DECHEMA FORSCHUNGSINSTITUT

Corrosion

Realization of Al/Mg-hybrid-joints by ultrasound supported friction stir welding and specification of the mechanical properties, the microstructure and the corrosion behavior of the joints

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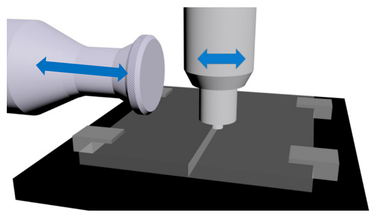
Aims

Realization of Al-Mg-Hybrid Joints

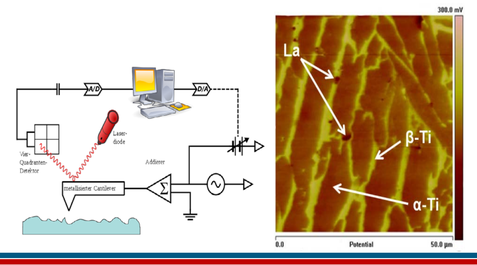
- combine the advantages of dissimilar materials with hybrid construction
- join Al-cast- and Mg-cast alloys by friction stir welding (FSW), because both material groups are well-established in industrial applications, but there is no possibility to realize joints between them by fusion welding; FSW enables a joining by plastic deformation
- additionally high power ultrasound is submitted into the welding area to eliminate strength reducing effects by occurring brittle phases and to improve the stirring in the joining area



Schematic view of the friction stir process with ultrasound

Characterization of Al-Mg-Hybrid Joints

- quality of the produced welds will be estimated by static and cyclic testing as well as non-destructive investigations
- detailed analysis and thermodynamical calculations will be carried out to understand the development of the microstructure in the joining zone
- corrosion properties of the hybrid materials will be determined by integral methods (immersion test, salt spray and electrochemical measurements) and local investigations (scanning kelvin probe, scanning kelvin probe force microscopy (SKPFM) as well as in-situ AFM and EC-AFM)

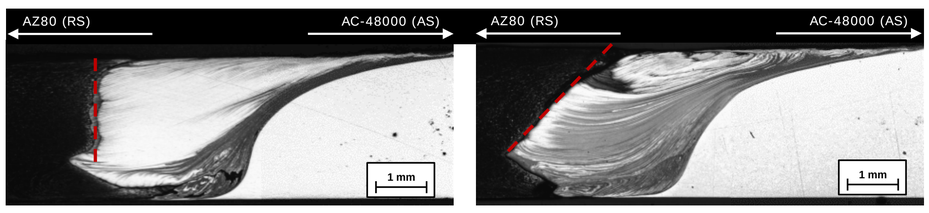


Schematic view of the SKPFM technique to determine potential differences between the individual phases within the microstructure

Results

Microstructure of Al-Mg-Hybrids

- cross sections of the hybrid joints show a more distinctive stirring zone due to ultrasound support and a change in the interface between Mg and nugget
- reduced amount of intermetallic phases with US-support

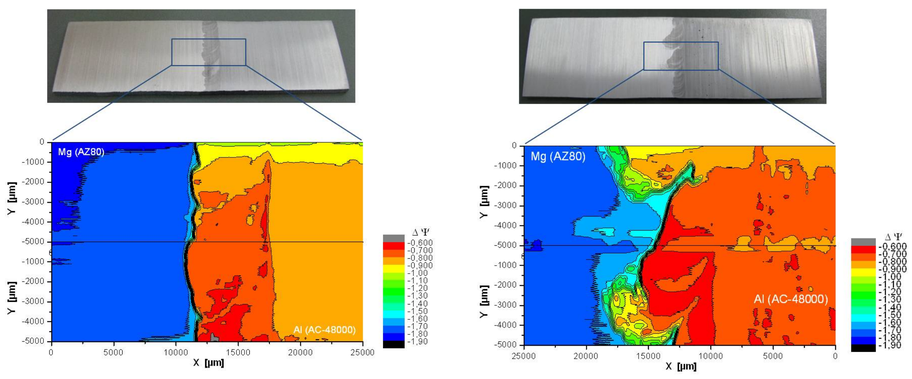


Microstructure of Al-Mg-joints produced without (left) and with US-support (right)

Volta Potential Maps (Scanning Kelvin Probe)

- potential difference between Mg- and Al-alloy about 1 V
- different oxidation properties observed for Al-alloy and hybrid phase
- improved mixing with ultrasound support indicated by more potential increments

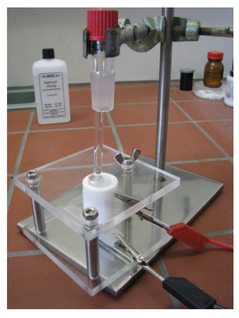
without ultrasound support | with ultrasound support



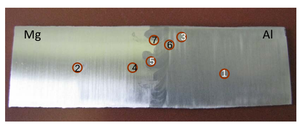
Volta potential maps of Al-Mg-joints produced without (left) and with US-support (right) measured with scanning kelvin probe

Electrochemical Set-up

- three electrode set-up with mini cell (∅ 3 mm)
- reference electrode: SCE (+245 mV vs. NHE)
- electrolyte: 0.5 M NaCl solution
- sample preparation: wet grinding with SiC-paper up to P1200, cleaning with ethanol/ultrasound
- measuring procedure:
  a) 60 min open circuit potential
  b) Potendiodynamic polarization:
  -100 mV to +500 mV vs. Eoc, 1 mV/s
- characterization of corrosion products with Raman microscope



