Application note | ElastoSens™ Bio

Testing the viscoelasticity of 3D printed hydrogels using ElastoSens™ Bio

ELASTOSENS™ BIO

3D BIOPRINTING

HYDROGEL FORMULATION

THERMO STIMULATION

SUMMARY

— The mechanical characterization of 3D printed scaffolds have been conventionally performed by destructive testing techniques.

— ElastoSens™ Bio has shown to provide reproducible and sensitive measurements of the viscoelastic properties of 3D printed scaffolds.

— The volume fraction and the printing pattern contributed to the mechanical properties of 3D constructs.

INTRODUCTION

3D printing technologies offer the advantage of precisely controlling the microstructure of scaffolds used for tissue engineering applications and drug delivery systems. The macro-mechanical properties of these scaffolds are directly related to their microstructure and both are important parameters for cell behavior and drug release [1,2]. The evaluation of the scaffold mechanical properties has been conventionally performed by destructive, in contact testing techniques (e.g. compression and tensile tests). This prevents the use of the 3D printed scaffold for further characterizations and requires multiple samples to test its mechanical stability over long periods of time. In addition, technical limitation of conventional instruments are usually an issue to precisely measure the soft nature of these scaffolds. In this short application note, the viscoelastic properties of two 3D printed scaffolds made of two different materials were tested using the ElastoSens™ Bio.

MATERIALS AND METHODS

RTV silicone rubber (Dow Corning, MI, USA) and poloxamer gel (Allevi, PA, USA) were 3D printed inside the ElastoSens™ Bio sample holder (Fig. 1) to produce scaffolds with different porosities (volume fraction). The Bioscaffolder printer (Analytik, Cambridge, UK) and the Allevi 2 printer (Allevi, PA, USA) were used for printing the silicone and the poloxamer gels, respectively. Scaffold's volume fraction was calculated as follows:

$$\text{Volume fraction} = \frac{\text{Printed polymer volume}}{\text{Total Scaffold volume}}$$

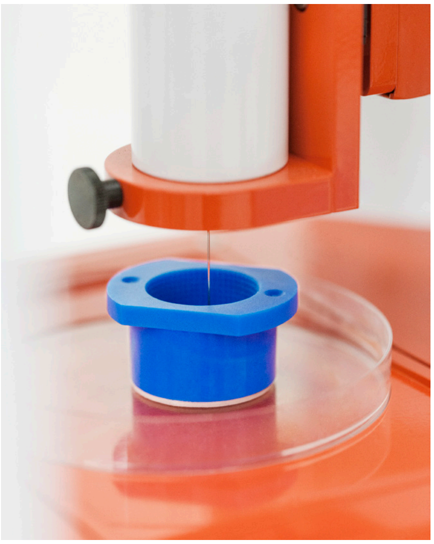
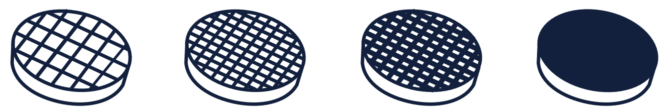


Fig. 1: 3D printing of poloxamer gel into ElastoSens™ Bio sample holders.

The printing patterns of the 3D printed silicone scaffolds are shown in Fig. 2. The structure varied in volume fraction (100 %, 75 %, 68 % and 54 %) by adjusting the line width (0.5 mm and 0.8 mm) and the void width (1.16 mm, 0.69 mm and 0.89 mm). A thin layer of silicone was printed between the sample and the holder to ensure their contact in order to meet the testing requirements of the ElastoSens™ Bio.



Silicone Volume Fraction	54%	68%	75%	100% (Bulk)
Printed Line Width	0.50 mm	0.50 mm	0.80 mm	-
Void Maximum Width	1.16 mm	0.69 mm	0.89 mm	-
Number of Tested Samples	4	4	4	4

Fig. 2: RTV silicone scaffolds printed inside the ElastoSens™ Bio's sample holders with different volume fractions: 54 %, 68 %, 75 % and 100% (bulk).

The structure of the 3D printed poloxamer scaffolds are shown in Fig. 3. For the porous scaffold, a circumferential layer of gel (1.0 mm thick) was also printed between the inner surface of the sample holder and the scaffold to ensure their contact.

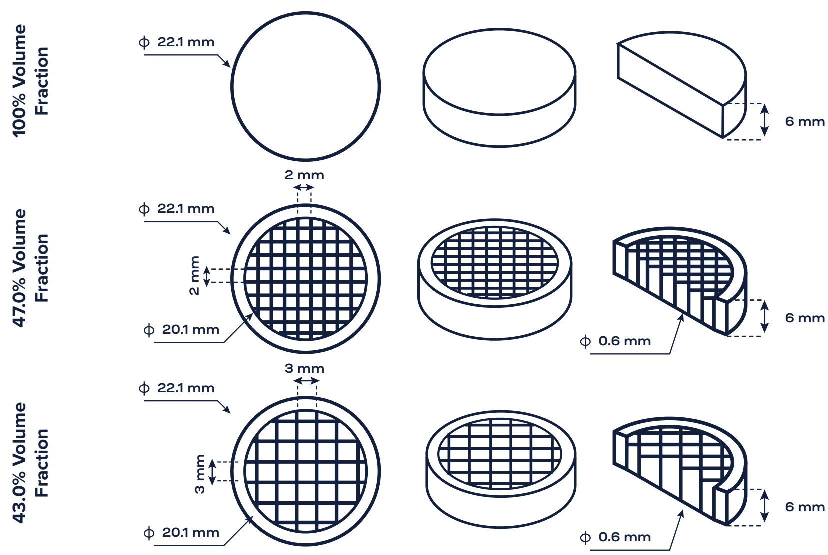


Fig. 3: Poloxamer scaffolds (bulk, 47.0 %, and 43.0 %) printed inside the ElastoSens™ Bio' sample holders.

