Artificial Aging of a Commercial Light Weight Alloy Studied by In-situ Positron Beam Doppler Broadening Spectroscopy

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Age-hardenable Al alloys with their main solutes being Mg and Si are widely used in automotive industry or for architectural and structural applications due to their low weight, high hardness and good corrosion resistance. These alloys obtain their maximum hardness by prolonged storage at elevated temperatures, a process referred to as artificial aging. During this heat treatment, precipitates grow within the Al matrix, which serve to harden the alloy by hindering dislocation movement. Although artificial aging is widely applied industrially the details of the precipitation sequence and especially the very early clustering stages are still under discussion; a rough model which is generally agreed on is the following [1]:

$$\text{SSSS} \rightarrow \text{Si-, Mg-clusters} \rightarrow \beta'' \rightarrow \beta'/U_1/U_2/B' \rightarrow \beta$$

Here, SSSS refers to the supersaturated solid solution, β’’ is a coherent phase, which is predominant in the peak-hardened microstructure, $\beta'/U_1/U_2/B'$ are semi-coherent phases and the equilibrium phase β is incoherent to the Al matrix. Especially initial clustering stages prior to the peak-hardened microstructure are of great interest to tailor the hardening response of the material. However, initial clustering takes place on short timescales and often only few atoms are involved which makes these precursor phases very difficult to investigate experimentally.

A unique opportunity to access these early clusters is the use of the positron beam of the NEPOMUC facility at FRMII. The high intensity of the beam enables Doppler broadening spectra acquisition at very short timescales, additionally the sample can be heated. This specifications made it possible to record the Doppler broadening S-parameter in-situ during artificial aging at two distinct temperatures, 180° C and 210° C.

The behavior of the S-parameter shows similar characteristics for the two applied aging temperatures, except for a temporal shift to longer aging times in the case of 180° C. Additional conclusions could be drawn from the comparison of this in-situ Doppler broadening data with ex-situ positron lifetime measurements and in-situ dilatometry [2]. Here, it has to be noted that the compared aging states for ex-situ and in-situ positron measurements are the exact same but the temperature of the sample during the measurements are different (ex-situ: -70° C, in-situ: 180° C/210° C). This affects whether positrons are captured (-70° C) or not captured (180° C/ 210° C) by shallow traps which appear in the alloy in the form of early clusters and small coherent precipitates [3].

In addition to the measurements during artificial aging at 210° C, the S-parameter was also recorded in-situ for the subsequent solution heat treatment of the very same sample. Here, with increasing temperature we could observe the dissolution of precipitates and the formation of vacancies.

References

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