Nanocrystalline metallic particles as building blocks

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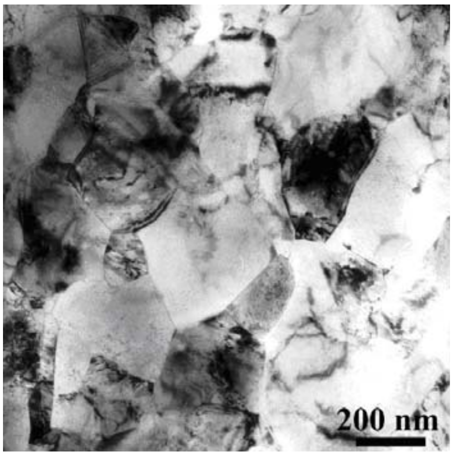
Miniaturizing devices is opening tremendous perspectives in wide diversity of fields as micro electronics for computer science, communication, in medicine for static and dynamic implants, for all type of sensors. Micro devices would be able to generate outstanding operations at micron and nano scales, based on the combination of mechanical, electrical, optical, thermal and magnetic phenomena. It comes that the development of such devices is extremely challenging since operations at minute scale are related at least to three dominant requirements: first a perfect control and reproducibility of the structure and chemistry related properties of the materials. Second, further miniaturising would need the use of nanoscale microstructures which properties is not fully understood. Third, nanostructured device size effect on properties is not known as well. These three aspects are mostly prominent for the mechanical behaviour of nanostructured [1]. Which is a key problem since this property is essential in the fabrication of devices that generally needs forming. To scientific and technical aspect, is added the financial one. It sounds obvious that development of miniaturising would need new materials synthesis and forming technologies for easy fabrication of devices in a reproducible manner and at low cost.

We study the synthesis, individual and collective properties (mechanical and magnetic) of metallic nanocrystalline particles as building blocks for fabrication of nanostructured materials. The population of nanoparticles is produced by a so-called evaporation and cryo-condensation process. The formation of these building blocks is based on metallic vapour condensation through out the control of nucleation and coalescent coagulation within a supersaturated cryogenic medium. Technically radio frequency induction heating and levitation is used to produce high vapour pressure from metal or alloys sample immersed inside a cryogenic liquid (argon or nitrogen).

The synthesis details will be addressed illustrated with copper nanopowder and series of Fe_xNi_y soft magnetic particles having particle size of 50 nm [2, 3]. Local structure and chemistry are examined using transmission electron microscopy (TEM). Direct observation of magnetic fields with the TEM holography technique reveals vortex structure of the magnetic moment in connection to collective effect in FeNi nanoparticles. These systems are of interest for medical application as magnetic probes [4].

Nanopowders of copper are studied as building blocks for the formation of bulk nanostructured specimen using powder metallurgy technique [5]. The nanostructured metal revealed unusual behaviour featured by near-perfect elasto-plasticity and high strength [6]. Ductility depends on the strain rate and along with strength on temperature. Strain rate sensitivity is unusually high compared to micron sized counterpart and reach the value of 0.17 at $\dot{\varepsilon} = 1 \times 10^{-5} s^{-1}$ and T=120°C. This new behaviour opens interesting perspective to fabricate micron size devices with relevant mechanical performance such as high strength and ductility.

From the mechanical measurements and TEM observations, elements of the mechanism for plastic deformation are derived. The role of dislocations, interaction between dislocations and dislocation with grain boundaries is emphasised.



Transmission electron microscopy micrograph of nanostructured copper prepared by powder metallurgy.

Keywords: copper, iron-nickel, nanostructure, nanoparticle, mechanical properties, magnetic properties.

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