 10 MeV Au ion irradiation (1.8–2.0 μm vs 8–9 μm), the Au ions actually cause more atomic displacements.

### III. Results and Discussion

#### (1) LaMgAl\textsubscript{11}O\textsubscript{19} Irradiated by 10 MeV Au

Microstructural evolution induced by the ion beam damage was investigated by plan-view SEM (Fig. 7). Although Al\textsubscript{2}O\textsubscript{3}, MgAl\textsubscript{2}O\textsubscript{4}, and ZrO\textsubscript{2} phases are unchanged, the monazite appears to have melted. Before irradiation, the LaMgAl\textsubscript{11}O\textsubscript{19} grain surface was flat and the same height as other neighboring phases (Fig. 7(a)]. After 10 MeV Au ion irradiation, the top surface of the LaMgAl\textsubscript{11}O\textsubscript{19} swelled (Fig. 7(b)], suggesting

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**Table I. Density for Different Phases Present in the System (unit: g/cm\textsuperscript{3})**

<table>
<thead>
<tr>
<th>Material</th>
<th>3Y-TZP</th>
<th>Al\textsubscript{2}O\textsubscript{3}</th>
<th>CeMgAl\textsubscript{11}O\textsubscript{19}</th>
<th>CeO\textsubscript{2}</th>
<th>LaMgAl\textsubscript{11}O\textsubscript{19}</th>
<th>LaPO\textsubscript{4}</th>
<th>MgAl\textsubscript{2}O\textsubscript{4}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>6.05</td>
<td>3.89</td>
<td>4.24</td>
<td>7.00</td>
<td>4.27</td>
<td>5.08</td>
<td>3.58</td>
</tr>
</tbody>
</table>

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**Fig. 4.** SRIM Monte-Carlo simulations of nuclear displacements in units of displacements per atom (dpa),\textsuperscript{27} as a function of target depth for (a) 10 MeV Au ion irradiations (fluence = $1 \times 10^{16}$ Au/cm\textsuperscript{2}) of five different phases present in LaMgAl\textsubscript{11}O\textsubscript{19} composite: 3Y-TZP, Al\textsubscript{2}O\textsubscript{3}, LaPO\textsubscript{4}, MgAl\textsubscript{2}O\textsubscript{4}, and LaMgAl\textsubscript{11}O\textsubscript{19}, and (b) 92 MeV Xe ion irradiations (fluence = $1 \times 10^{12}$ Xe/cm\textsuperscript{2}) of three different phases present in CeMgAl\textsubscript{11}O\textsubscript{19} composite: CeO\textsubscript{2}, MgAl\textsubscript{2}O\textsubscript{4}, and CeMgAl\textsubscript{11}O\textsubscript{19}.

**Fig. 5.** SRIM simulation estimates for $S_n$ and $S_e$ as a function of depth for (a) 10 MeV Au ions in five phases present in LaMgAl\textsubscript{11}O\textsubscript{19} composite and (b) 92 MeV Xe ions in three phases present in CeMgAl\textsubscript{11}O\textsubscript{19} composite. Note that although the damage range of the incident Au ions is much more shallow compared with Xe ion irradiation (1.8–2.0 μm vs 8–9 μm), the Au ions actually cause more atomic displacements.

### (3) Microstructural Characterization

Crystalline phases were identified before and after ion irradiation by XRD, Siemens/Bruker D5000 XRD (Siemens/Bruker, Karlsruhe, Germany). Plan-view microstructure evolution before and after ion irradiation was investigated using scanning electron microscope (SEM), Zeiss Ultra Plus 55 (Zeiss, Jena, Germany). Chemical compositions of grains were identified by energy-dispersive X-ray spectroscopy (EDS). Accordingly, cross-section transmission electron microscopy (TEM) samples of ion-irradiated composites were prepared using focused ion beam (FEI Quanta 3D FEG Dual Beam, FEI, Eindhoven, the Netherlands) to include both pristine and radiation-damaged regions for comparison. TEM observations were carried out to study radiation damage at different depths of the materials [FEI Tecnai F20 (FEI, Eindhoven, the Netherlands) and Philips CM20 (Philips, Eindhoven, the Netherlands) operated at 200 keV, JEOL 3010 (JEOL, Tokyo, Japan) operated at 300 keV].
possible irradiation-induced volume expansion due to amor-
phization. XRD results on the Au-irradiated LaMgAl\textsubscript{11}O\textsubscript{19} composite could not be obtained due to the small irradiated
area. Instead, the degree of crystallinity of the LaMgAl\textsubscript{11}O\textsubscript{19} phase after Au irradiation was verified by TEM

