

SHAPE MEMORY POLYMERS-(SMPs) NANOSTRIP MULTILAYERS APPLIED ON THE NEW BEARING GENERATION FOR HARD WEARING IN TURBOCHARGES

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ABSTRACT: Shape Memory Polymers-(SMPs) nanostrip multilayer's shows one way effect like shape memory alloys (SMAs). SMPs represent co-polymers which generally the structure consists of two types of components. One component, like nanostrip multilayer's, with the higher glass transition or melting temperature, represent the hard component. This hard component (elastomer) represent the main element of SMP, which improve the tribological (wearing resistance) properties and provides the mechanical strength of SMP at high temperature, T_{trans} , where the soft component (thermoplastic), which stabilizes the hard component at low temperature, loses its strength. Compared to metallic shape memory alloys, SMPs have the ability to store and recover larger strains (up to more than 200%). They are cheap, light in weight, non-toxic, and easy to process. The most important is capacity to be biocompatible and biodegradable. These properties and characteristics offer to SMPs like one potential candidate for future bearings in turbochargers.

Keywords: shape memory polymer, tribology, wear, nanostrip, elastomer

1. INTRODUCTION

Biodegradable polyesters such polyurethane, poly (lactic/glycolic) acid copolymers (PLGA), SMPs based on polycaprolactone, are preferred materials for shape memory polymers.

Their surface hydrophobicity however, triggers the fast clearance of carrier monomers from the body [1, 2].

Surface hydrophilization by immobilization of poly (ethylene glycol) (PEG) might prolong their circulation time and hence allows the programmed SMP release [3].

In the present work thin polymer nano-films on a solid support were used as a model system to study their surface properties by various techniques. The polymer nano-films were prepared by spin coating casting method from the elastomer mixed with the modifying thermoplast - containing compound at various concentrations.

Wettability and surface analytical techniques were applied to characterize the composition and hydrophilicity of the surface layer.

The increased hydrophilicity and hence the reduced polymers adsorption on the surface is supposed to be in correlation with its biocompatibility.

To investigate the poly-elastomer adsorption in situ ellipsometric studies are planned to be performed.

In the present work we show SMPs nanostrip multilayers experiments and results on the nanostrip

multilayers sample of the *Vybormem-SMP*, (Figure 1), which is compared with NiTi-shape memory alloys.

This work describes the investigation Tribology Laboratories, IfM- Univ. of Cambridge-UK, and D8 DISCOVER with GADDS -BRUKER AXS - Germany.

2. EXPERIMENTAL RESULTS

Shape memory polymers-(SMPs) nanostrip multilayers, show a new challenge effect against shape memory alloys (SMAs).

Its can be deformed into a new shape and recover to a programmed permanent shape by heating.

The SMPs effect of polymers can be established in different classes of polymers like: polyethylene, polyurethanes and biodegradable, SMPs based on polycaprolactone.

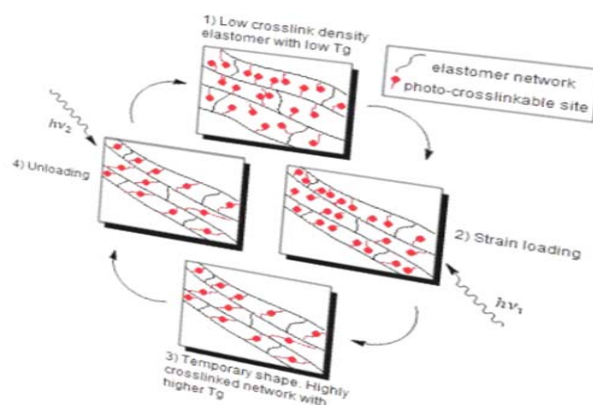


Figure 1. Shape Memory Polymer nanostrip multilayers-Vybormem

Table 1. The Comparison Shape Memory Polymer-SMP, Vybornem vs. Shape Memory Alloys

Parameters	Shape Memory Polymer-SMP Vybornem	Shape Memory Alloys- NiTiX [6]
Density, g/cm ³	0,8-1,2	6,3-6,7
Deformation, %	Up to 237	8
Young modulus T Trans, GPa	0,0088-1,0	72-98
Tensile strength, Yield, MPa	19,0	27,0
Temperature work , °C	(-15) / (+310)	(-50) / (+100)
Thermal conductivity, W/mK	0,12-0,35	12-18
Biocompatibility /degradability	Can be biocompatible and / or biodegradable	Good biocompatible and not biodegradable
Processing conditions	Low pressure, 250°C	High pressure, 1000°C
Corrosion resistance	Excellent	Very good
Costs	185€/kg	300-360€/kg
Hardness, Shore A	75	50-64
Compression set	72 hours @ 200°C	-

