UV-Cured bio-based vitrimeric scaffold reinforced with Te-doped bioactive glasses

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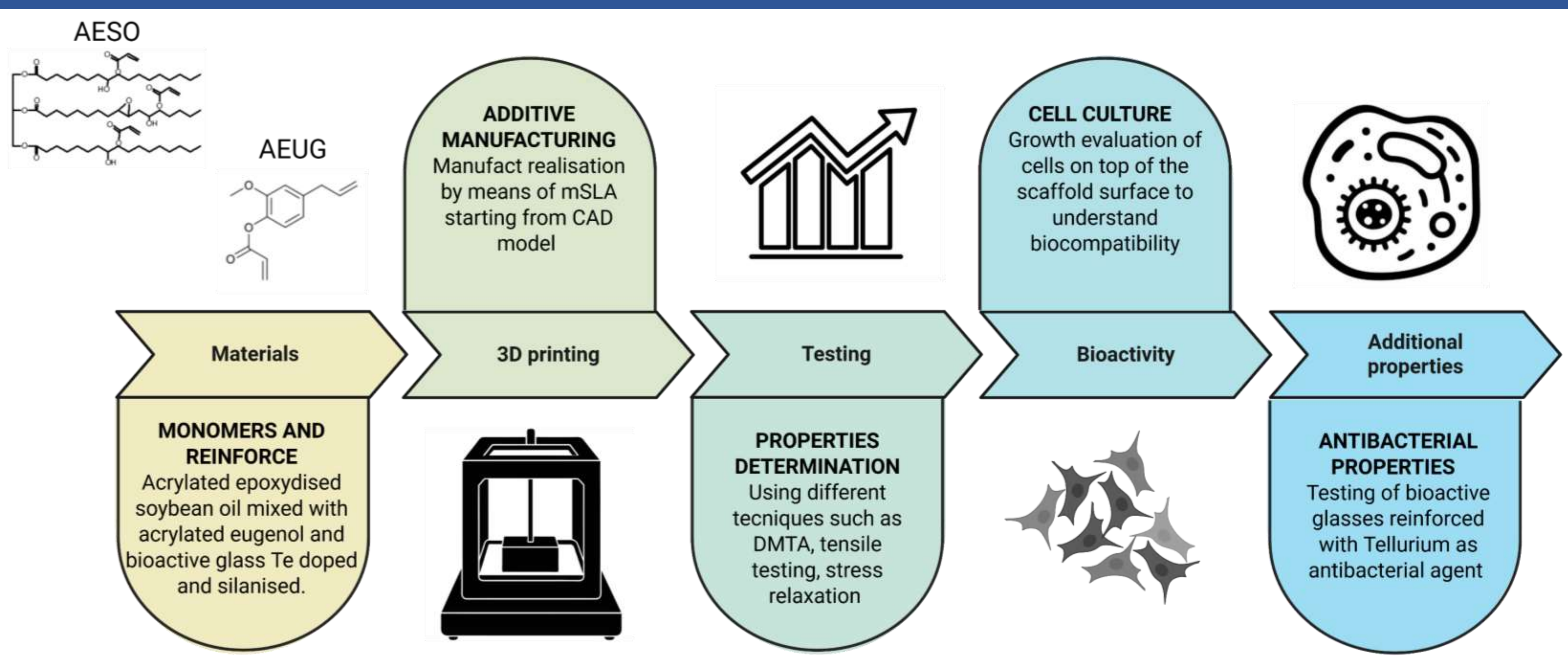
INTRODUCTION

Scaffolds provides **three dimensional support** for **tissue regeneration** by guiding cell growth. The materials used for scaffolds possess different limitation: **metals** have high strenght but **may release toxic ions** causing metallosis; **ceramics** are inert but are **brittle and may release debris**; **natural polymers** are higly biocompatible but **lack in strenght** and degrade quickly, **syntetic polymers** have tunable mechanical properties but **low** bioactivity.

Combining biobased polymers with bioactive glasses, ceramic material known to be higly osteoinductive, can overcome these limitations enhancing both **biocompatibility** and **mechanical performance**. Here, we studied **UV-cured scaffolds** derived from acrylated soybean oil **(AESO)** and **synthetised** acrylated eugenol **(AEUG)** , reinforced with **Tellurium** to improve biological and functional properties.

