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Shape memory material based on potato starch

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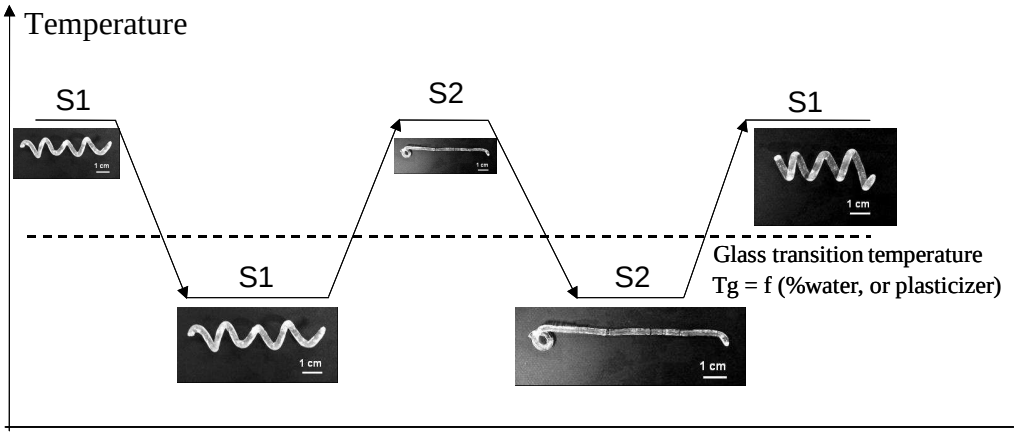
Abstract –Shape memory behaviour has been evidenced on extruded potato starch. It can change spontaneously its macroscopic temporary shape in a programmed shape under temperature or humidity surrounding conditions. Its efficiency is comparable to shape recovery of "classic" shape memory polymers. Mechanisms imply residual stress relaxation at glass transition temperature.

Shape-memory polymers (SMP) are a new class of smart materials which possess the ability to recover a "programmed" permanent shape from a temporary one, when submitted to an external stimulus[1]. This study shows a remarkable shape memory capability of glassy starch materials, stimulated by temperature or surrounding humidity.

Potato starch were extruded using a single-screw device to obtain a completely amorphous state (27% water w.b., 120°C), which was checked by calorimetry and X-Ray measurements. Then, the programmed permanent shape (S1) and the temporary shape (S2) are given during a thermomechanical processing described on the figure below. It is a combination of temperature and mechanical treatments applied in the rubbery state and fixed in the glassy state, similar to the treatment used for "classic" SMP. The recovery of the programmed permanent shape is spontaneous when ambient conditions, temperature or humidity, lead to a glassy / rubbery state change (glass transition). The efficiency of programming and recovery behaviour of extruded starch is expressed by the recovery rate Rr (%) calculated by the deformation recovered divided by the fixed deformation. Recovery rate has been determined in the case of recovery triggered by water sorption in high humidity conditions (RH 97%). A value of 94% obtained for a fixed deformation of 135% indicates a very efficient shape recovery behaviour. It competes with the value of 90% for semi crystalline polyurethane (PU) [2] and copolymer containing polylactid glycolid caprolactone (PLAGC) segments for similar deformation. The glass transition, which is the trigger of the shape change can be controlled in a temperature range from 10°C to 100°C, by the additi on of a plasticizer such as glycerol or sorbitol. Potato starch materials are perfectly transparent and a birefringence effect, evidenced under polarized light, demonstrates the presence of residual stress stored in the samples[3]. The shape recovery, simultaneous to the disappearance of birefringence, is due to the relaxation of residual stress at Tg.

Starch presents very interesting shape-memory capabilities, at similar levels than those obtained with synthetic shape-memory polymers, such as PU, or biopolymer-based such as PLAGC. It opens new perspective of cheap, biodegradable and alimentary shape memory products.



Thermomechanical process of shape programming / recovery of extruded potato starch

References

[1] M. Behl and A. Lendlein. Materials Today, 10, (2007), 20 – 28
[2] J. Hu, in Shape memory polymers and textiles, Woodhead Publishing, Cambridge, (2007)
[3] L. Chaunier and D. Lourdin, *Starch-Starke* (2009), 61, 116