

Reactivity and Charge Transfer in Aluminum Alloy AA2618 Reinforced with Alumina Particles

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Introduction

Lightweight materials with high strength and excellent dimensional stability are in great demand in the transportation industry. Particulate aluminum metal matrix composites (MMCs) reinforced with ceramic particles have been developed to address this need. The use of MMCs in vehicles will reduce fuel consumption and hence greenhouse gas emission.

Although the ceramic particles contained in particulate MMCs are considered inert, some of them can react with aluminum alloys during fabrication [1-4], thereby complicating the analysis of their properties and microstructures. Hitherto, thermal analysis, electron microscopy (EM) and X-ray diffraction (XRD) techniques have been widely used to study matrix-reinforcement reactions in particulate MMCs [2, 4].

X-ray absorption spectroscopy (XAS) is an electronic structure technique that provides complimentary structure and bonding information. However, literature on its use to study reactivity in MMCs is very scarce. In this work, reactivity and charge transfer in Al-Mg-Cu-Fe-Ni alloy AA2618 containing alumina (Al_2O_3) particles was investigated using XAS. AA2618 has a very good elevated temperature strength which makes it an attractive material for fabricating automobile and aircraft engine components.

Materials and Methods

The materials studied were aluminum alloy AA2618 and its composites containing 10 and 15 vol.% Al_2O_3 particles (AA2618/ Al_2O_3 /10p and AA2618/ Al_2O_3 /15p, respectively). High purity aluminum (99.999%), α - Al_2O_3 (99.99%) and spinel (99%) powder were used as reference materials. Test samples of AA2618 and its composites used in XAS measurements were solution heat treated at $530 \pm 5^\circ\text{C}$ for 2 hours, water quenched, polished metallurgically, rinsed in methanol and distilled water, and then overaged at 200°C for about 7 days (168 h). The microstructures of the test samples in the as-quenched and polished conditions were characterised using scanning electron microscopy (SEM).

The XAS measurements at the Al L- and K-edges were conducted on the Variable Line Spacing Plane Grating Monochromator (VLS-PGM) and Spherical Grating Monochromator (SGM) beamlines. Data were acquired simultaneously in the Total Electron Yield (TEY) and Fluorescence Yield (FLY) modes. TEY and FLY are sensitive to the surface and bulk chemistry of materials, respectively. The step size was 0.1eV and the size of the entrance and exit

slits were $50 \times 50 \mu\text{m}$. The WINXAS™ software was used for normalizing the XAS data as well as for pre-edge background subtraction using the double spline method.

Results and Discussion

Figure 1 shows the SEM micrographs of AA2618 and AA2618/Alumina/10p. It can be seen that the reinforcing alumina particles are uniformly distributed, irregularly shaped, and of various sizes.

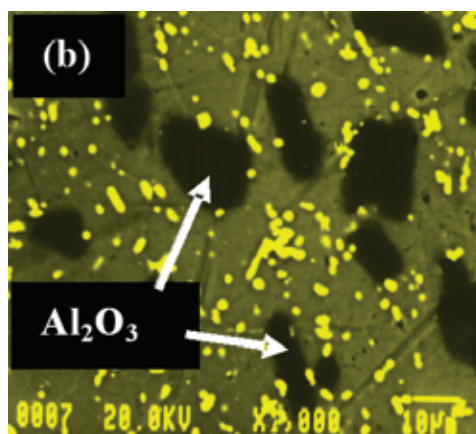
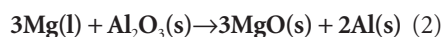


Figure 1: SEM micrographs of (a) AA2618 and (b) AA2618/Alumina/10p showing Al_2O_3 and Al_3FeNi particles.

The plots of normalized TEY Al K-edge ($s \rightarrow p$) for high purity Al, AA2618 and its MMCs are shown in Figure 2. Peaks a and b are common to both high purity aluminum and AA2618. They suggest that similar reaction products form on the surfaces of these materials. However, the p -orbital population decreases with the addition of alumina particles to AA2618. The high level of occupied p -orbital in the composites suggests a charge transfer from aluminum in the matrix alloy to the alumina particles, which can be discerned from the following reaction schemes [3]:



Peak c is common only to the composites; therefore, it most likely is a contribution from alumina particles. Between 1580 and 1610eV, it can be seen that the aluminum coordination and geometric structure in AA2618 changed with the addition of alumina particles.

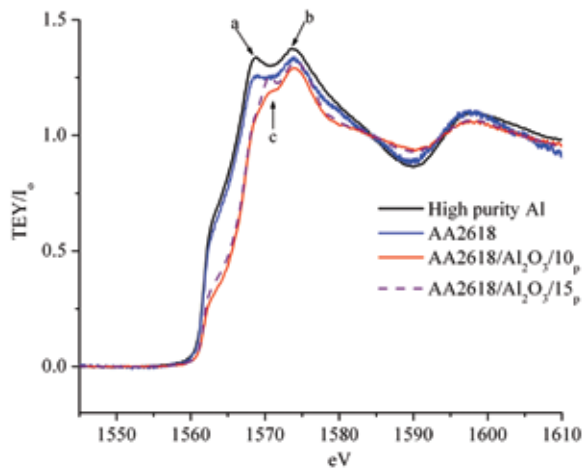
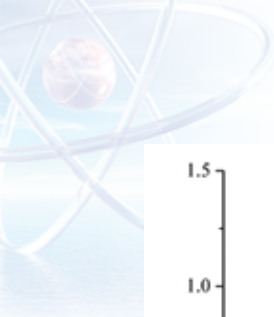


Figure 2: Comparison of the normalized TEY Al *K*-edge of high purity Al, AA2618 and its composites.

Figure 3 shows the plots of normalized FLY Al *K*-edge (*s* → *p* transitions) for high purity Al, AA2618 and its composites. It can be seen that the bulk chemistry of AA2618 and high purity aluminum is about the same. However, there is a marked filling of the *p*-orbital population of aluminum in AA2618 with the addition of alumina particles. A decrease in the *p*-orbital population suggests a change in the conductivity and metallic character of AA2618. The region beyond 1580eV shows that alumina particles do not change the structure of the bulk of AA2618.

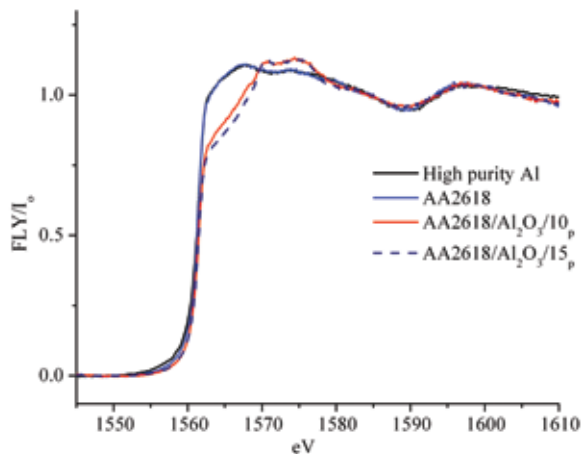


Figure 3: Comparison of the normalized FLY Al *K*-edge of high purity Al, AA2618 and its composites.

Conclusions

1. XAS is a promising tool for probing the electronic structure of aluminum alloys and their composites.
2. Similar reaction products form on the surface and in the bulk of both high purity Al and AA2618.
3. The addition of alumina particles to AA2618 perturbs the occupation of *p*-orbitals at the surface and in the bulk of aluminum in AA2618.

References

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