TEM investigation of the fine scale microstructure of an Al-alloy from a WW2 USA bomber (A26 Invader airplane)

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Keywords: TEM, Al-alloy, cultural heritage material

In the field of cultural heritage, industrial artefacts made in Al-alloys have to be more and more considered. They are real testimonies in regard to the technical and industrial evolution during the previous century. A typical example is well illustrated by aeronautic materials, which very early adopt newly-developed materials. These light materials, such as Duralumin, with good mechanical properties linked to precipitation hardening offering advantages not previously available, have been used since the 1920s in aircrafts. Permanent studies were required to extend these new properties, allowing for new Al-alloys to emerge, which often are still in use.

Today a large number of aircrafts mainly made with Al alloys have been preserved in air and space museum collections. Unfortunately, these Al-alloys are sensitive to corrosion. This is mainly related to intermetallic precipitates initially produced inside the Al matrix, taking place during the ageing process [1, 2]. Thus in these alloys, intermetallic phases (up to nanometric size) are necessary to provide mechanical resistance, but also induces a bad corrosion behaviour, affecting their long-term conservation. Several studies have considered the role of these particles inducing galvanic coupling, but up to now no real investigation of the nature of these intermetallic phases in ancient alloys has been performed.

In the present work, we report the transmission electron microscopy study of the fine structure of these Al-alloys and in this communications we report the first results obtained on an Al-alloy from a Douglas A-26 Invader, a plane of the World War II. The studied specimen was provided by the *French Air and Space Museum* (Le Bourget). Previous investigation was already performed by other techniques and in particular by synchrotron X-ray diffraction [2]. XRF analyses showed that this Al-alloys contained Cu, Mn and Mg and had a composition close to the 2024 modern alloys types. The TEM samples were electropolished with a Struers A2 electrolyte at –13°C in a Tenupol III apparatus. The thin foils were then examined using a JEOL 2010 electron microscope operating at 200 kV equipped with a double tilt goniometer stage. Observations and Electron Energy Loss Spectroscopy (EELS) analyses were also performed using a Tecnai F20.

The observations revealed that the density of metallic precipitates is rather high as shown in Figure 1. EELS experiments (Fig. 2) have shown that manganese compound is essentially found in the medium precipitates while copper can be found both in the precipitates and in the Al matrix. A large density of dislocations was observed in all investigated zones (Fig. 1 b & c). Their curved shapes attest that they are pinned by small obstacles, which indirectly confirms the presence of very small precipitates (with a diameter smaller than 10 nm). Compared to the modern 2024 Al-alloys, the precipitate size distribution is rather large. The grain size, often superior to 10 microns, is also larger than in modern alloys used in aeronautics. More interesting for the understanding of the corrosion processes is the systematic presence of large amorphous particles with dark contrast as shown in Figure 3. These particles usually present faceted shapes while diffraction experiments show that these particles are amorphous. Investigations are in progress to identify their real nature.

