Electronic Supplementary Material (ESI) for Materials Horizons.

Supplementary data

Programming the shape-shifting of flat soft matter: from self-rolling/-twisting materials to self-folding origami

S. Janbaz, R. Hedayati, A.A. Zadpoor

Department of Biomechanical Engineering, Faculty of Mechanical, Maritime, and Materials Engineering, Delft University of Technology (TU Delft), Mekelweg 2, 2628 CD, Delft, The Netherlands

THERMOMECHANICAL CHARACTERIZATION OF THE HYPERELASTIC POLYMERS

Three different types of rubber sheets were used as the passive layer of self-rolling and self-helixing bilayers. Rubber sheets were made of NR/SBR (natural rubber/styrene-butadiene rubber), NR (natural rubber) and soft PVC. Uniaxial tensile tests were performed to characterize the mechanical and thermomechanical properties of the rubbers. Specimens were tested at five different temperatures ($22, 40, 60, 80,$ and 100 °C). An electromechanical testing machine (Zwick) with a $10kN$ load cell and pneumatic grippers equipped with an environmental chamber were used to stretch the strips up to 100% at a deformation rate of 10 mm/min. The strains were measured based on the movement of crosshead. Figure S1 illustrates the effect of temperature on the mechanical behaviour of different polymers. In ambient temperature, soft PVC is the stiffest material. Rise in temperature to 100 ℃ softens PVC very much such that this material shows the lowest stiffness compared to the other polymers. The stiffness of soft PVC drops to 3.2% of its stiffness in the ambient temperature as a result of increasing the temperature to 100 ℃. Natural rubber does not show significant change in its mechanical properties within the range of temperatures used here. The NR/SBR rubber exhibits 50% reduction in its stiffness as temperature is increased to 100 ℃. The initial Young's modulus of the three types of hyperelastic polymers are listed in Table S1. In addition, Polyolefin heat shrink polymer used in this study were tested to estimate the actual shrinkage ratio at different temperatures.

Figure S1. The thermomechanical behaviour of various hyperelastic polymers used in the current study.

(a)

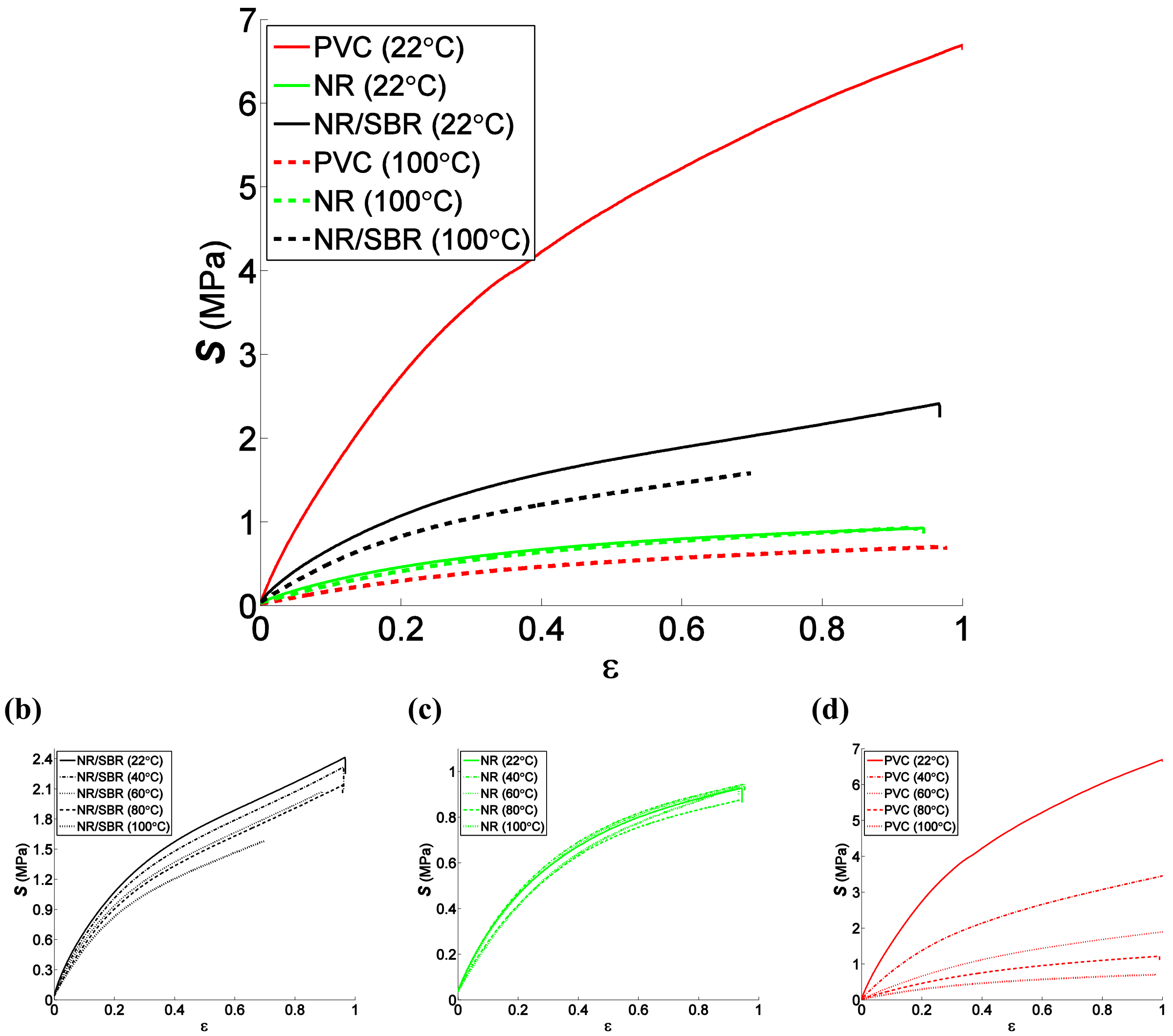

Table S1. The initial Young's modulus of three different hyperelastic polymers used as the passive layer of self-rolling and self-twisting bilayers at ambient temperature and 100℃.

Material	E_0 **at** 22℃ (MPa)	E_0 **at** 100℃ (MPa)
NR/SBR	12.45	5.72
NR	3.83	2.40
Soft PVC	23.83	0.77

Figure S2. The shrinkage in the polyolefin SMP strips measured at different temperatures. The programmed SMP strips show a 4.5% shrinkage at 70℃.