Journal of Bioengineering and Bioelectronics

Short Communication
Vol.3, Iss.2
2020

Nano Congress 2019: Nano-glasses: A new kind of non-crystalline solids with new applications in technology and medicine: Herbert Gleiter- Karlsruhe Institute of Technology - KIT, Germany

Herbert Gleiter
Karlsruhe Institute of Technology - KIT, Germany

Today's technologies are based primarily on utilizing crystalline materials such as metals, semiconductors or crystalline ceramics. The way to a new world of technologies based on non-crystalline materials may be opened by means of nano-glasses. Nano-glasses consist of nanometer-sized glassy regions connected by (nanometer-wide) interfacial regions with atomic and electronic structures that do not exist in melt-cooled glasses. If the size of the nanometer-sized glassy regions is 5 nm or less the volume fraction of these interfacial regions is 50% or above. Due to their new atomic/electronic structures, the properties of nano-glass differ from the corresponding properties of melt-cooled glasses. For example, FeSc nano-glasses were (at 300K) strong ferro-magnets although the corresponding melt-cooled glasses were paramagnetic. Similarly, the ductility, the biocompatibility, the catalytic properties of nano-glasses were improved by up to several orders of magnitude. Moreover, nano-glasses open the way to new kinds of alloys as they permit the alloying of components that are immiscible in crystalline materials. Just like in the case of crystalline materials, the properties of which may be changed by varying the sizes and/or chemical compositions of the crystallites, the properties of nano-glasses may be controlled by varying the sizes and/or chemical compositions of the glassy clusters. This analogy opens the perspective that a new age of technologies - a "glass age"- may be initiated by utilizing the new properties of nano-glasses and modifying their properties by varying the sizes and/or chemical compositions of the glassy clusters.
The majority of materials that have been used by mankind since the Neolithic age are crystalline materials. The oldest known examples are granite and quartz used for producing stone-age tools. More recent examples are light weight metals (e.g., Al), semiconductors (e.g., Si), materials with high strength (e.g., steels), superconductors, ferroelectrics, special ferromagnetic materials etc. The main reason for the preference of crystalline materials is the fact that one can control their properties by modifying their defect microstructures and/or their chemical microstructures. Figure 1 displays the remarkable enhancement of the diffusivities of Cu, Ni and Pd by varying the defect microstructure by means of introducing a high density of incoherent interfaces [1]. The modification of the properties of materials by varying their chemical microstructure is displayed in Figure 2 indicating the increase of the work hardening of an (Al-1.6 atom % Cu) alloy if the chemical microstructure (at constant chemical composition) is changed.
Glassy materials, although known for about 11000 years, have not yet been utilized to a similar extent. The main reason is that, so far, glasses are produced by quenching the melt and/or the vapor. Obviously, this approach does not permit the introduction of defect microstructures (e.g., similar to grain boundaries, Figure 1) or chemical microstructures (e.g., similar to the one shown in Figure 2). As a consequence, one cannot control the properties of today's glasses by the controlled modification of their defect and/or chemical microstructures.

It is the idea of nanoglasses to generate a new kind of glass that will allow us to modify the defect and/or the chemical microstructures of glasses in a way comparable to the methods that are used today for crystalline materials. The basic concept of this approach is schematically explained by comparing the microstructures of nanoglasses and of nanocrystalline materials (Figure 3). If we consider a melt of identical atoms (Figure 3a and Figure 3e), we obtain a single crystal (Figure 3b) if we solidify this melt under conditions close to equilibrium. A nanocrystalline material with a high density of defects in the form of incoherent interfaces is obtained by consolidating nanometer-sized crystals (Figure 3c). If the consolidated nanometer-sized crystals have different chemical compositions, e.g., Ag crystals and Fe

The work is partly presented at 31st Nano Congress for Future Advancements during August 29-30, 2019 at London, UK

crystals (labeled as A and B in Figure 3d), we obtain a multiphase nanocrystalline material (Figure 3d). In summary the structural model of metallic nanoglasses that emerges from these observations is as follows (Figure 15). Nanoglasses are noncrystalline solids consisting of the following two regions. There are regions (red and yellow in Figure 15) with the same atomic structure as a glass produced by quenching the melt. These regions originate from the nanometer-sized glassy spheres that were consolidated in order to produce the nanoglass. Between these glassy regions, interfacial regions (dark blue in Figure 15) exist. In these interfacial regions, layers of a new kind of noncrystalline atomic structure (different from the atomic structure in the red and yellow regions) are formed. This new noncrystalline structure is associated with an electronic structure that differs from the one of the corresponding melt-quenched glass. The new kind of noncrystalline structure is, according to the results reported above, characterized (relative to the glassy structure in the red yellow regions) by a reduced density, an enhanced spacing between next-nearest-neighbor atoms and a reduced number of nearest-neighbor atoms. The new electronic structure of these interfaces is suggested by the observation of a reduce s-electron density (Mössbauer spectroscopy), an enhanced Young’s modulus and atomic force constant in NRVS, an enhanced Curie temperature and enhanced hyperfine field as well as itinerant ferromagnetism instead of a spin glass structure. In other words, nanoglasses seem to consist of the following two noncrystalline phases: one phase with a glassy structure and another phase with a new kind of noncrystalline atomic structure as well as a new electronic structure. This paper started by considering the role of materials in the history of mankind. Hence it seems appropriate to close the paper by considering the conceivable historical implications of the development reported here.

In the past, the understanding and utilization of materials such as metals, semiconductors, ceramics, etc., resulted in specific periods in the development of mankind. In fact, the names of some of these periods were selected according to these materials such as the Iron Age, the Bronze Age etc. All of these periods are characterized by the fact that the properties of the new materials that became available by controlling their structure were utilized and permitted new technologies to be developed. Today, we seem to be in a comparable situation for materials with noncrystalline structures. In fact, nanoglasses seem to open the way to a new class of noncrystalline materials with controllable atomic and electronic structures and, hence, new properties (in comparison to glasses produced by quenching the melt). Hence, by analogy with the developments of the past, nanoglasses may permit the development of technologies that are not possible today by utilizing the new properties of nanoglasses.

The work is partly presented at 31st Nano Congress for Future Advancements during August 29-30, 2019 at London, UK