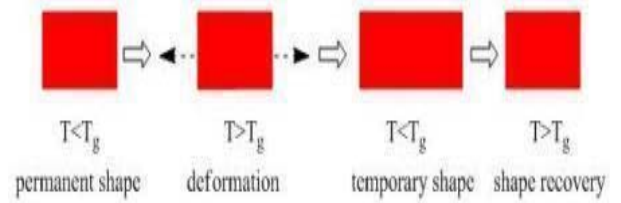
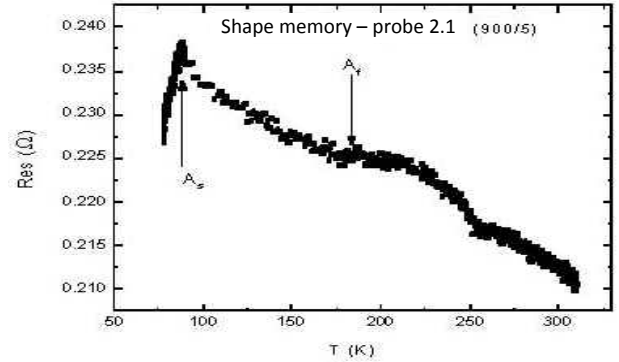
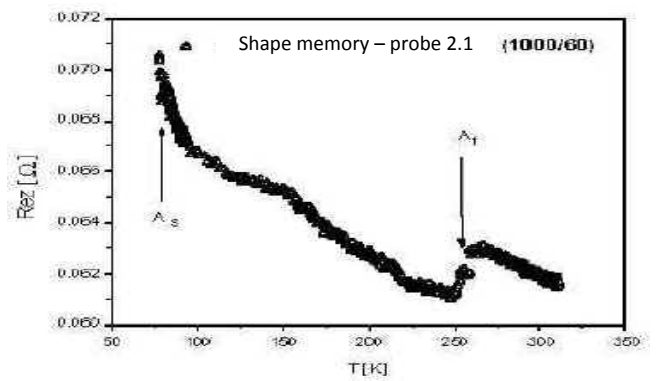


Figure 3. Effect of the glass transition



a)



b)

Figure 4. a-Electrical / b-Friction vs. Temperature for Shape Memory Polymer-SMP, Vybornem



Figure 2. Shape Memory Polymer-SMP, Vybornem: the nanostrip dimensions: 5 x 25 x 125 nm; Presentation of the Shape Memory Polymer after 25 tests, max. Strain 100%;

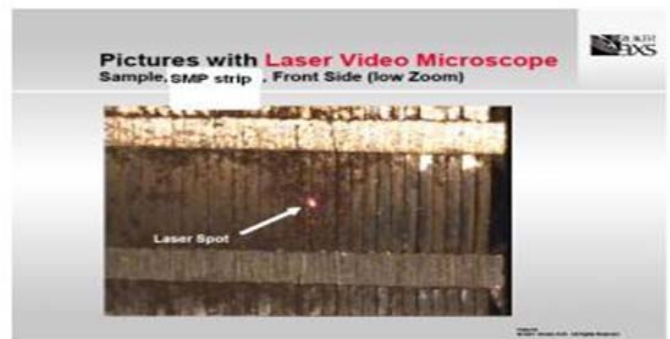


Figure 5.a. Shape Memory Polymer-SMP, Vybornem nanostrip spot front size, low zoom (up), and spot-size front size

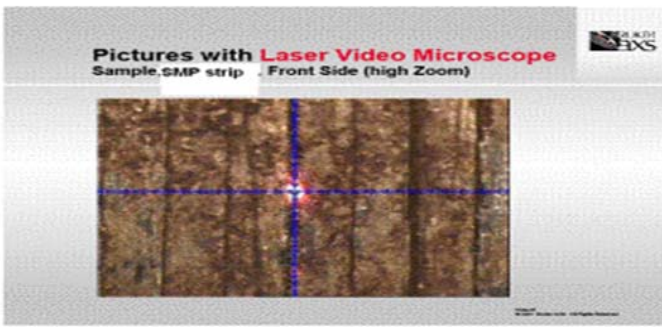


Figure 5.b. Shape Memory Polymer-SMP, Vybornem nano-strip spot front size high zoom (down);

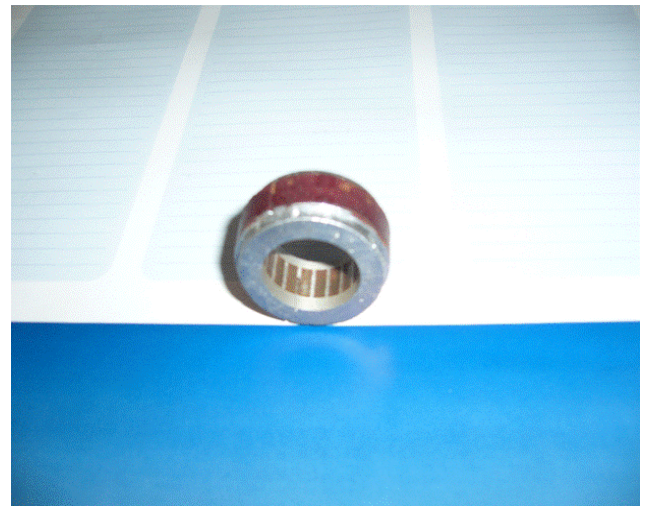


Figure 7b. SMPs nano-strip multilayer's covering O-Ring used in the bearing turbocharger after one full test

