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Yield stress agent for silicone 3D printing

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3D printing deposition technology allows surgeons to produce patient-specific implants with high degree of effectiveness. However, biomimetic properties (mechanical behavior) of implants can only be obtain with silicone elastomers which are some of the most challenging materials to be 3D printed. Rheological behavior, particularly yield stress character, of viscoelastic materials is well known to be the key parameter to successfully use 3D deposition technology. Thus, if the stress reach a high enough value, the shape of printed object is holded during and after deposition, but also during post-printing polymerization process. Unfortunately, the yield stress properties of high viscosity silicone is often too low to permit efficient 3D printing. Addition of yield stress agents in silicone formulations might be a solution to this problem and silica or glass fiber are commonly used in silicone formulations to change rheological properties. However, the presence of these charges implies modifications of the final mechanical properties of the silicone related to the high rigidity of the added charges. The consequence here is then the production of 3D objects with poor biomimetic behavior. We propose the use of polyethylene glycol (PEG) as low rigidity, yield stress enhancer charge, to be used with high viscosity silicone formulations, as a breakthrough toward silicone biomimetic implants 3D printing. This charge interacts with the surface of the silica dispersed in silicone formulation through hydrogen bonds. A secondary network is then created which provides a strong enough yield stress character, leading to efficient 3D printing capability. The low energy of this network unchange the initial mechanical properties of silicone after curing. Clear experimental results will be presented together with case study of highly challenging 3D printing, demonstrating the superiority of the approach.

Figure 1: Hexagon 3D printing with silicone (left) vs silicone + PEG (right).

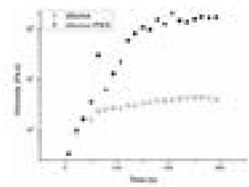

Figure 2: Yield stress character of silicone vs silicone + PEG (Stress ramp test with stress controlled rheometer).

Recent Publications

1. Mouser V H M, Melchels F P W, Visser J, Dhert W J A, Gawlitta D, Malda J (2016) Yield stress determines bioprintability of hydrogels based on gelatin-methacryloyl and gellan gum for cartilage bioprinting. Biofabrication. 8(3):035003. Doi:10.1088/1758-5090/8/3/035003.
2. Mirta I Aranguren, Elsi Mora, Christopher W Macosko and J Saam (1994) Rheological and mechanical properties of filled rubber: silica-silicone. Rubber Chem. Technol. 67(5):820-833.
3. Kotsilkova R G W (1990) A study of transient and steady-state shear and normal stresses in glass fiber suspensions. In: Oliver D.R., ed. Third European Rheology Conference and Golden Jubilee Meeting of the British Society of Rheology. Springer, Dordrecht; 280- 282. Doi:10.1007/978-94-009-0781-2¬¬_98.

Biography

Edwin Joffrey Courtial has completed his PhD from IMP (Ingénierie des Matériaux Polymères) Lab, Université Claude Bernard Lyon 1, Lyon, France. He is a Researcher specialized in materials science and rheological behaviors, and working in Institute of Molecular aand Supramolecular Chemistry and Biochemistry CBMS, Lyon, France in the innovative platform 3D FAB. These main activities are focused on correlation between (bio)materials formulations and rheological behaviors to define 3D (bio)printable conditions. His interest includes: 3D printing, rheological and mechanical behaviors and polymer formulation.

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