References

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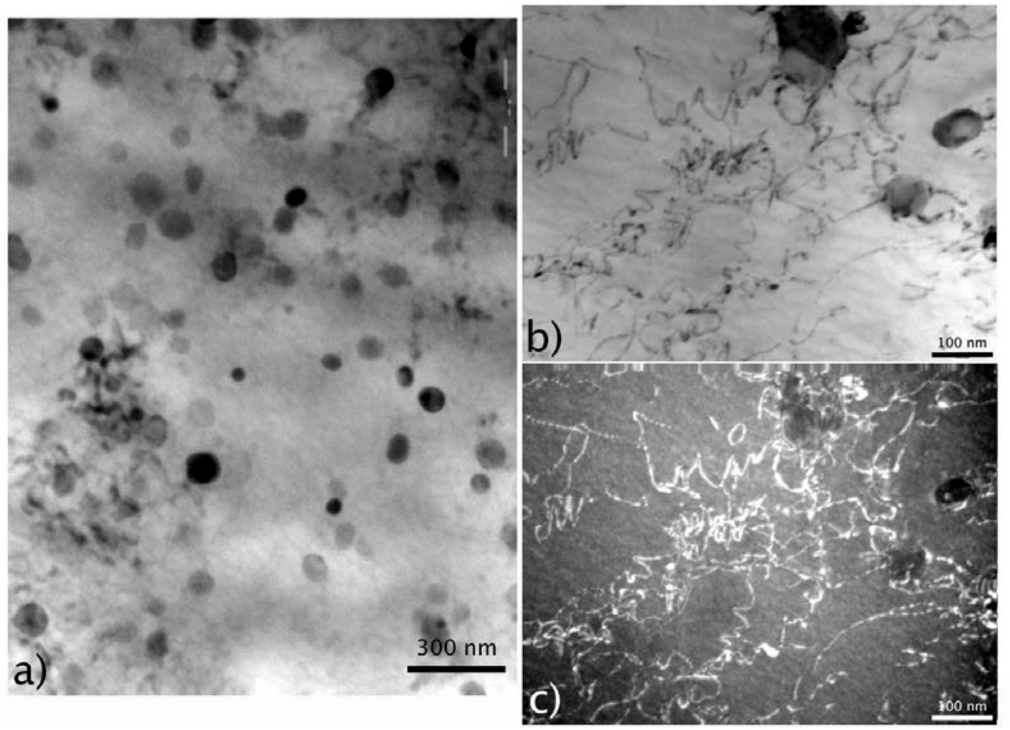

Figure 1. *TEM observations of the microstructure of the Al-alloy of a WWII bomber, in a) showing a large density of medium-sized precipitates, in b) a bright field and in c) a dark field observation of the same area attesting of the large density of dislocations and showing the curved shapes adopted by the dislocations, which result from their interaction with very small precipitates.*

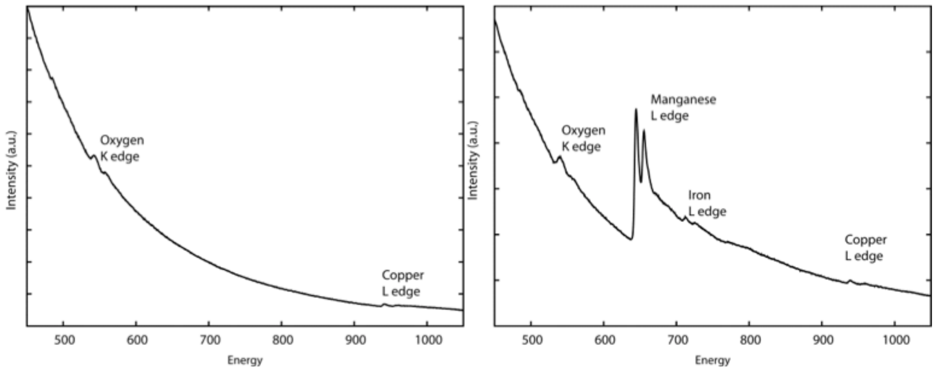

Figure 2. *Comparison of EELS Spectra within the matrix (left) and within a medium sized precipitate (right) showing the presence of Mn in the medium-sized precipitates as well as some traces of Fe, but no difference in Cu content.*

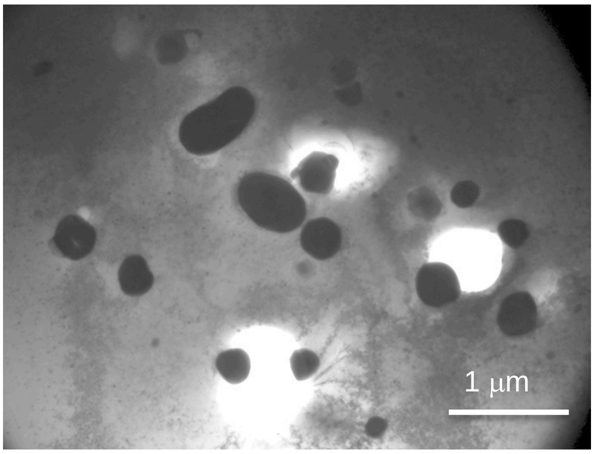

Figure 3. *Large amorphous precipitates found within the Al matrix.*