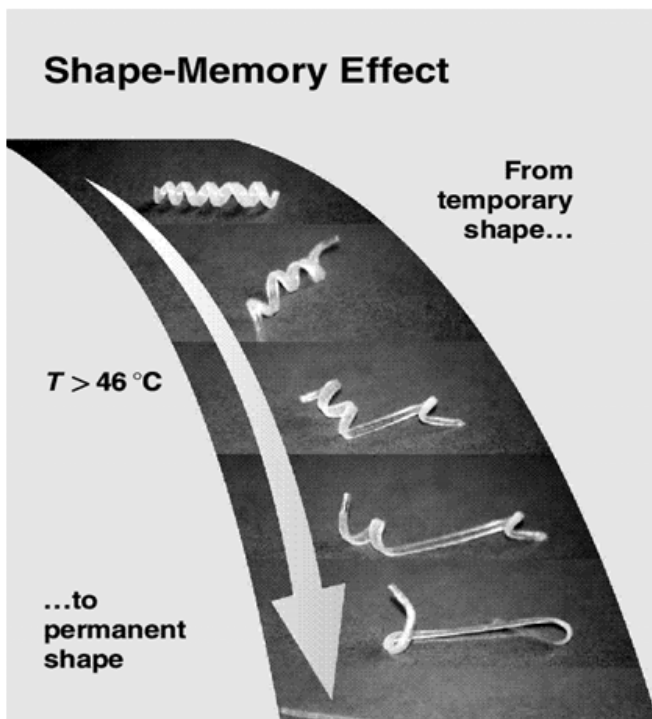


Figure 6. Shape Memory Effect of Shape Memory Polymer Nano-strip Multilayer's, SMP- Vybornem over 46°C



Figure 7a. SMPs nano-strip multilayer's covering O-Ring used in bearing turbocharger

3. DISCUSSIONS

Figure 1, shows physico-chemical evolution of SMPs.

In figure 2 and 3, we show nano-strip real forms of Vybornem coated nano-layer deposited and short flow chart of SMP shape against T_g [4, 5].

Moreover in order to characterize the elastic-plasticity of nano-layers in coated deposition, we show electrical measurements (fig.4).

The electrical resistance R_{ez} (Ω) against temperature shows damping over a glass temperature T_g [6]. Table 1, shows real parameters of this new Vybornem SMPs nano-layer material against Classical SMA-NiTiInol, well known.

In figure 5 (a and b), it is shown the real coated deposit of nano-layers by new method LVM (Laser Video Microscopy) [7, 8].

Diorama from figure 6 shows evolution of nano-strip layers Vybornem below and up T_g .

In figure 7 (a and b), it is shown one specific aircraft turbocharger device in use with coated nano-layer Vybornem.

Shape memory polymers SMPs are sometimes considered as being *smart materials*, because they respond to external stimuli.

SMPs show one way effect like shape memory alloys (SMAs).

They can be deformed into a new shape and recover to a pre-programmed permanent shape by heating [6].

It results from the physical properties of the constituents of the polymer structures, chemistry,

and morphology (tendency of chains to adapt high entropy configurations, melting and freezing of soft segments in a co-polymer).

Suitable polymer structures / morphologies are obtained using specific processing and programming procedures.

4. CONCLUSIONS

Shape Memory Polymer-SMP, Vybormem have been prepared by the IfM method through variation of the cooling procedure.

A monomodal elastomer size distribution was obtained by applying a slow cooling procedure, while a fast cooling procedure gave rise to a hierarchically structured bimodal thermoplast size distribution.

It was possible to demonstrate that the hierarchically structured polymer exhibited improved shape-memory properties with respect to the shape-recovery rate and the absolute recovery.

As it was found by mechanical and morphological analysis on the macro and micro scale (by using a micro compression device), the hierarchically structured SMPs can store more energy due to microscopic bending of the large structural walls during compression of the SMPs at elevated temperatures compared to the non-hierarchical polymers.

The surface of the nano-layer SMP Vybormem is flat with no apparent features which could be discerned in the optical microscopy.

Further work is required to rationalize this observation and to study the evolution of the surface morphology as function of maximum applied strain of cycle number.

In a next step, the hierarchically structured SMP might be investigated as actively moving scaffold for tissue engineering purposes to mechanically stimulate cells, as it is currently only achieved by external loading through turbo-chargers and the incorporation of magnetic particles might allow a non-contact triggered recovery.

5. REFERENCES

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