ESRF	**Experiment title:** A detailed atomic investigation of the precipitations on a joint of a Friction-Stir-Welded Al-Cu-Li alloy (AA2198)	**Experiment number**: MA-3443
Beamline: ID24	**Date of experiment**: from: 05.04.2017 to: 11.04.2017	**Date of report**: 29.08.2017
Shifts: 16	**Local contact(s)**: Manuel Monte Caballero	*Received at ESRF:*

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Report:

XAFS measurements were carried out at the K-edge of copper in transmission.

First experiment: To extract the T1-phase [1] in the Basematerial (BM) of a Friction-Stir-Welded commercial Al-Cu-Li-Mg alloy (AA2198-T8) the following conditions were measured as a reference first:

- Al-4wt%Cu: „as-quenched“ (AQ) condition (Guinier-Preston-Zones 1 & 2 (GP1))
- Al-4wt%Cu: Guinier-Preston zone 2 (GP2/Θ‘‘)
- Al-4wt%Cu: Θ‘
- Al-4wt%Cu: Θ
- Al-1wt%Cu-2wt%Mg: „as-quenched“ (AQ) condition (Guinier-Preston-Bakarayatsky Zone (GPB))
- Al-1wt%Cu-2wt%Mg: Guinier-Preston-Bakarayatsky zone 2 (GPB2/S‘‘)
- Al-1wt%Cu-2wt%Mg: S‘
- Al-1wt%Cu-2wt%Mg: S
- Al-2wt%Cu-3.4wt%Li: „as-quenched“ (AQ) condition (GP1)
- Al-2wt%Cu-3.4wt%Li: T1 + Θ‘

The measured reference conditions were compared with FDMNES simulations subsequently.
In figure 1 one can follow the precipitation-sequence of the alloy Al-4wt%Cu:

GP1 -> GP2/ Θ‘‘ -> Θ‘.

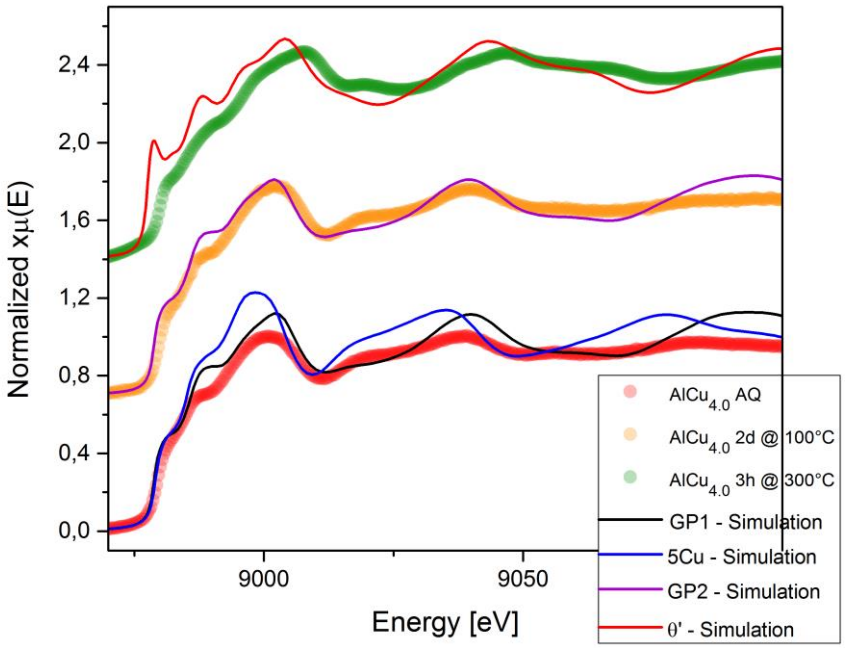

Figure 1: Precipitation-Sequence of Al-4wt%Cu. Solid curves show the simulated spectra with FDMNES.

Substracting a linearcombination of the measured reference-spectra of S‘‘, GP1 and Θ‘ from the spectrum of the Basematerial retrieves a spectrum similar to the T1-phase. Due to the varity of existing precipitates at the same time one “true” structure (of the several proposed in [2]) could not be clearly identified unfortunately.

In a second experiment the aim was it to obtain the kind of clusters and precipitates in the Weld-Nugget (WN) of the AA2198-T8. This region reached temperatures of >500°C within ~10s during the welding-process. The prescence of GPB-, GP1-zones and/or CuMg-Clusters was assumed by Malard at al. [3]. A comparison with FDMNES-simulations of S‘‘ [2] and GP1-zones confirms the assumption absolutely (see figure 2).

