Multilayer antimicrobial biomedical devices for the treatment of chronic wounds: from disinfection to dermal tissue regeneration

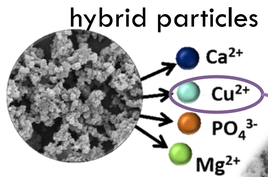
G. Vicinelli [1,2], A. Panocchia [1,2], E. Campodoni [1], M. Sandri [1]

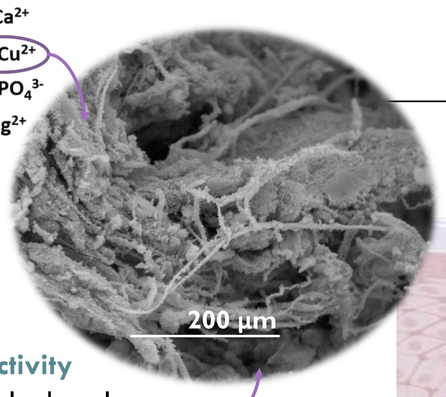
[1] Institute of Science Technology and Sustainability for Ceramics (ISSMC), National Research Council (CNR), Via Granarolo 64, 48018 Faenza, Italy

[2] University of Parma, Via Università 12, 43121 Parma, Italy

- Highly porous morphology
- CuHA nanoparticles to guarantee tissue disinfection

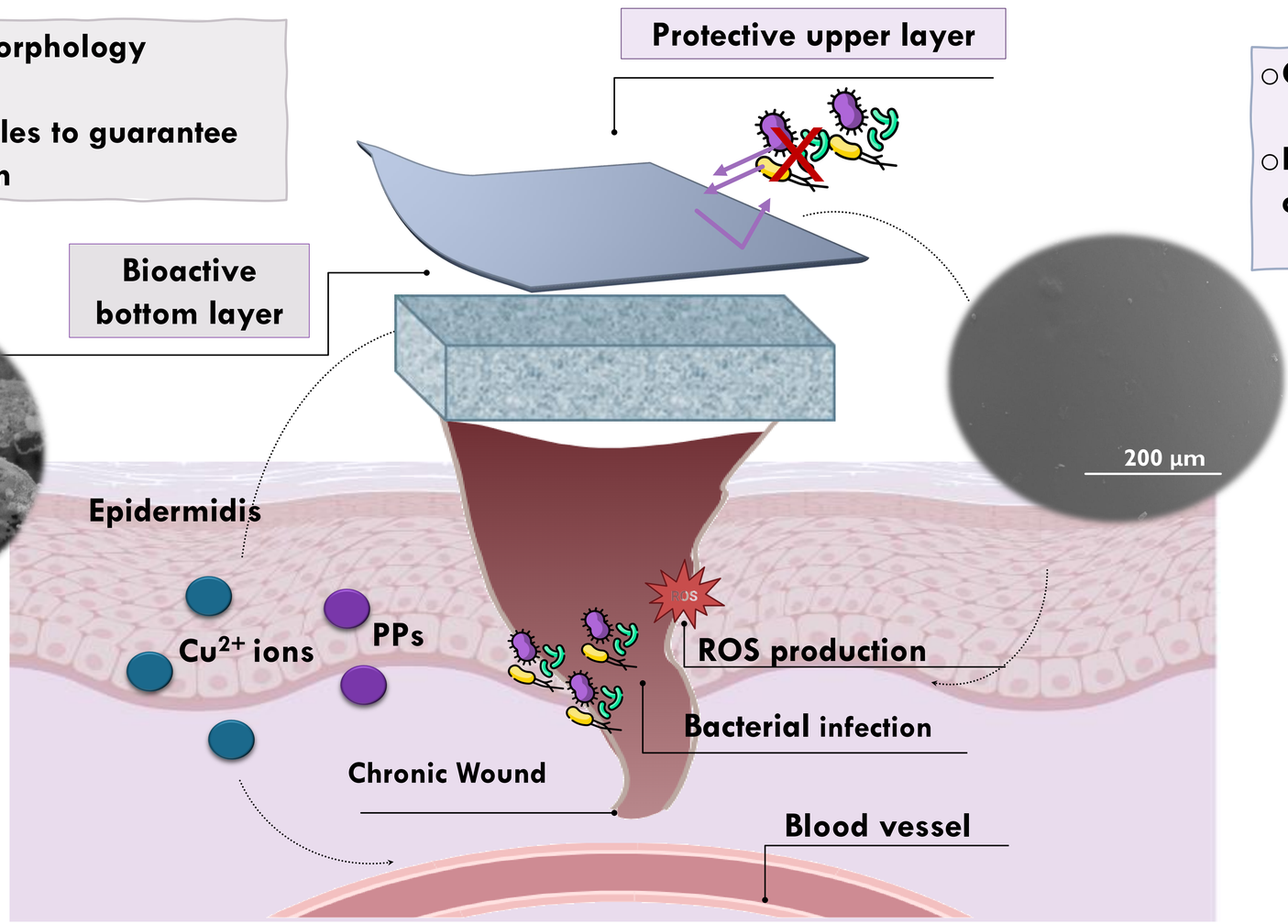
Antimicrobial (Cu^{2+})-doped hybrid particles