Electrochemical mini cell set-up

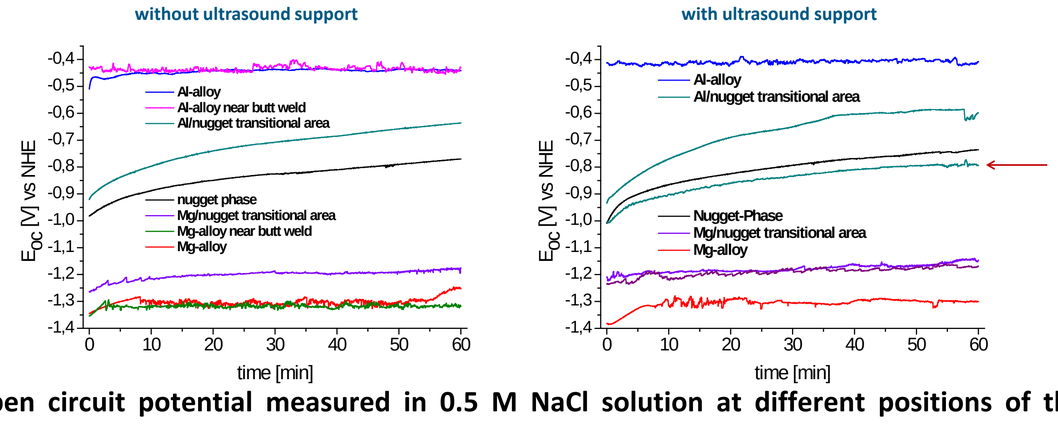


Different measurement positions

Electrochemical Corrosion Experiments

Open Circuit Potential

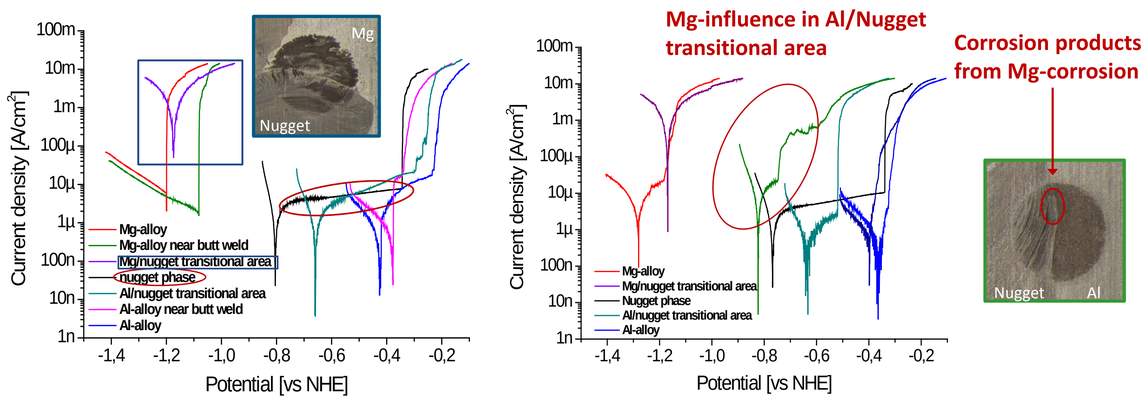
- continuous increase of E_{OC} of the nugget phase indicates passivation behaviour
- lower E_{OC} of Al/nugget transitional area of US-supported hybrid indicates Mg influence



Open circuit potential measured in 0.5 M NaCl solution at different positions of the Al/Mg-joints

Potentiodynamic Polarization (I/E-Plots)

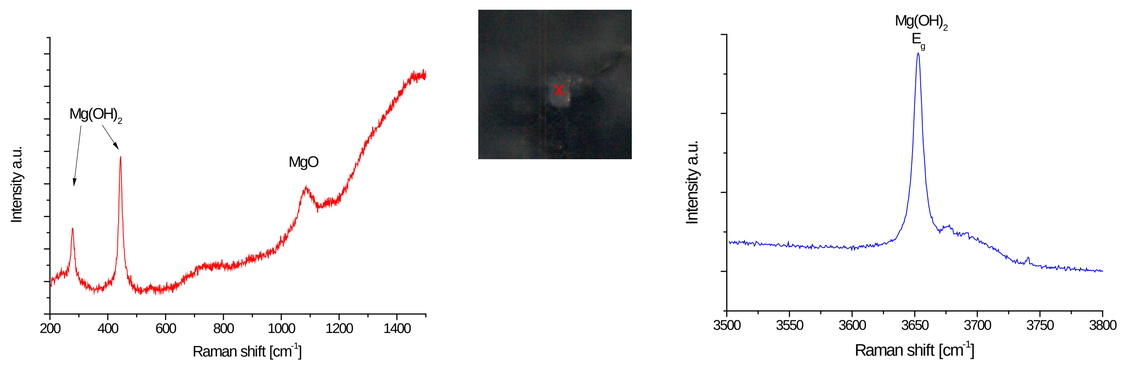
- phase with broad passive region in the nugget area
- accelerated Mg-corrosion if simultaneous electrolyte contact with nugget phase



Potentiodynamic polarization curves measured in 0.5 M NaCl solution at different positions of the Al/Mg-joints produced without (left) and with ultrasound support (right)

Raman Spectroscopy of corrosion products

- white precipitates were identified as mixture of $Mg(OH)_2$ (brucite) and MgO



Raman spectra of white corrosion products, finger print region (left) and OH-region (right) with typical bands of brucite and MgO

Outlook

- realization of hybrid-joints of different alloy combinations (with AlMg1SiCu and AZ91D)
- immersion tests with pure alloys and hybrid materials
- investigation of the influence of corrosion on mechanical properties

Project Partners

- Prof. Dr.-Ing. G. Wagner, M. Thomä; TU Chemnitz, Lehrstuhl Verbundwerkstoffe
- Prof. Dr.-Ing. C. Boller, C. Conrad; Fh IZFP, Saarbrücken

Fraunhofer IZFP