A cross-section TEM sample of Au-irradiated LaMgAl\textsubscript{11}O\textsubscript{19} shows a large LaMgAl\textsubscript{11}O\textsubscript{19} grain, which stretches
from the irradiated surface over to the end of the irradiation
zone (Fig. 8). High-resolution TEM (HRTEM) imaging and
selected-area diffraction (SAD) were performed on three dif-
f erent locations within the LaMgAl\textsubscript{11}O\textsubscript{19} grain (\textit{a}, \textit{b}, and \textit{c})
to investigate the microstructure with respect to irradiation
depth. The HRTEM image obtained from position \textit{a} in
Fig. 8, 500 nm in the Au irradiation surface, shows an amor-
phous structure [Fig. 9(a)], corresponding to diffuse rings
both in the fast Fourier transform (FFT) pattern of the
HRTEM image and in the SAD pattern from this region
[Fig. 9(a\textsuperscript{'}) and (a\textsuperscript{''})]. Further away from the surface, 1.5 \textmu m in depth (position \textit{b} in Fig. 8), diffraction maxima dimly
appears both in the FFT pattern and SAD, indicating the
existence of short-range order in the structure [Fig. 9(b\textsuperscript{'}) and
(b\textsuperscript{''})]. In position \textit{c} at 3 \textmu m radiation depth, clear lattice
fringes are observed in the HRTEM image and sharp diffra-
tion maxima in the SADP, both of which are characteristic
of a highly crystalline state [Fig. 9(c–c\textsuperscript{'})]. Therefore, it can
be concluded that LaMgAl\textsubscript{11}O\textsubscript{19} is amorphized by 10 MeV
Au ions in regions within the approximately 2 \textmu m radiation
depth from the irradiated surface, the depth predicted to be
affected by Au ions according to SRIM simulations.

All other phases present in this LaMgAl\textsubscript{11}O\textsubscript{19} composite, namely Y-TZP, Al\textsubscript{2}O\textsubscript{3}, MgAl\textsubscript{2}O\textsubscript{4}, and LaPO\textsubscript{4}, were verified
to be crystalline after 10 MeV Au irradiation with no amor-
phization detected throughout the ion beam damage zone.\textsuperscript{2}

\subsection*{(2) CeMgAl\textsubscript{11}O\textsubscript{19} irradiated by 92 MeV Xe}

Figure 10 compares XRD patterns of the CeMgAl\textsubscript{11}O\textsubscript{19} com-
posite before and after 92 MeV Xe irradiation. The only
existing XRD pattern of CeMgAl$_{11}$O$_{19}$ (JCPDS # 00-026-0872) shows inaccurate relative intensity ratios of the peaks, so the pattern for LaMgAl$_{11}$O$_{19}$ (JCPDS 78-1854) was used instead for identification. No changes such as peak broadening or peak shifts occur in the XRD patterns after irradiation, suggesting that all phases are stable under swift heavy-ion irradiation without amorphization. Similarly, no obvious changes in the microstructure can be detected in plan-view SEM for the CeMgAl$_{11}$O$_{19}$ composite before and after 92 MeV Xe irradiation (Fig. 11).

