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# Characterization of oxide layers developed on ZrCuAI-based bulk metallic glasses during gaseous thermochemical treatment

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# ISMANAM

# Roma, 2-6 July 2018

25<sup>TH</sup> INTERNATIONAL SYMPOSIUM ON METASTABLE, AMORPHOUS AND NANOSTRUCTURED MATERIALS



## Programme

## MONDAY 2 July

mechanical properties. Jürgen Eckert, Austrian Academy of Science & Montanuniversitat Leoben, Austria Auditorium Chair: To be defined         1100       Coffee Break         11100       Parallel Session 1 Auditorium       Parallel Session 2 Accademia       Parallel Session 3 Taurini       Parallel Session 3 Taurini       Parallel Session 1 Caudini         Metallic Glasses I Chair: To be defined       Nanostructured Materials I Chair: To be defined       Advanced Preparation and Processing 1 Chair: To be defined       Crystallization proce Chair: To be defined         11130       ID-999 (Invited) Origin of fragility and the onset of ragility and the onset of medianes behaviour of zr.Cu.ucAg but metallic glass in artificial physiological situ to masses the anset of metamesion ion implantation treatment enhances bit rominet phases in artificial physiological solutions.       ID-100 Mechanical properties of nanostructured materials in artificial physiological solutions.       ID-121 Al-Si-Ni-Cr-Fe alloy prepared by selective laser mething and melt spinning.       ID-232 Influence of co other small dicarboxylic physiological solutions.         12 <sup>15</sup> ID-1533 Nitrogen plasma in artificial physiological solutions.       ID-128 Interface-modulated strengthening ability of nanoscale Cu/Au multilayers.       ID-2365 Processes involved phases involved additives: A density-functional study.       ID-330 Controlling if microscond laser heatin production by pulsed laser additives: A density-functional study.	<b>08</b> 00	Registration				
mechanical properties.       Jürgen Eckert, Austrian Academy of Science & Montanuniversitat Leoben, Austria         Jürgen Eckert, Austrian Academy of Science & Montanuniversitat Leoben, Austria       Auditorium         Chair: To be defined       Parallel Session 1       Parallel Session 2       Parallel Session 3       Parallel Session 3         11 <sup>00</sup> Coffee Break       Parallel Session 1       Parallel Session 2       Parallel Session 3       Parallel Session 3       Crystallization proce         Metallic Glasses I       Nanostructured Materials I       Advanced Preparation and Processing I       Crystallization proce         11 <sup>30</sup> ID-99j (Invited) Origin of rapility and the onset of racicrystallize in ancrystalline high entropy alloys.       ID-382 (Invited) Rapid similer of phase memory.         12 <sup>00</sup> ID-98 Corrosion and impedance behaviour of zerolev dynamics in liquids.       ID-100 Mechanical properties of anostructured material embedded with nanotwins.       ID-421 Al-Si-Ni-Cr-Fe alloy propared by selective laser metting and met spinning.       ID-332 Influence of cloperative dynamics in liquids.         12 <sup>10</sup> ID-98 Corrosion and impedance, bidod cloperative dynamics in liquids.       ID-100 Mechanical properties of anostructured material embedded with nanotwins.       ID-232 Influence of cloperative dynamics in liquids.         12 <sup>15</sup> ID-1533       Nitrogen plasma intering ability of anostructured material embedded with nanotwin	<b>09</b> <sup>30</sup>	Conference Opening				
Parallel Session 1 Auditorium         Parallel Session 2 Accademia         Parallel Session 3 Taurini         Parallel Session 3 Taurini         Parallel Session 3 Taurini           Metallic Glasses I Chair: To be defined         Nanostructured Materials I Chair: To be defined         Advanced Preparation and Processing I Chair: To be defined         Crystallization proce Chair: To be defined           11 <sup>30</sup> 11 <sup>145</sup> [ID-99] (Invited) Origin of ragility and the onset of cooperative dynamics in liquids.         ID-423] (Invited) Stability and deformation behaviour of nanocrystallization to te solutions.         [ID-421] (Invited) Chair: To be defined         (ID-52) (Invited) nanocrystallization to te speed limit of phase memory.           12 <sup>00</sup> [ID-98] Corrosion and impedance behaviour of ractificial physiological solutions.         [ID-100] Mechanical properties of nanostructured materials mededed with nanotwins.         [ID-421] Al-Si-Ni-Cr-Fe alloy prepared by selective laser methanea trifficial physiological solutions.         [ID-128] Interface-modulated reagmening ability of nanoscale Cu/Au multilayers.         [ID-422] Mechanical alloying and spark plasma sintering of nanostructured CuCrFeTIM(N) high-entropy alloys.         [ID-282] Crystallization thin film metallic g femtosecond laser heatin corrosion resistance, blood of ZrCuAl-based bulk metallic glass of Zr-based bulk metallic glass of Zr-based bulk metallic glasses during gaseou thermochemical treatment.         [ID-174] Enhancing the wetability of nano-scale Cu thi mon ZrOu-Al-based bulk metallic glasses during gaseou thermochemical treatment.         [ID-149] Cooling strategies for . (ID-119] Creep testing	10 <sup>00</sup>	Jürgen Eckert, Austrian Academy of Science & Montanuniversitat Leoben, Austria Auditorium				
AuditoriumAccademiaTauriniCaudiniMetallic Glasses I Chair: To be definedNanostructured Materials I Chair: To be definedAdvanced Preparation and Processing I Chair: To be definedCrystallization proce Chair: To be defined1130 11130 11145[ID-99] (Invited) Origin of tragility and the onset of cooperative dynamics in liquids.[ID-423] (Invited) Stability and deformation behaviour of aloys.[ID-382] (Invited) Rapid solidification of AlSi <sub>16</sub> Mg + Cu mixed powders by single track laser melting and melt spinning.[ID-52] (Invited) nanccrystallization to the speed limit of phase memory.1200 1200[ID-98] Corrosion and impedance behaviour of Zr42Gu-Aga bulk metallic glass solutions.[ID-100] Mechanical properties of nanostructured materials embedded with nanotwins.[ID-421] Al-Si-Ni-Cr-Fe alloy prepared by selective laser melting: microstructure and mechanical properties.[ID-332] Influence of cl other small dicarboxylic hydroxyapatite nr nucleation, growth and properties.1215[ID-133] Nitrogen plasma immersion ion implantation treatment enhances the corosion resistance, blood coaguiation, and cell response of Zr-based bulk metallic glass for implant applications.[ID-174] Enhancing the wettability of nano-scale Cu/hu multilayers.[ID-385] Processes involved during nanostructured material production by pulsed laser abalton in liquid.[ID-30] Controlling th temporature in amorphic coade microwires I treatment.1230[ID-152] Characterization of oxide layers developed on ZrCuAl-based bulk metallic glasses during gaseous thermochemical treatment.[ID-174] Enhancing the we	11 <sup>00</sup>	Coffee Break				
