

Editorial

Microstructural and Mechanical Characterization of Alloys

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Abstract: This Special Issue on “Microstructural and Mechanical Characterization of Alloys” features eight papers that cover the recent developments in alloys (engineering materials), methods of improvement of strength and cyclic properties of alloys, the stability of microstructure, the possible application of new (or improved) alloys, and the use of treatment for alloy improvement.

Keywords: metallic alloys; chemical composition; microstructure; treatment; mechanical properties

Metals and their alloys are currently the basic construction materials used in various fields of technology. The functional properties of these metallic materials depend on their chemical composition, (micro)structure and production technology. Optimizing the functional properties of materials used in construction to reduce their weight and increase the safety of use is currently the primary goal of engineers. This is achieved not only by introducing new types of materials with a better combination of properties, but also by modifying the chemical composition as well as heat, thermo-mechanical and thermo-chemical treatment.

The process of the engineering alloy’s microstructure modification takes place not only through conventional plastic forming processes but also modern, unconventional methods, e.g., equal channel (micro)angular pressing (ECAP). In the case of the copper-based alloy Cu-0.43Mg [1], the ECAP process applied contributed to significant hardness increase, and the lower hardness region appeared at the area nearby the bottom surface. With the number of ECAP passes, the hardness gently increased and finally became saturated. The yield strength of the alloy increased from 124 MPa before the ECAP process to 555 MPa after eight ECAP passes.

Additionally, in the case of rolling of magnesium alloy Mg-2Y-0.6Nd-0.6Zr [2], the ECAP process contributed to obtaining high strength and low plasticity after rolling. As the number of ECAP passes increased, the grain size of the alloy gradually reduced, and the texture of the basal plane gradually weakened. The ultimate tensile strength of the alloy first increased and then decreased, the yield strength steadily lowered, and the plasticity continuously increased. After four passes of ECAP, the average grain size decreased from 11.2 μm to 1.87 μm , and the alloy obtained excellent comprehensive mechanical properties.

Another hardening mechanism for metallic alloys significantly influencing the increase in strength properties is the dispersion hardening and precipitation hardening. Strengthening the AA6063 aluminum alloy with fly ash (FA) particles and the production of AA6063-FA composite, as shown by research [3], leads to an increase in wear rate with increasing load, time and sliding velocity and the friction coefficient decreased with increasing these parameters. In the case of AZ91 magnesium alloy aged at different temperatures ($T_a = 100$ to 300 °C) for different durations ($t_a = 4$ to 192 h), the

strengthening process was carried out through intermetallic β -Mg₁₇Al₁₂ phase-separated in the matrix α -Mg [4]. At lower ageing temperatures (100 and 150 °C) in the microstructure, only discontinuous precipitates were observed, while continuous precipitates invaded and formed at a high ageing temperature (300 °C). In regard to the ageing process, with the time at various ageing temperatures, magnesium alloy also contributed to the change in the crystalline lattice parameter ratio.

The effectiveness of the interaction of secondary (strengthening) phase particles depends not only on their size and distribution in the matrix but also on their thermodynamic stability. Increase in stability (low coarseness rate of the particles) strengthening fine molybdenum carbides precipitate in novel 5Cr5Mo2 steel during tempering treatment compared to H13 steel was observed [5]. Moreover, owing to their pinning effect on the dislocation slip, the dislocation density of the 5Cr5Mo2 steel decreases more slowly than that of the H13 steel. A slowdown of matrix softening of the steel processes can be obtained by modifying and optimizing the chemical composition and parameters of the heat treatment of the tested steel.

The softening process leads to a decrease in the strength properties of the alloys by reducing the strengthening mechanisms. Understanding the basic phenomena and processes related to the softening mechanism occurring in materials is not only the domain of steel but also such processes are observed in other groups of construction materials. In work [6], the study on the Al-Cu-Li-Mg-Ag alloy was performed. The alloy was deformed in a temperature range of 350–470 °C and a strain rate range of 0.01–10 s⁻¹. It has been shown that the main softening mechanism of this alloy is dynamic recovery. The conducted research allowed for the development of hot processing maps, which will enable the optimal selection of temperature and deformation parameters of the aluminum alloy.

Another way of increasing the functional properties of alloys is the fragmentation of the microstructure—reducing the grain size, reducing the width of the martensite/bainite strips, which allows one to obtain not only better strength, but also plastic properties. By modifying the austenitizing parameters of medium-carbon low-alloy martensitic steels, as shown in the studies presented in [7], it is possible to obtain steels with different lath martensite microstructures. It has been shown that with increasing the austenitizing temperature, the prior austenite grain size and block size increased, while the lath width decreased. Further, the yield strength and tensile strength increased due to the enhancement of the grain boundary strengthening.

Powder metallurgy is an alternative method of obtaining finished details and elements of machine or equipment parts. In the case of wear resistance of Co-based alloys with low carbon content [8], the application of the Selective Laser Sintering (SLS) and Powder Injection Molding manufacturing technique allowed us to obtain a product characterized by high properties, such as resistance to abrasive wear. The better resistance to abrasive wear for SLS was explained by the presence of a hard, intermetallic phase, present as precipitates limited in size and evenly distributed in the cobalt matrix and the structure of the cobalt matrix, with dominant content of the hexagonal phase.

This Special Issue covers very different aspects of microstructural–mechanical property relations identified by a wide variety of research techniques and their application in crystal engineering and material science.

The broad spectrum of topics included in the articles in this Special Issue shows that the microstructural and mechanical characteristics of alloy research are very modern. They are also of interest to scientists in other research centers [9–12], showing the long-term effects of temperature and time, as well as stresses on changes in the microstructure and the mechanical characterization of these materials, and that we can still expect new developments in this investigation field.

Conflicts of Interest: The authors declare no conflict of interest.

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