Cross-sectional TEM and SAD on the irradiation zone of CeMgAl$_{11}$O$_{19}$ composite after irradiation by 92 MeV Xe ions reveals that the three phases present, namely CeMgAl$_{11}$O$_{19}$, MgAl$_2$O$_4$, and CeO$_2$, are all crystalline and can be indexed to the initial crystalline phases (Fig. 12 and 13). This is true for all regions from the surface to the interior and shows that CeMgAl$_{11}$O$_{19}$ and the other phases are not amorphized by the Xe ion beam.

Although there was no amorphization, multiple parallel dark lines of contrast were observed by cross-section TEM imaging in CeMgAl$_{11}$O$_{19}$ grains within a 5 µm depth from the irradiation surface (Fig. 14). These lines are parallel to the Xe ion direction, marked by arrows in Fig. 14. This contrast and the direction of the damage is similar to that expected for ion track damage, although high-resolution nanodiffraction and additional TEM (HRTEM) studies are most likely required to provide definitive proof. Figure 14(e′) shows a HRTEM image of the CeMgAl$_{11}$O$_{19}$ grain e on the irradiation surface in Fig. 12. The morphology of ion tracks cannot be clearly delineated in this image from the magnetoplumbite grain at the surface, which might be partly due to the fact that the high fluence of the Xe ion irradiation
(10^12 Xe/cm^2) could produce numerous, overlapped damage tracks that are difficult to distinguish. Dislocations and strain contrast appear in CeMgAl_{11}O_{19} grains deeper in the sample, where there is no ion track contrast. The ion track damage appears to end approximately 5 µm into the material.

Although the SRIM Monte-Carlo Simulation shows that the displacement damage in CeMgAl_{11}O_{19} is greater at around 8 µm depths than near the surface [Fig. 4(b)], grain f (diffraction not shown) is 7.5 µm away from the surface and the c planes were still strongly diffracting with no indication of amorphization.

(3) Comparisons

When comparing these current results on lanthanide-containing magnetoplumbites with the earlier results on CaAl_{12}O_{19}, several important differences need to be noted. Ca hexaaluminate contains no heavy lanthanide ions. Although the ion fluxes used for the irradiation study on CaAl_{12}O_{19} are in a similar range to those used in this study, Ar^+ ions used in that study are much smaller and lighter than Xe^+. The irradiation temperature is also not reported for the CaAl_{12}O_{19} studies so direct comparisons cannot be made, but as minimal damage was observed both in that study and in this study for Xe irradiation of CeMgAl_{11}O_{19}, this indicates the stability of the magnetoplumbite crystal structure under certain conditions.

Dark line contrast found by TEM in BaFe_{12}O_{19} irradiated with 3 GeV Xe ions has also been attributed to nuclear tracks. The ion track damage in that magnetic magnetoplumbite BaFe_{12}O_{19} was postulated to be due to the dominance of electronic stopping, similar to this study of 92 MeV Xe^+ irradiation in Ce-magnetoplumbite. Single crystal BaFe_{12}O_{19} irradiated with 1.8 GeV Ar^+ ions at 90–160 K and a fluence of 10^{12} ions/cm^2 is reported to have less damage in the high-energy zones near the surface than in regions deeper into the sample that experienced lower energy, but became amorphous. Similarly, a higher degree of radiation damage is seen in these studies of 10 MeV Au^+ irradiated La-magnetoplumbite compared with the 92 MeV Xe^+-irradiated Ce-magnetoplumbite that did not amorphize. Another magnetic magnetoplumbite ferrite, SrFe_{12}O_{19}, became partially amorphized when irradiated at room temperature with 50 MeV Li^+ ions and a fluence of 10^{14} ion/cm^2 (evaluated by XRD). The studies on other types of magnetoplumbite are difficult to directly correlate, however, as the temperature of those experiments is usually at room temperature in contrast to the higher temperatures used in these current experiments. Temperature can play a significant role as described in the next paragraph.

