# Shape Memory Effect and Thermomechanical Properties Shape Memory Polymer Fabric Composite in Tension Mode

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Fibres and fabrics are often used to reinforce shape memory polymers to improve their mechanical strength and properties, and the composites have been widely used in engineering as functional and structural materials with great potential for advance applications such as spacecraft, self-deployable devices and vibration control devices. They are also excellent in providing bending mode structures and have been widely used for repairing cars and as fixers for temporary shapes. Since a lot of applications require high recovery stress, using SMPCs in tension mode to provide large recovery stress or as a fixation medium, it is extremely important and of much interest to understand the behaviours of SMPCs under tension deformation mode and to use information relating to deformation and degradation prior to designing appropriate SMPC based structures [1-3]. So far little effort has been made in this area. The thermomechanical properties and the deterioration mechanism of a commercial shape-memory polymer composite (SMPC) VeriTex were investigated and the results are reported.

Instron Tensile tester were used to investigate the stress vs. strain, fixity, recovery ratio, recovery stress and stress relaxation, SEM and optical microscope were used to investigate the microstructure behaviour and deterioration of the of the composites after extension and under thermal stimulation. The results can be summarized as follows:

- Linear stress-strain behaviour was observed for these SMPCs at temperatures higher than transient temperature $T_g$ with strains up to 150%. But the residual strain is larger for samples deformed at lower temperatures, and it increases with strain.
- SMPC samples showed good shape recovery for samples extended up to 100% if they are reheated at $T>T_g$ for a few minutes, The recovery ratio is in the range of 85~95%, depending on the strain and temperature for the deformation. Shape recovery ratio was found to increase with temperature. Non-full recovery was observed for samples extended at >100%, where broken fibres and delamination of SMP from fibres were directly responsible for this.
- Shape recovery of the SMPC even occurs at a temperature 25°C lower than Tg, and the recovery stress increases with temperature rapidly, but decreases with cyclic test.
- Pre-extended (or strained) SMPC sample showed a stress relaxation with time with a process dominated by a single process and can be expressed by a semilog equation with time, differing from pure SMPs. The relaxation time constant was found to increases with temperature, significantly different from pure SMPs.
- Delamination of SMP from fibres and broken fibres are the main reason for reduced shape memory effect and reduced recovery stress (force) if the samples are extend beyond 100%. However localized areas still possess shape recovery properties even a large proportion of the SMPCs were broken or delaminated. Therefore these SMPCs are limited to applications with extension less than 100%.
- Nonuniform shape memory effect exists for these SMPCs and non-uniform elasticity of the fabrics impregnated is responsible for this.

References:

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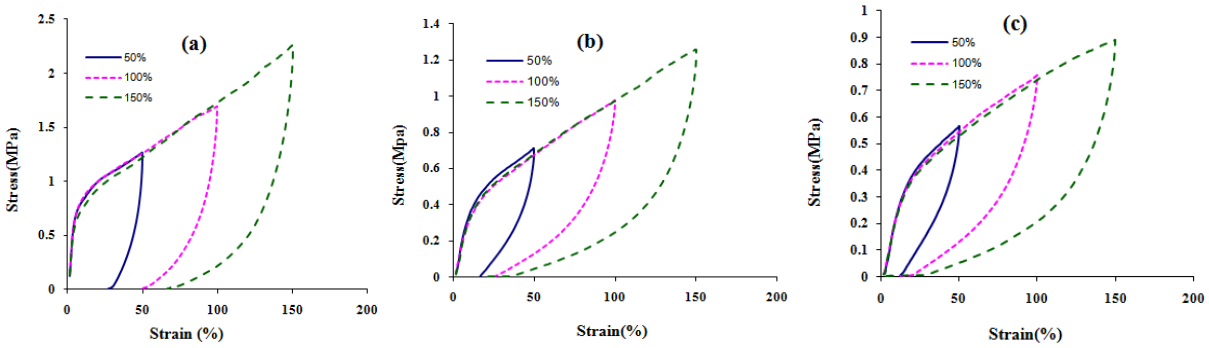


Fig.1: Stress/Strain relationship at strain of 50%, 100% and150% tested at 90 (a)100 (b) and 110°C (c) respectively.

