ANISOTROPIC REINFORCEMENT OF NANOCOMPOSITES TUNED BY MAGNETIC ORIENTATION OF THE FILLER NETWORK

J. Jestin[1], F. Cousin[1], I. Dubois[1], C. Ménager[2], R. Schweins[3], J. Oberdisse[4] and F. Boué[1]

[1] *Laboratoire Léon Brillouin, CNRS-CEA, 91191 Gif-sur-Yvette*
[2] *Laboratoire Liquides Ioniques et Interfaces Chargées (LI2C) CNRS/Université Paris 6 75252 Paris Cedex 05*
[3] *Institut Laue-Langevin, DS/LSS 6 rue Jules Horowitz, 38042 Grenoble Cedex 9*
[4] *Laboratoire des Colloïdes, Verres et Nanomatériaux (LCVN) Université Montpellier II 34095 Montpellier Cedex 05*

The improvement of the mechanical properties of polymer films by inclusion of mineral particles is a well known industrial practice used since the end of the XIX century. A classical example is the rubber industry for which the addition of carbon black as fillers permits to increase the elastic modulus of the pneumatics. Nevertheless, the mechanisms which govern the reinforcement properties are still not completely described by experiments and theory. More recently, the use of fillers of nanometric size and of controlled geometry like colloidal silica allowed significant advances in the understanding of these mechanisms and in the conception of innovative materials. In this context, an original approach is to try to improve and to control the specific properties of the material with an external trigger like a magnetic field. We have obtained polymer films with anisotropic mechanical properties by inclusion of magnetic particles inside the matrix which can be aggregated in a controlled way during the film processing and oriented with an external magnetic field. The orientation of the fillers during the processing condition with the field is a new approach when magnetic composites are usually exploited to modulate the mechanical properties after the synthesis.

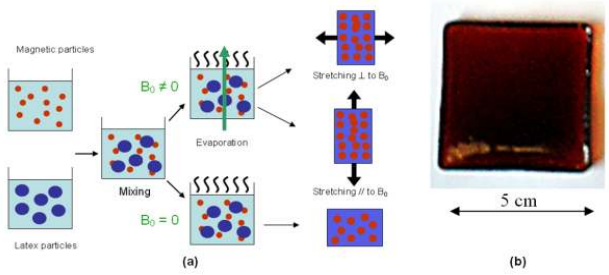

Fig. 1: (a) Principle of films processing without and with magnetic films, (b) picture of the final film.

The film synthesis was adapted from a previous work [1] on films formed by simple drying of aqueous solutions of nano-latex and of silica particles (D=10nm). The morphology of the aggregates of particles controlled the macroscopic properties of the materials and can be modulated with the physical-chemistry conditions of the solutions before casting. Our magnetic particles (maghemite γ-Fe_2O_3, D=10nm) have been covered with a thin silica layer to realize the synthesis in the same conditions as [1] and to control the aggregation. Films have been dried without/with magnetic films (150 Gauss) (Fig. 1a). Resulting composites are macroscopically homogeneous (Fig. 1b).

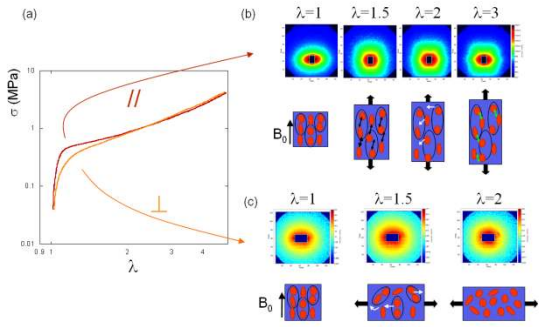

Fig. 2: (a) Stress-strain isotherm for a sample synthesized under magnetic field, stretched along the field direction or perpendicular to it, (b) 2D SANS curves for stretched sample parallel to the field (top) and perpendicular to it (bottom) as a function of the deformation, and resulting filler structure in the real space.

When the films are drying under magnetic films, the mechanical properties are very anisotropic. The reinforcement is larger along the direction parallel to the field than along the direction perpendicular to the field in the low deformation regime (figure 2). The rapport between the reinforcement factors is larger than 2! For larger deformations, the mechanical properties become similar and are close to the modulus of the pure matrix. These spectacular properties can be explained by the local structure of the magnetic particles inside the polymer matrix which has been determined with SANS. During the drying process, anisotropic aggregates are formed and oriented along the field direction. When the films are stretching along the field direction, the aggregates re-arrange and connected to form a filler network which increases strongly the reinforcement. Conversely, when the films are stretching perpendicular to the field direction, the aggregates filler network is breaking and the resulting reinforcement is lower [2].

References:

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Contacts: jacques.jestin@cea.fr
fabrice.cousin@cea.fr