As the two magnetoplumbites are expected to be chemically similar, observation that 10 MeV Au irradiation causes amorphization in LaMgAl_{11}O_{19}, whereas 92 MeV Xe results in presumed ion track damage in CeMgAl_{11}O_{19} may be attributed to (1) difference in energy loss of the two irradiation damage sources and (2) higher irradiation temperatures during the 92 MeV Xe ion irradiation. The irradiation damage zone simulated by SRIM is approximately 1.8–2.0 µm deep for 10 MeV Au irradiation, and 8–9 µm deep for 92 MeV Xe irradiation (Fig. 5). Although the damage range of the Au ions is much shallower in LaMgAl_{11}O_{19} as compared with Xe ions in CeMgAl_{11}O_{19} (1.5 µm vs 9 µm), the ratio of electronic-to-nuclear stopping is lower in the case of 10 MeV Au than 92 MeV Xe. As all energetic ions lose energy and cause modifications by both Se and Sn, and most of the researchers usually state one or the other, thus to be realistic, it is important to compare damages to the ratio of...
In our case, this is hugely different for Xe as compared with Au. The Au ions cause more atomic displacements compared with 92 MeV Xe ion, which predominantly loses energy via ionization of the target atoms.

Fig. 12. Cross-section TEM bright-field image of CeMgAl_{11}O_{19} composite irradiated by 92 MeV Xe ions to a fluence of 10^{12} Xe/cm². One grain from each phase is marked for corresponding selected-area diffraction observations in (Fig. 13). Grain a = MgAl_{2}O_{4}; Grain b = CeO_{2}; Grain c = CeMgAl_{11}O_{19}. Imaging at higher magnification was done on three additional CeMgAl_{11}O_{19} grains (d, e, f) to better show ion track morphology (Fig. 14).

Fig. 13. SAD patterns obtained from the three grains representing as marked in Fig. 12, and indexed based on the crystal structures of each phase. (a) MgAl_{2}O_{4} with [2 1 1] zone axis, (b) CeO_{2} with [1 1 1] zone axis, (c) CeMgAl_{11}O_{19} with [1 1 0 0] zone axis.

Fig. 14. (d)–(f) Cross-section TEM bright-field images of CeMgAl_{11}O_{19} regions d, e, and f, as marked in Fig. 12. The direction of the Xe ions entering the sample is indicated by arrows in each micrograph. Regions d and e show dark line contrast interpreted to be Xe ion irradiation ion track damage. Further in the interior, no such contrast is observed in grain f, just dislocations and strain contrast. (e′) is a high-resolution TEM (HRTEM) image obtained from grain e.

\[ \frac{S_e}{S_a} \] In our case, this is hugely different for Xe as compared with Au. The Au ions cause more atomic displacements compared with 92 MeV Xe ion, which predominantly loses energy via ionization of the target atoms.

The higher energy ions can create a large transient rise in lattice temperatures, which could lead to rapid annealing of the damage. In addition, higher irradiation temperatures
used for Xe irradiations can further facilitate the damage recovery. If the damage is recovered by high irradiation temperatures then the critical temperature for amorphization could be between 500°C and 800°C. On the other hand, if the damage is self-annealed due to deposition of energy predominantly in the electronic stopping regime by ions similar to fission fragments (in this case 92 MeV Xe), then magnetoplumbites could be used as a potential candidate for inert matrix fuels where the damage caused by PKA would be annealed by the fission fragments and high reactor operating temperatures. To further support these conclusions, studies of the detailed irradiation response as a function of temperatures and the stability of (001) magnetoplumbite planes need to be conducted, not possible in this study using XRD due to the low intensities relative to other phases in the composites.

IV. Conclusions

Radiation damage studies were carried out on two types of magnetoplumbites, LaMgAl11O19 and CeMgAl11O19. LaMgAl11O19 became amorphous after 10 MeV Au ion irradiation at 500°C to depths of approximately 2 µm. Radiation-induced dark lines of contrast were observed in CeMgAl11O19 after irradiation by 92 MeV Xe ions at 800°C, interpreted to be due to ion track damage at depths up to 5 µm from the surface, but in this case the magnetoplumbite remained crystalline. It can be concluded that radiation damage in magnetoplumbites can cause amorphization, however, irradiations at temperatures near 800°C with swift heavy ions may also facilitate the recovery of damage.

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