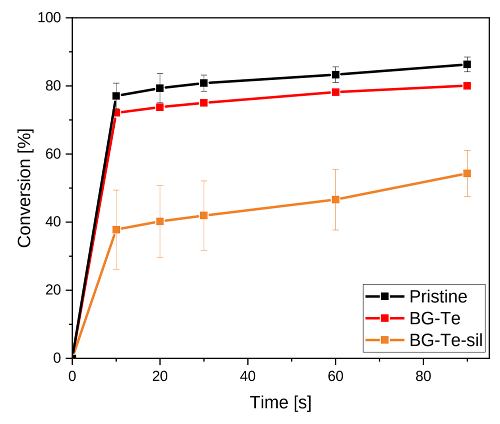
SCHEME

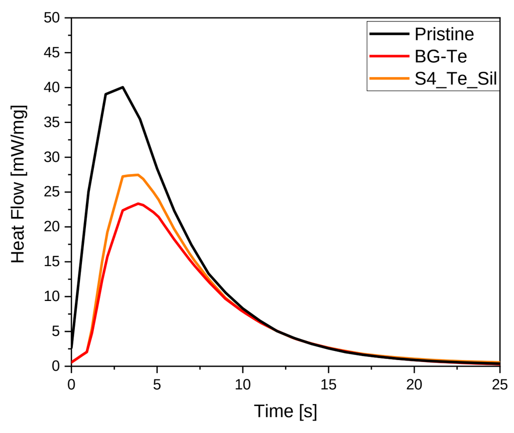


RESULTS

Conversion studies: FTIR and photo-DSC

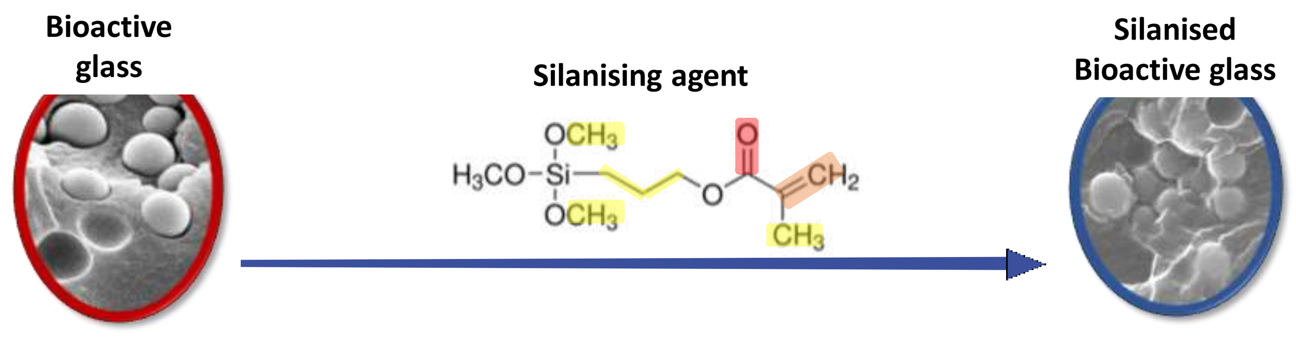
- **Transmission-FTIR** was used to **verify the acrylate conversion** during UV-curing reaction.
- **Pristine, 30 phr BG-Te** and **30 phr BG-Te-sil formulations** were **investigated**

