Overview on 3d printing techniques for graphene functionalized hydrogels

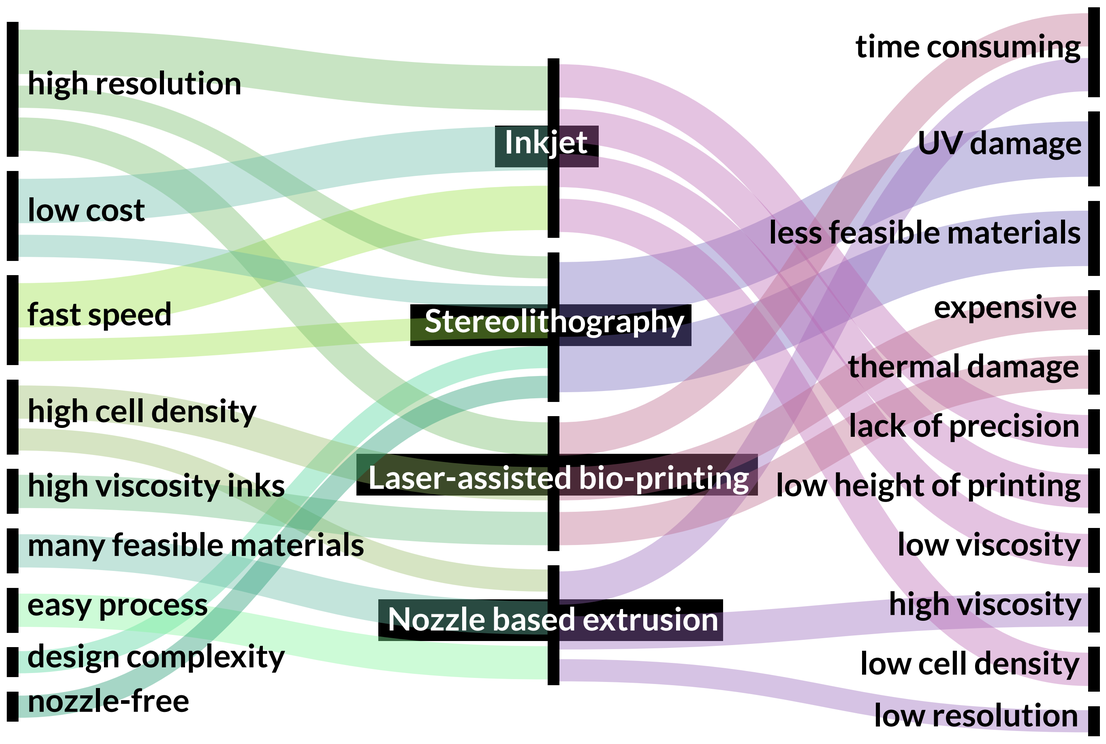
Giulia Grassi[1], Ilaria Denti[2], Ingrid Paoletti[1], Chiara Castiglioni[2], Gianlorenzo Bussetti[3]
[1] ABC Department Politecnico di Milano, [2] CMIC Department Politecnico di Milano, [3] Physics Department, Politecnico di Milano

INTRODUCTION

Hydrogels are widely employed in regenerative medicine, due to their high biocompatibility and similarity to human tissue composition. Moreover, hydrogels are suitable for **bio-printing**, a technique to create smart micro-structures layer by layer, reaching more complex mechanical properties. For these reasons, they are especially used to fabricate scaffolds for cells encapsulation to reconstruct biological tissues.
However, **most hydrogels do not exhibit high stretchability, toughness, stiffness and mechanical stability.**
To solve this issue, nanoparticles, fibers or fillers are currently added to the compound.
Graphene is nowadays in the spotlight as inorganic filler, drawing the attention of industries and universities due to its outstanding properties: it improves not only the stiffness and robustness of the compound, but also the electrical properties. Furthermore, it has proved to be bio-compatible and non-toxic in the short-period.
This overview focuses on techniques, challenges and potentials of additive manufacturing of hydrogel-graphene composites.

