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Development and characterization of architected silicone membranes

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Some medical applications need the elaboration of membranes with specific anisotropic mechanical behaviour. The present study aims at proposing a solution based on the use of only one material. The idea lies on the creation of architected membranes by controlling the cross-linking heterogeneities at scale of the representative elementary volume. A silicone rubber is chosen for the elaboration of such membranes, because of its elastomeric properties and its easiness to modify chemistry.

The cross-linking density is locally controlled by the use of a photo-inhibitor UV irradiated before the elastomer crosslinking. Irradiated zones crosslink less during the elastomer curing, and have therefore weaker mechanical properties than the non-irradiated zones. A minimum cross-linking density is imposed to the weak zones to keep an elastomeric behaviour with a moderate residual deformation. A modulus ratio between soft and hard phases of about 3.5 has been reached. An example [1] is proposed in figure 1 during a manual uniaxial tensile test. Different zones can be observed on the specimen due to the different cross-linking degrees. The heterogeneous deformation of the specimen is observed with smaller lateral deformations in the highly cross-linked zones of the specimen.

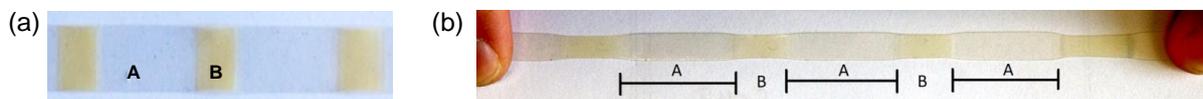


Figure 1. Architected membrane (a) with no loading (b) manually stretched (A: Hard zones, B: Soft zones).

A circular membrane was finally processed. It presents a circular central zone weakly cross-linked and an exterior zone highly cross-linked. A bulge test was performed with this membrane (cf. figure 2). The tests highlight a strong influence of the heterogeneous cross-linking state in the membrane.

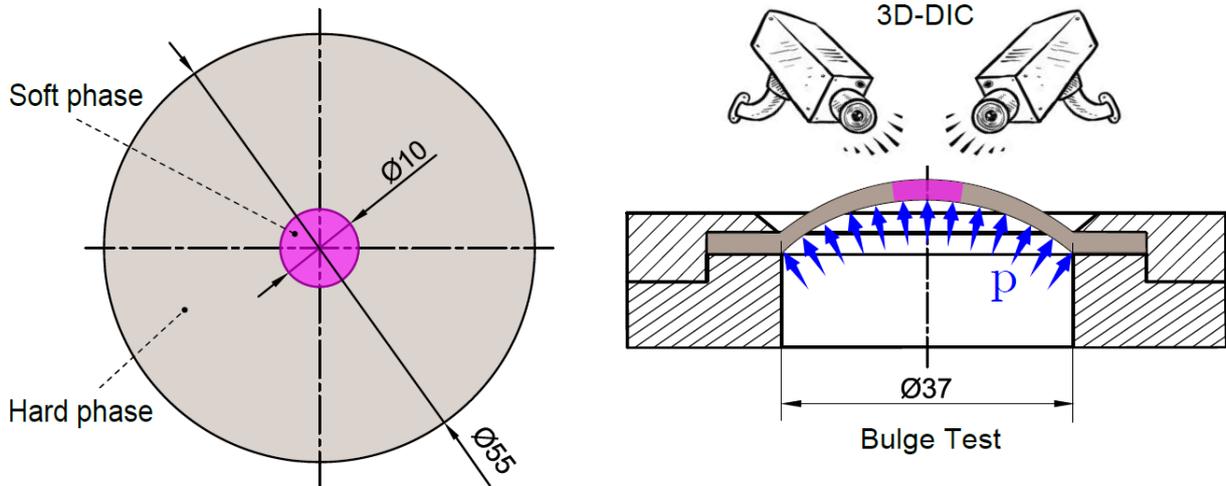


Figure 2. Description of a circular membrane with two zones (a soft and a hard one) and of the bulge test apparatus.

The stresses of the bulge test are obtained through the method developed in [2]. A simulation of the same test was performed using with two different Mooney-Rivlin (MR) constitutive equations fitted on the uniaxial tests performed on each phase. Large differences are observed between experimental results and simulations at the interface between soft and hard phases in the membrane. Finally an inverse analysis is carried out, identifying which should be the MR parameters in each point of the membrane. The results of the simulation are presented in Figure 3. It can be observed that the centre and the border of the membrane are quite homogeneous whereas an interface of about 3mm width exists.

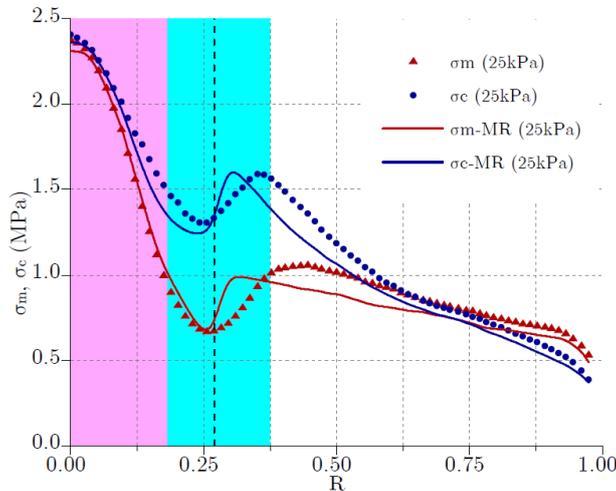


Figure 3. Comparison of experimental and numerical circumferential and meridian stresses along the normal radius of the membrane for a bulge test at a pressure of 25kPa.

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