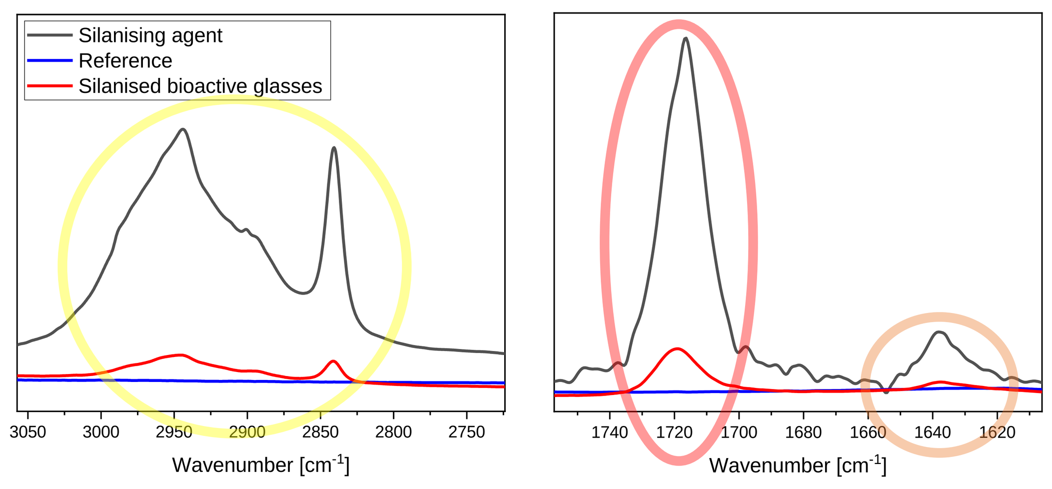




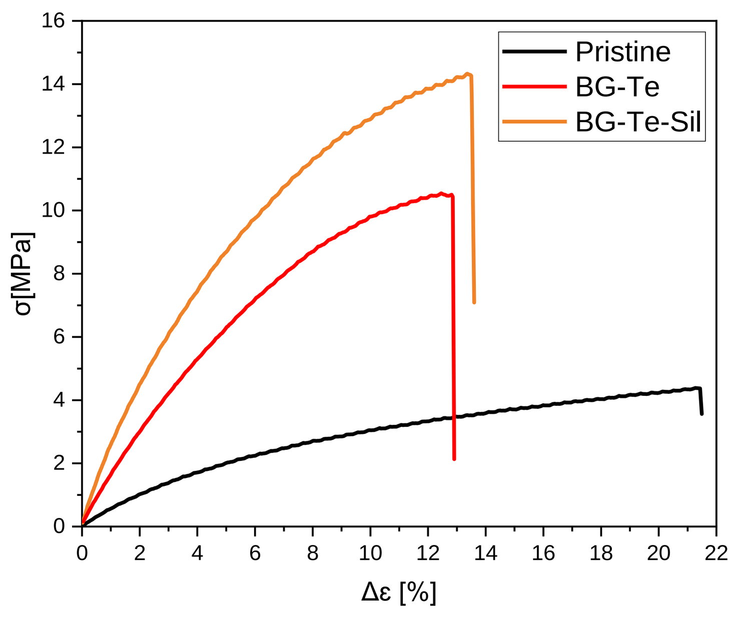
- **Photo-DSC** was employed to validate **ATR-FTIR analysis**.
- The **exothermic peak** was followed under UV-irradiation.
- The study confirmed ATR-FTIR analysis, demonstrating average **optimal conversion** adding bioactive glass.

