VitriMetTech Report Summary

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Periodic Report Summary 1 - VITRIMETTECH (Vitrified Metals Technologies and Applications in Devices and Chemistry)

VitriMetTech
Marie Curie International Training Network
Publishable Summary after Mid-Term Review

New metallic materials have high strategic and technical value for European industry and society to compete successfully in the global market for sustainable products and resource efficiency. Metallic glasses and composites based on them are of interest for functional, biomedical, chemical and miniaturized structural applications. The VitriMetTech network aims at improving materials and technologies in fields where metallic glasses are already in commercial production (e. g. magnetic devices), and at opening new fields of application in chemistry (e. g. catalysis and spectroscopy) and electronics (e. g. actuators).
Metallic glasses can be made as thin films, foils, and small ingots according to composition and synthesis technique. They are thermodynamically metastable and crystallize when heated in suitable temperature ranges forming in situ crystalline-amorphous composites. Some metallic glasses can be heated above their glass transition without crystallizing and can be moulded similarly to thermoplastics by exploiting their reduced viscosity in the supercooled-liquid region. One aim of the Network is to develop deposition, casting, moulding, annealing and etching techniques to obtain a whole range of vitrified metals from nanometres to centimetres in thickness and composites, including porous metals.
VitriMetTech is an interdisciplinary EC FP7 funded Marie Curie Initial Training Network providing world-class training to a cohort of ten Early Stage Researchers (ESRs) and six Experienced Researchers (ERs) It is coordinated by Prof. Livio Battezzati at the Department of Chemistry, University of Turin (IT). It is a partnership of twelve beneficiaries, consisting of research groups at the Universities of Turin (IT), Cambridge (UK), Göttingen (D), Ulm (D), Zürich (CH), and Ioannina (GR), at the Polytechnics of Grenoble (F) and Warsaw (PL), at IFW Dresden (D), at ESRF (F), at NIRDTP Iasi (RO), and at Breuckmann AG (D). In addition there are five industrial and one academic associated partners. The project website is: http://www.vitrimettech.unito.it/.
Training events are organized at both the network and partners' levels. Two Industry-Network meetings have taken place: the first one in Cambridge (UK) in September 2014 on the synthesis of alloys, the second one in Dresden (D) in September 2015 on mechanical properties of metallic glasses.
The scientific work at the beginning of the project whose kick-off took place in Turin on 01/10/2013, has been focussed on the synthesis of vitrified samples having thickness from 50 nm to 1 cm (Bulk Metallic Glasses) by means of thin-film deposition and casting techniques. Rapid solidification in the form of ribbons, tens of micrometres thick, has been widely employed both to verify the suitability for vitrification of selected compositions, and to produce samples for testing mechanical, magnetic and chemical properties. So far, around fifty multi-component alloys based on Fe-Co, three Au-based ones, and several model systems based on Cu, Zr and Pd, have been synthesized. The casting is being modelled by accounting for basic issues of heat transfer, melt viscosity, and capillarity to design and develop a high-pressure-die casting tool. A laboratory caster was built to compare closely results of mould-filling simulation obtained using the dedicated software (ProCast®) with those of casting runs in a copper mould. A bulk magnetic stator for an electronic motor has been successfully produced from stacks of amorphous ribbons.
The structure and microstructure of alloys are analysed as a function of shape and size after synthesis and after each processing step e.g. mechanical or corrosion tests. The structure at the atomic scale has been studied so far by indirect techniques, such as resonant ultrasound spectroscopy or magnetometry, and by computer simulation, since the relevant ESRF beam line is being refurbished and will be available early in 2016.
Mechanical testing by nanoindentation has provided significant results demonstrating that the hardening induced by stress cycling in the elastic range is an effect of anelastic strain. Previously, it was thought that the hardening indicated a mechanical annealing effect in which the metallic glass reached a more relaxed state. The new results force a reinterpretation and it now seems the hardening is transient and reflects a state that is less relaxed. The local entities of the deformation process are studied by using the statistics of critical phenomena after creep experiments at constant temperature under different stresses. A crossover in the scaling exponent of the waiting time distribution has been reported which could be due to a transition between deformation mechanisms: in the first regime the so-called Shear Transformation Zones (STZ´s) interact in 3D, and in the second they form nano-shear bands and start to interact in 2D.

For soft magnetic glasses and composites produced by nano-scale crystallization, efforts have been made to identify compositions having high saturation magnetization which can be vitrified in the form of very thin ribbons (< 20 □m). The issue of quality of products, i.e. constancy in thickness, surface finish, content of crystalline phases, has also been tackled. By exploiting the harmonic undulatory response of vitrified metallic foils, a novel electromechanical switch has been proposed.
Aiming at designing glassy alloys with improved biocompatibility, experiments have been performed to study the correlation between chemistry, glassy structure, mechanical and corrosion response highlighting the role of Cu and Ga in Ti-Zr-Pd based glasses.
Au-based metallic glasses and Cu-Zr fine eutectics in ribbon form are employed as precursors to make electro-catalysts and substrates for Raman spectroscopy having a fine nanoporous structure. Electrodes with different thickness, composition, size of ligaments and pores have been made by de-alloying obtaining stable catalysts for methanol electro-oxidation. Their efficiency remains high after hundreds of voltammetry cycles. The amorphous precursors provide the nanoporous gold with a peculiar microstructure of fine domains different from those reported so far in de-alloyed crystalline alloys. They also contain some Ag and Pd trapped in the ligaments from the original alloy.
The first results of the modelling by molecular dynamics of the diffusion of atoms in the Cu-Zr model system indicate that at low temperature diffusion distances are short, the nearest neighbours of atoms are preserved and the local structure is distorted, whereas above the glass transition in the supercooled-liquid region diffusion distances are much larger, the type of nearest neighbours changes and the structure is relaxed. Considering the plastic regime for Cu-Zr, molecular dynamics shows avalanches of stress drops upon mechanical deformation. Results show that the distribution of stres- drop size follows a power law with an exponent close to 1.5 which is in very good agreement with the theoretically predicted exponent of the avalanche-dynamics theory.
Two discoveries of the project are being considered for patenting. Results have been presented by all Fellows at several conferences. Among these, the ISMANAM Conference (Paris, 13-17/07/2015, organized by the INPG partner) and a Symposium on Metallic Glasses, Rapid Solidification, Nanocrystallization at EUROMAT (Warsaw, 20-24/09/ 2015, organized by the IFW partner) were excellent opportunities for dissemination. Papers are being submitted to journals in the relevant fields. Some outreach presentations have been given by Fellows in open days at the respective university or research centre.
Ten ESRs were recruited. Gender balance is: 6 males and 4 females; eight are Europeans (Greece, Germany, France, two from Spain, Switzerland, Ukraine, Russia) and two from Asia (India, Pakistan). Four ERs have been hired. Gender balance is: 4 males and 1 female; three are Europeans (two from Greece, Hungary) and two from Asia (India and China). One ESR has left his position soon after recruitment and is being replaced

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