GRAPHENE BASED BIO-INKS

3D BIO-PRINTING



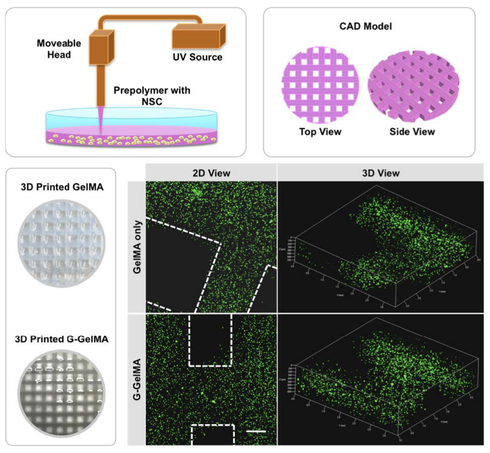
GRAPHENE advantages

+ biocompatible
+ non-toxic
+ good sterility, viscosity, flow
+ homogenous degradation of the polymer
+ enhanced mechanical and structural stability
+ improved adsorption
+ neurogenically bioactive
+ surgically friendly
+ viability of multiple distinct cells

CASE STUDIES

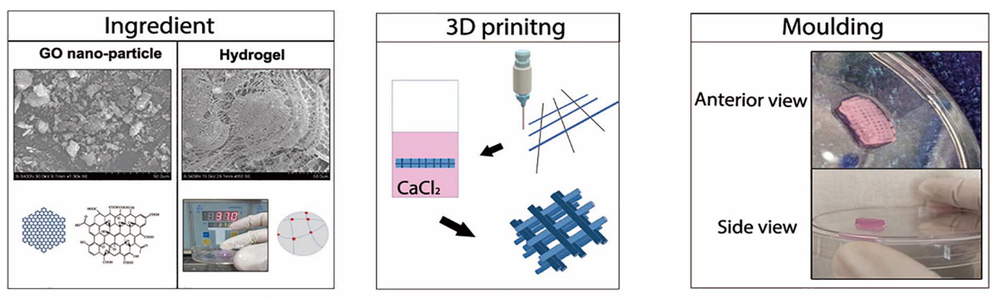
1 *Gelatin methacrylamide hydrogel with graphene nanoplatelets for neural cell-laden 3D bioprinting* (Zhu, Harris et Zhang)

scope **nerve tissue regeneration**
application **cell-laden neural scaffold printing**
technique **stereolitography**
materials **gelathine methacrylamide (GelMA) + neural cells + bioactive graphene nanoplates**
why graphene **inducing neuronal differentiation during neural differentiation + promoting the formation of neural networks**



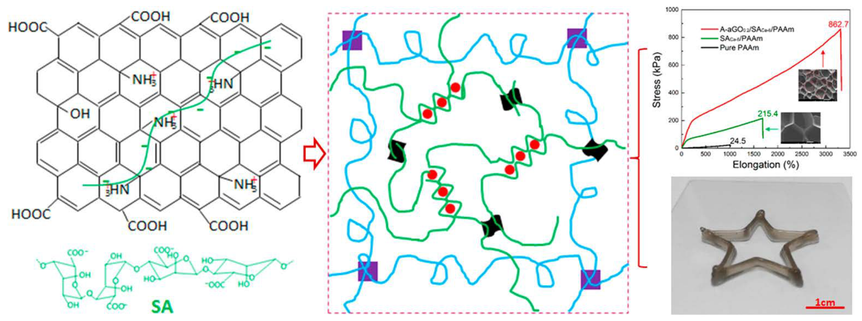
2 *3D printing hydrogel with graphene oxide is functional in cartilage protection by influencing the signal pathway of Rank/Rankl/OPG* (Cheng, Landish, Chi, Nannan, Jingyu, Sen, Xiangjin)

scope **cartilage tissue regeneration**
application **in-vitro 3D heterogeneous cartilage tissue printing**
technique **nozzle-based extrusion (Regenovo printer)**
materials **collagene-chitosan hydrogel + chondrocytes + graphene oxide nanoplates (GO-np)**
why graphene **inducing/controlling chondrogenesis + protecting cartilage + inhibiting inflammatory response**



3 *A 3D printable and mechanically robust hydrogel based on alginate and graphene oxide* (Liu, Bastola et Li)

scope **fabrication of 3D printable stretchable tough hydrogel**
application **biomedical devices / artificial tissues**
technique **nozzle based extrusion**
materials **A-aGO/SA/PAAm Nanocomposite hydrogel**
why graphene **acting as crosslinker, thus increasing strenght and toughness + endowing shear-thinning behaviour**



CONCLUSIONS

As the case studies have shown, the addition of graphene-based fillers, allows to increase mechanical and conductive properties of the inks. Furthermore, much more complex structures can be printed, leading to the expansion of the horizons in biomedicine and tissue regeneration. The few researches currently available illustrate the potential of graphene also for its bioactive properties such as inducing neural cells differentiation.