Silanisation: grafting of bioactive glasses



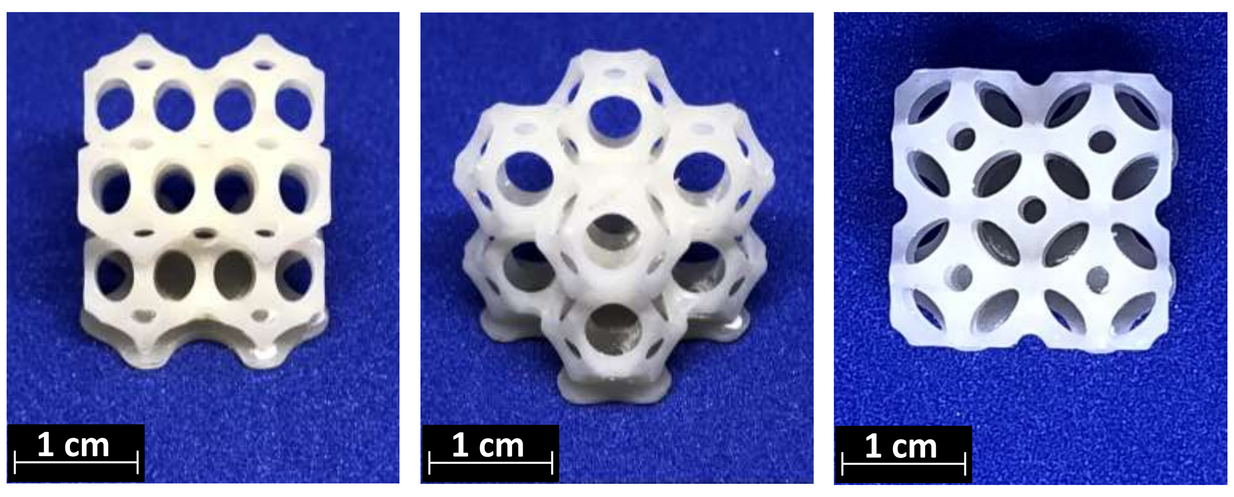


Mechanical testing: reinforcing phase influence

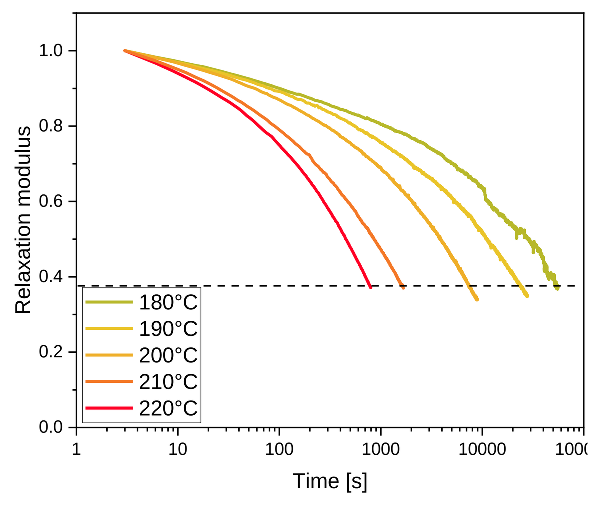


- **Silanized** BG **improved** scaffold **stiffness** by enhancing filler–matrix interactions.
- The **elastic modulus** of 1.5 MPa approached that of **trabecular bone and skin**, suggesting suitability for both hard and soft tissue applications.
- **Further tuning** is possible **via scaffold architecture optimisation** by modifying the porosity and shape of the 3D printed sample.

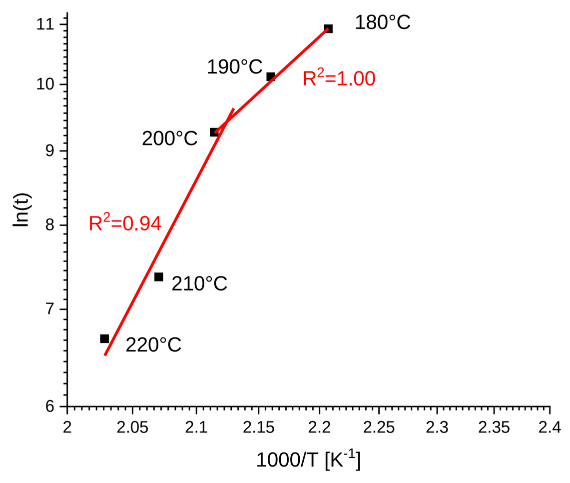
3D printing of complex porous structures



Stress relaxation measurements

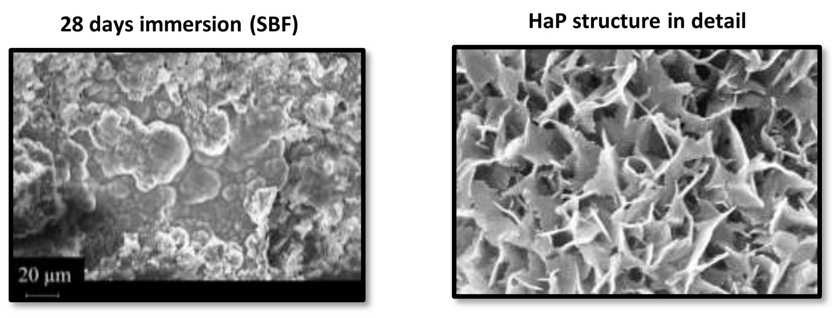


- **Increasing** the **temperature** in stress relaxation experiments from 180°C resulted in a **lower relaxation time gradually**.
- This shows that **hydroxyl and acrylate groups** in AESO **can induce transesterification reactions** with the AEUGP catalyst.



- Relaxation times can be reported as a function of temperature in an **Arrhenius plot**.
- A double **linear fitting** can be **obtained**, proving the **activation** of the **covalent adaptable network**, hence vitrimeric properties and **reprocessability** of the **biobased thermoset**.