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<ul> <li>11<sup>95</sup> [ID-99] (invited) Origin of fragility and the onset of fragility and the onset of anocrystalline high entropy alloys.</li> <li>11<sup>95</sup> cooperative dynamics in liquids.</li> <li>12<sup>00</sup> [ID-98] Corrosion and impedance behaviour of Zr<sub>42</sub>Cu<sub>50</sub>Ag<sub>8</sub> bulk metallic glass in artificial physiological solutions.</li> <li>12<sup>15</sup> [ID-133] Nitrogen plasma immersion ion implantation treatment enhances the corrosion resistance, blood coagulation, and cell response of Zr-based bulk metallic glass for implant applications.</li> <li>12<sup>30</sup> [ID-122] Characterization of Zr-CuAl-based bulk metallic glass for implant applications.</li> <li>12<sup>30</sup> [ID-132] Characterization of Zr-CuAl-based bulk metallic glass for implant applications.</li> <li>12<sup>30</sup> [ID-132] Characterization of XZ-CuAl-based bulk metallic glass during gaseous thermochemical treatment.</li> <li>12<sup>45</sup> [ID-163] Atomic structure and [ID-41] Tribological and [ID-149] Cooling strategies for . [ID-119] Creep testing</li> </ul>				Processing I	Crystallization processes I <b>Chair</b> : To be defined	
11 <sup>45</sup> cooperative dynamics in liquids.       alloys.       alloys.       laser melting and melt spinning.       memory.         12 <sup>00</sup> [ID-98]       Corrosion and impedance behaviour of Zr <sub>42</sub> Cu <sub>50</sub> Ag <sub>8</sub> bulk metallic glass in artificial physiological solutions.       [ID-100]       Mechanical properties of nanostructured materials embedded with nanotwins.       [ID-421]       Al-Si-Ni-Cr-Fe alloy prepared by selective laser melting: microstructure and melt spinning.       [ID-332]       Influence of clother small dicarboxylic hydroxyapatite materials embedded with nanotwins.         12 <sup>15</sup> [ID-133]       Nitrogen plasma indication plasma of Zr-based bulk metallic glass for implant applications.       [ID-128]       Interface-modulated strengthening ability of nanoscale Cu/Au multilayers.       [ID-422]       Mechanical alloying embedded laser heating and spark plasma sintering of nanostructured CuCrFeTiMn(Ni) high-entropy alloys.       [ID-282]       Crystallization thin film metallic glass for implant applications.         12 <sup>30</sup> [ID-152]       Characterization of oxide layers developed on ZrCuAl-based bulk metallic glasses during gaseous thermochemical treatment.       [ID-174]       Enhancing the wettability of nano-scale Cu thin film on ZnO substrate by gas additives: A density-functional study.       [ID-149]       Cooling strategies for coated microwires the ablation in liquid.         12 <sup>45</sup> [ID-163]       Atomic structure and       [ID-41]       Tribological and       [ID-149]       Cooling strategies for       [ID-119]       Cree	11 <sup>30</sup>	fragility and the onset of	deformation behaviour of	solidification of AlSi10Mg + Cu	nanocrystallization to break the	
<ul> <li>impedance behaviour of Zr42Cu<sub>50</sub>Age bulk metallic glass in artificial physiological solutions.</li> <li>12<sup>15</sup> [ID-133] Nitrogen plasma immersion ion implantation treatment enhances the corrosion resistance, blood coagulation, and cell response of Zr-based bulk metallic glass for implant applications.</li> <li>12<sup>30</sup> [ID-152] Characterization of oxide layers developed on ZrCuAl-based bulk metallic glass during gaseous thermochemical treatment.</li> <li>12<sup>34</sup> [ID-163] Atomic structure and [ID-41] Tribological and [ID-149] Cooling strategies for . [ID-149] Creep testing.</li> </ul>	11 <sup>45</sup>	cooperative dynamics in liquids.	, , , , , , , , , , , , , , , , , , , ,			
ICimmersion ion implantation treatment enhances the corrosion resistance, blood coagulation, and cell response of Zr-based bulk metallic glass for implant applications.strengthening ability of nanoscale Cu/Au multilayers.and spark plasma sintering of 	12 <sup>00</sup>	impedance behaviour of $Zr_{42}Cu_{50}Ag_8$ bulk metallic glass in artificial physiological	of nanostructured materials	prepared by selective laser melting: microstructure and	nucleation, growth and surface	
Oxide layers developed on ZrCuAl-based bulk metallic glasses during gaseous thermochemical treatment.       wettability of nano-scale Cu thin film on ZnO substrate by gas additives: A density-functional study.       during nanostructured material production by pulsed laser ablation in liquid.       temperature in amorphy coated microwires I treatment         12 <sup>45</sup> [ID-163] Atomic structure and       [ID-41] Tribological and       [ID-149] Cooling strategies for       . [ID-119] Creep testing	12 <sup>15</sup>	immersion ion implantation treatment enhances the corrosion resistance, blood coagulation, and cell response of Zr-based bulk metallic glass	strengthening ability of	and spark plasma sintering of nanostructured CuCrFeTiMn(Ni)	<b>[ID-282]</b> Crystallization of Cu-Zr thin film metallic glass via femtosecond laser heating.	
12 <sup>45</sup> [ID-163] Atomic structure and corrosion property of Fe-based droplet solidification of class fabric flax-poly	12 <sup>30</sup>	oxide layers developed on ZrCuAl-based bulk metallic glasses during gaseous	wettability of nano-scale Cu thin film on ZnO substrate by gas additives: A density-functional	during nanostructured material production by pulsed laser		
	12 <sup>45</sup>	devitrification of Ca-based	corrosion property of Fe-based metallic glass nanocomposite coatings synthesized by thermal	droplet solidification of glass	. <b>[ID-119]</b> Creep testing of woven fabric flax-polypropylene composite using digital correlation image (DIC).	