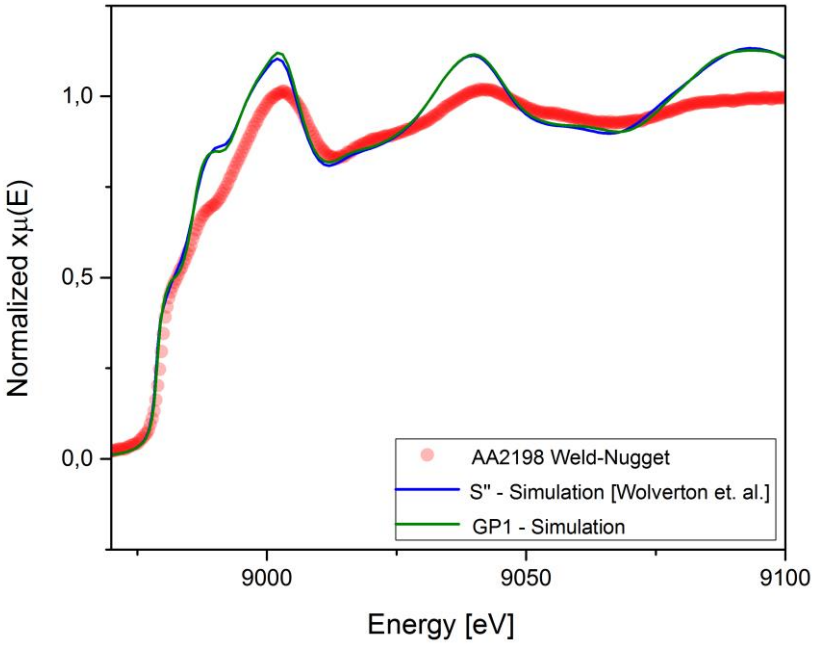

Figure 2: EXAFS-spectrum of the Weld-Nugget (WN) material of a Friction-Stir-Welded commercial AlCuLiMg-alloy (AA2198-T8). The FDMNES-simulations of S’’ and/or GP1-zone fit the measured spectrum.

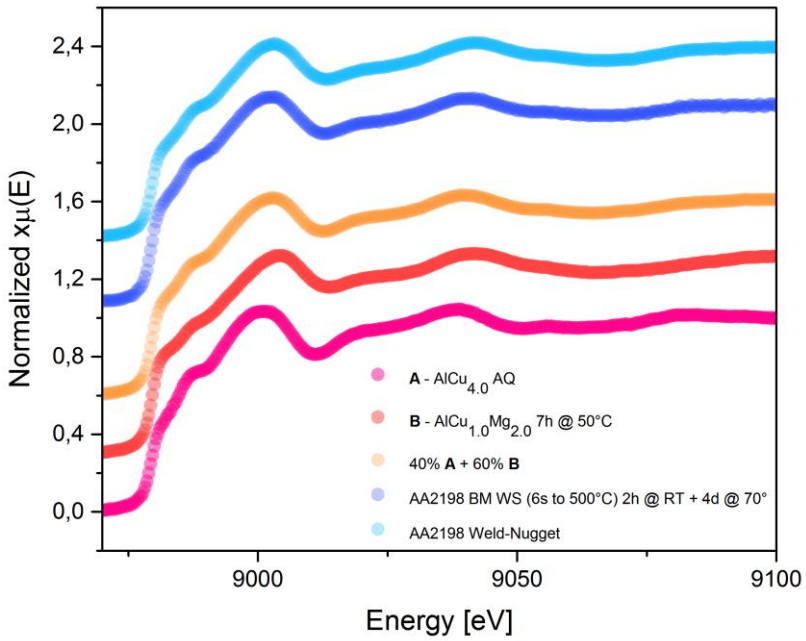

Figure 3: Fingerprint-method to retrieve the kind and content of the precipitates in the Weld-Nugget (WN). A linearcombination of GP1-zone (pink curve) and S'' (red curve) results in a curve-shape (orange) similar to the real Weld-Nugget sprectrum (light blue) and the "Welding-Simulated" spectrum (dark blue).

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In the third experiment the Basematerial of the AA2198-T8 was quickly heated to 500°C within 6s to represent the heat-influence due to the welding and to follow the precipitation- and clustering-process directly after welding („Simulated Welding" or "Welding Simulated – WS"). To accelerate the clustering and precipitation the samples were aged at 70°C.
We found out a linearcombination (see figure 3, orange curve) of the AQ-condition of Al-4wt%Cu (see figure 3, pink-curve) and S''-phase condition of Al-1wt%Cu-2wt%Mg (see figure 3, red curve) looks almost similar to the Weld-Nugget material (WN) (see figure 3, light blue curve) and the welding-simulated material (WS) after 4d @ 70°C (see figure 3, dark blue curve).
Therefore, the „Simulated-Welding" can be used to investigate the clustering and precipitation after welding.

In the fourth experiment we performed a XAFS-scan over different zones (Basematerial, Heat Affected Zone - HAZ, Thermomechanically Affected Zone – TMAZ - and Weld-Nugget) of the weld-joint. By comparing the spectra we could identify a clear difference between the WN and BM due to their different microstructre. The HAZ and TMAZ on the other hand showed a signal almost identical to the BM.

In conclusion one can say that EXAFS is a viable method for identifying and characterizing of the atomic structures in aluminium alloys.

References:

[1] P. Donnadieu, Y. Shao, F. De Geuser, G.A. Botton, S. Lazar, M. Cheynet, M. de Boissieu, A. Deschamps. Acta Mater. 59 (2011) 462-472
[2] S.C. Wang and M.J. Starink, Review of precipitation in Al-Cu-Mg(-Li) alloys, Int Mater Rev., 2005, Vol. 50, pp 193-215
[3] B.Malard, F. De Geuser, A. Deschamps, Acta Mater. 101 (2015) 90-100