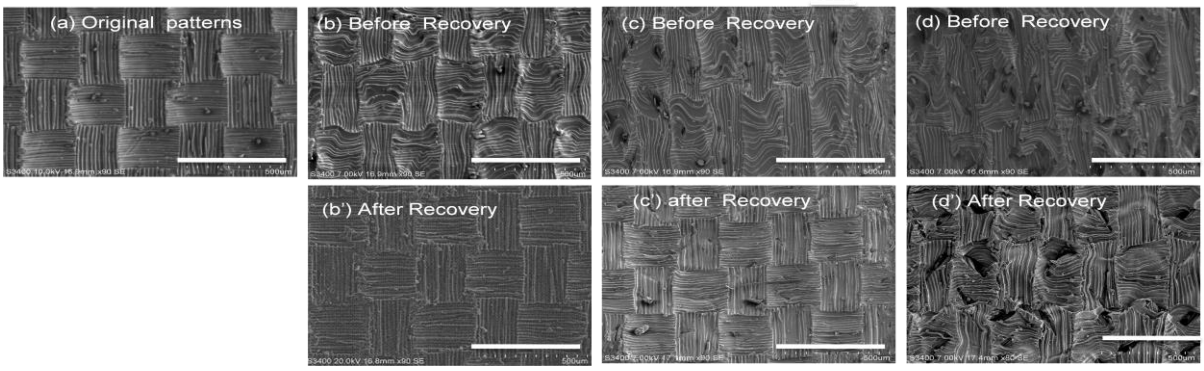


Fig.2 SEM pictures of SMPCs. The upper row are samples strained at 0, 50, 100 and 150% strained at 100 $^{o}$C, and the lower row are the extended samples recovered after heating at 110°C for 5 mins. White bars are 500 μm scale for all.

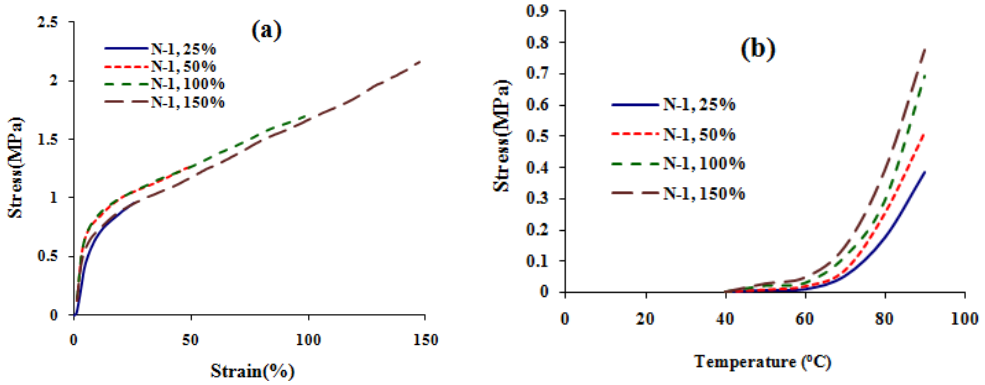


Fig.3a and b: SMPC extended at 90$^{o}$C at different strains, as per deformation recovery stress generated by individual SMPC samples respectively.

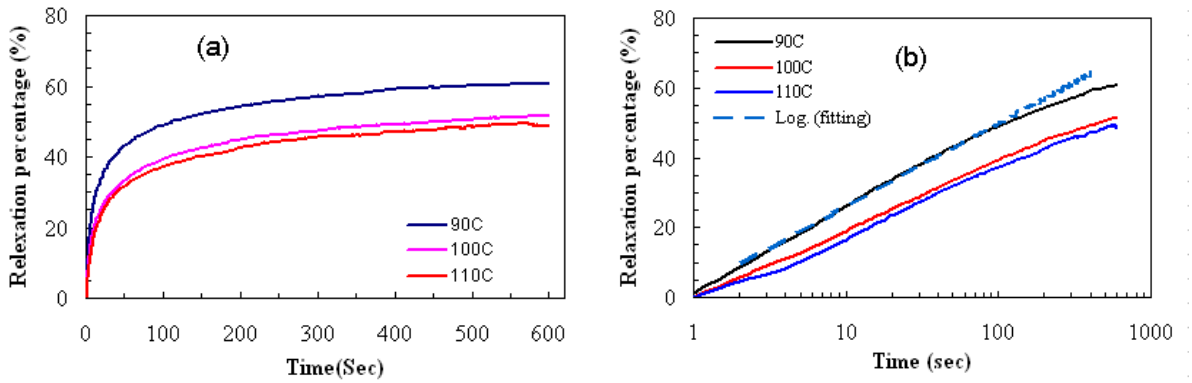


Fig.4: stress relaxation of the SMPC samples extended at 100% with strain as a parameter in linear (a) and semi-log scale (b).