After the complete gel formation, water was added into the sample holders containing the scaffolds in order to replace the air in the pores. A vacuum chamber was used to produce a negative pressure and force air to be expelled from the scaffold pores. By doing so, the macro density of the scaffold was close to 1.0 (a requirement of the testing method). The scaffolds were then tested in the ElastoSens™ Bio.

RESULTS AND DISCUSSION

The storage modulus showed to increase with the volume fraction of silicone in the scaffolds (Fig. 4). The increase in the storage modulus from a volume fraction of 54 % to 68 % showed to be substantially higher than the increase from 68 % to 100.0 % (105 % increase versus 30 % increase, respectively). This shows a nonlinear relationship between the volume fraction and the shear elastic modulus of the scaffold. The nonlinear relationship suggests that not just the volume fraction but also the printing pattern contributed to the mechanical properties of the scaffolds.

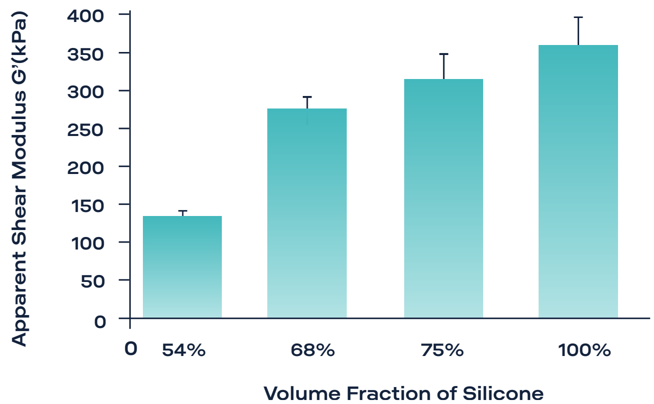


Fig. 4: Shear storage modulus (G') of 3D printed scaffolds composed of RTV silicone rubber at different volume fractions.

For the poloxamer scaffolds, the storage modulus also decreased when porosity increased as a direct consequence of the lower amount of polymer present in the construct (Fig. 5) (lower volume fraction). Printed scaffolds with 47 % and 43 % of volume fraction had a decrease of 85 % and 88 % in the storage modulus when compared to the bulk gel, respectively.

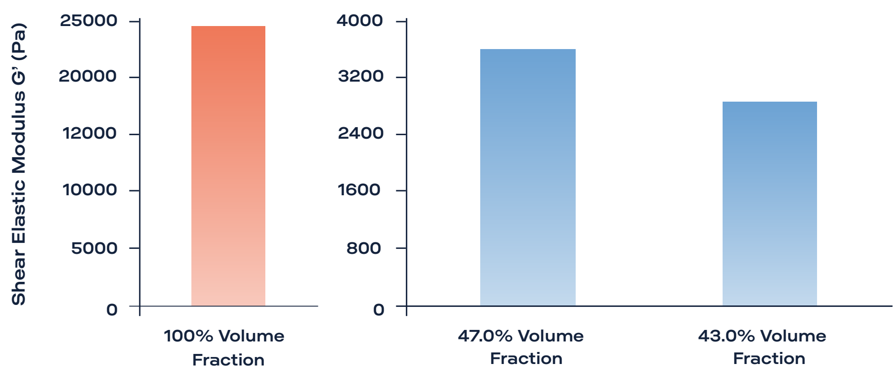


Fig. 5: Shear storage Modulus (G') of three 3D printed scaffolds made of Poloxamer at 100%, 47.0 % and 43.0 % volume fraction.

CONCLUSION

RTV silicone-based and poloxamer-based scaffolds with different porosities were successfully 3D printed inside ElastoSens™ Bio's sample holders. Volume fraction and printing pattern showed to impact the mechanical properties of the 3D printed constructs.

PERSPECTIVES

- The direct printing inside the sample holder of ElastoSens™ Bio avoids the excessive manipulation of soft and fragile constructs which can cause sample damage and contamination.
- ElastoSens™ Bio is an easy-to-use, non-destructive and contact free instrument that measures the viscoelasticity of 3D printed scaffolds.
- The system offers the possibility to easily tune the mechanical properties of 3D printed scaffolds by altering the composition of the bioink as well as the printing pattern [3].
- Testing the mechanical evolution of the same sample over short or long periods of time is now possible thanks to the non destructive nature of ElastoSens™ Bio.
- ElastoSens™ Bio allows testing the viscoelasticity of biomaterials under different physical (e.g. photo or thermo stimulation), chemical (e.g. crosslinking solution) and physiological (e.g. enzymatic solution) conditions to simulate *in vivo* behaviors.

REFERENCES

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