## ISMANAM

### ID-152

Characterization of oxide layers developed on ZrCuAl-based bulk metallic glasses during gaseous thermochemical treatment

S. Haratian, M. Villa, F.B. Grumsen, T.L. Christiansen, M.A.J. Somers

#### Technical University of Denmark (DTU)

The current study addresses an investigation of low-temperature oxidizing treatment (<T\_) of ZrCuAl- based BMGs, which have been monitored by thermogravimetry. The thermochemical treatment was applied in two different gaseous atmospheric conditions providing low and high oxygen partial pressures. The microstructural evolution and surface morphology of the oxidation zone developing during the treatment of ZrCuAl-based BMGs were investigated utilizing X-ray diffraction and advanced electron microscopy techniques. The oxygen-containing case formed in the metallic glassy substrate was further investigated with in-situ ion beam channeling. The results demonstrate that after conducting the oxidizing treatment in the atmosphere containing high oxygen partial pressure, an outer oxidation layer and an inner oxide zone develop. In the gas with a low oxygen partial pressure only the inner oxidation zone results. Interestingly, four oxide regions with different chemical composition, which mainly consist of ZrO<sub>2</sub> (with two different lattice structures; tetragonal and monoclinic) and Al<sub>2</sub>O<sub>3</sub> are present in the inner layer where the oxygen is distributed through the substrate. Furthermore, the outer oxide layer is enriched in copper which has diffused out of the BMG. Cracks have developed adjacent to the surface, which is ascribed to the stresses resulting from oxide formation in the inner oxidation zone. Some of the cracks are filled out with copper. This phenomenon was also observed in Ag-containing BMG, where both copper and silver enrich at the surface.