

High-strength Nanostructured Titanium Alloys with Improved Deformation Behavior

C. Duhamel¹, K.B. Kim^{1,2}, J. Das¹, W. Xu¹, M. Calin^{1,3}, G. He⁴, J. Eckert¹

¹ FG Physikalische Metallkunde, FB 11 Material- und Geowissenschaften, Technische Universität Darmstadt Petersenstraße 23, D-64287 Darmstadt, Germany

² Department of Advanced Materials Engineering, Sejong University, 98 Gunja-dong, Gwangjin-gu, Seoul 143-747, Korea

³ University "Politehnica" of Bucharest, Materials Science and Engineering Faculty Spl. Independentei 313, R-060032 Bucharest, Romania

⁴ Shanghai Jiao Tong University, School of Materials Science and Engineering, Welding Engineering Institute 1954 Huashan Road, Shanghai 200030, P.R. China

Bulk metallic glasses and nanostructured materials with grain sizes of the order of 100 nm and below are known to be high-strength materials, with yield strength of about an order of magnitude higher than their coarse-grained crystalline counterparts [1]. However, such materials do not deform through the classical work hardening processes as in conventional metals and alloys. They show very little ductility and room temperature failure occurs rapidly after plastic deformation begins. Due to this lack of work hardening, deformation of glassy and nanostructured materials tends to become unstable and is prone to localization such as shear banding and necking in tension. This is a severe drawback causing concerns for catastrophic failure in many load-bearing applications. To circumvent such limitations, the concept of using heterogeneous glassy or nanostructure-based materials and grain size distributions has been recently employed to develop high-strength bulk composite materials with improved room temperature ductility [2].

For this purpose, *in-situ*-formed Ti-based quinary Ti-Cu-Ni-Sn-Nb alloys were synthesized by copper mold casting [3]. The resulting microstructure consists of a nanocrystalline matrix in which a ductile dendritic phase is homogeneously embedded. This nanostructure-dendrite composite exhibits promising mechanical properties, i.e. high yield strength (in the range 1 to 2 GPa), strain-hardening and dramatically improved compressive plastic strain, up 30% (Fig 1). The high strength is attributed to the nanostructure of the matrix whereas the dendrites contribute to the plastic deformation and strain-hardening by dislocations and slip bands. Moreover, they design a network inside the nanocrystalline matrix, which acts both as seed to the initiation of shear bands and as obstacles to their propagation. A detailed microstructural investigation of the deformed samples [4] shows that primary shear bands penetrate the interface between the dendrites and the matrix, leading to a stepped morphology and contributing to the overall ductility of the sample. On the contrary, secondary shear bands, which tend to be arrested by the nanostructured matrix, are more likely to contribute to the overall strength. The fracture mechanism is supposed to result from the heterogeneous repartition of the shear strains, due to the geometrical effects on the interaction of the shear bands and the different morphologies of the interfaces between dendrites and nanograins.

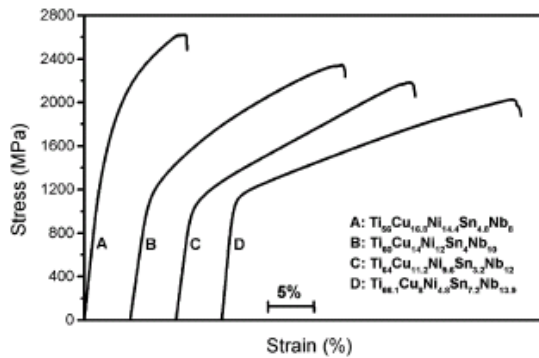


FIG 1: Room temperature compressive curves for Ti-Cu-Ni-Sn-Nb alloys with different compositions

Another approach, consisting in developing ultrafine ductile eutectic with no additional phases, was carried out on Ti-Fe-Sn alloys. The addition of Sn controls the morphology of the eutectic and refines the microstructure. Compared to the Ti-Fe binary alloy, the ductility is significantly enhanced and higher fracture strength is reached [5].

The high strength and high ductility of these materials are thus promising for applications. This study emphasizes the possibility to manipulate such composite microstructures in favour of either strength and ductility, or a combination of both and also reveals the acquired ability to process such *in situ* high-strength nanostructures in bulk form through inexpensive processing routes.

Keywords: Ti alloy, Mechanical Properties, Plastic deformation

REFERENCES

- [1] W.L. Johnson, Bulk glass forming metallic alloys: science and technology, *Mater. Res. Bull.*, 24, 42-56 (1999)
- [2] M. Calin and J. Eckert, Formation, thermal stability and deformation behaviour of high-strength Cu-based bulk glassy and nanostructured alloys, *Adv. Eng. Mater.*, 10, 960-965, (2005)
- [3] G. He, J. Eckert, W. Löser, L. Schultz, Novel Ti-base nanostructure-dendrite composite with enhanced plasticity, *Nature Mater.*, 2, 33-37, (2003)
- [4] K.B. Kim, J. Das, F. Baier, J. Eckert, Heterogeneous distribution of shear strains in deformed $\text{Ti}_{66.1}\text{Cu}_8\text{Ni}_{4.8}\text{Sn}_{7.2}\text{Nb}_{13.9}$ nanostructure-dendrite composite, *Phys. Stat. Sol. (a)*, 202, 2405-2412, (2005)
- [5] J. Das, K.B. Kim, F. Baier, W. Löser, J. Eckert, High strength Ti-base ultrafine eutectic with enhanced ductility, *Appl. Phys. Lett.*, 87, 161907, (2005)

CONTACT INFORMATION

C. Duhamel

E-mail : c.duhamel@phm.tu-darmstadt.de

Tel: +49 (0)6151 163512

Fax: +49 (0)6151 165557