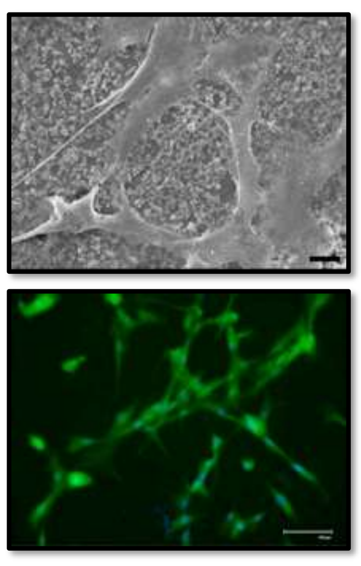
Hydroxyapatite (HaP) formation

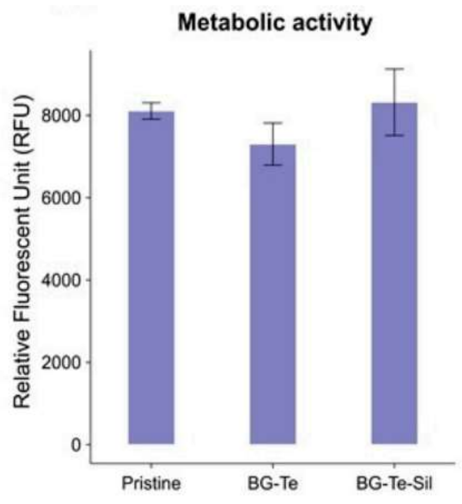


- After immersion for **28 days** in simulated body fluid (SBF) **hydroxyapatite** was **visible** on the scaffold surface, **proving** the **osteoinductivity** typical of the bioactive glass, still maintained with BG-Te doped.

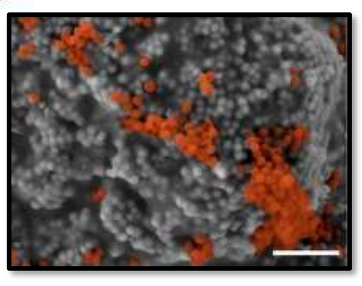
Metabolic activity

- Seeded **bMSCs** cells after 24 hours **are spread** onto the surface of polymeric-based scaffolds, indicating **good surface adhesion from cells**.
- The **BG** reinforcement **does not interfere with** the **metabolic activity** of cells.





Antibacterial activity: effect of Te doping



Viable bacterial colonies count ($\times 5 \times 10^6$)	
Samples	**CFU count**
Pristine	15 (±7)
BG-Te	2 (±1)
BG-Te-Sil	7 (±1)

- The **antibacterial properties** of **Te** and **Te-Sil-doped** scaffolds were tested against *S. aureus* **bacteria**.
- **BG-Te** showed **~87% and ~54% fewer viable bacteria than** the **control** and BG-Te-Sil, respectively.
- Only scattered bacteria were found on BG-Te, while the **control** and **BG-Te-Sil** bacteria **formed biofilms**.
- The **reduced effectiveness** of **BG-Te-Sil** is likely due to **silane coating** masking the Te, limiting bacterial uptake.

CONCLUSIONS

- Biobased **AESO scaffolds** reinforced with **Te-doped** and **Te-silanised bioactive glasses** exhibit excellent **biocompatibility, mechanical tunability** and **antibacterial** activity**.**
- **Silanisation** improved **matrix-filler interaction** and **mechanical strength** but reduced Te bioavailability, affecting antibacterial performance
- The materials show **vitrimeric behaviour,** enabling **thermal reprocessability** and **recyclability**, adding sustainability to biomedical applications.
- Overall**,** these **3D printed composites** are **suitable for** customisable and **sustainable scaffolds** for hard and soft tissue engineering

[1]. Bergoglio, M.; Kriehuber, M.; Sölle, B.; Rossegger, E.; Schlögl, S.; Najmi, Z.; Cochis, A.; Ferla, F.; Miola, M.; Vernè, E.; et al. 3D-Printed Acrylated Soybean Oil Scaffolds with Vitrimeric Properties Reinforced by Tellurium-Doped Bioactive Glass. Polymers 2024, 16, 3614. https://doi.org/10.3390/polym16243614

[2] Bergoglio M, Najmi Z, Cochis A, Miola M, Vernè E, Sangermano M. UV-Cured Bio-Based Acrylated Soybean Oil Scaffold Reinforced with Bioactive Glasses. Polymers. 2023 Oct 14

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