Antioxidant Activity
Extraction of polyphenols (**PPs**) from waste biomass

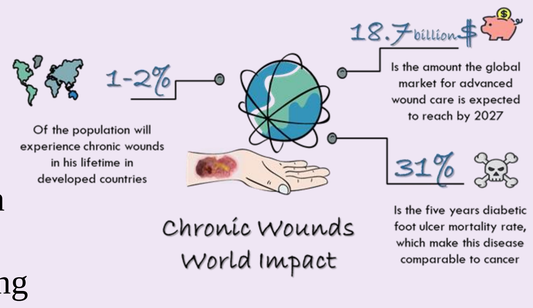




- Compact morphology
- Protection against external contaminarion

Introduction

Chronic wounds represent a significant socio-economic concern, particularly among patients afflicted with comorbidities such as diabetes and sickle cell anaemia, which impede the healing process. Current treatment approaches, including surgical debridement and antibiotics, are often ineffective or incompatible with patient needs. In this context, biomaterials present a compelling alternative, offering the potential to tailor their properties to specific characteristics such as biocompatibility, biodegradability and the capacity of delivering therapeutic agents in a controlled manner at the infection site [1, 2].



Innovative solution: ANTIMICROBIAL and REGENERATIVE BILAYER PATCH

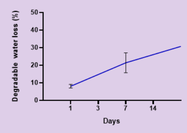
BIOCOMPATIBILITY AND PROMOTION OF SKIN TISSUE REGENERATION

- Careful selection of biomimetic and bioactive biomaterials: *collagen, glycerol, chitosan and hydroxyapatite*



BIODEGRADABILITY

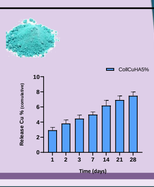
- Degradation time controlled through physical methods (DHT)





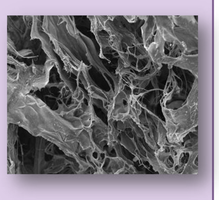
ANTIMICROBIAL PROPERTIES

- effective and controlled release of Cu 2+ ions directly at the infection site (**CuHA**)



EXHUDATE ABSORPTION AND VAPOUR PERMEABILITY

- Microarchitecture and porosity control through fabrication technique : *Freeze-dryng and Air-dryng*



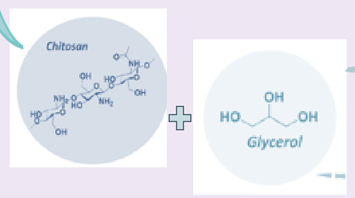
ANTIBACTERIAL EFFECT

Ability to accelerate wound disinfection and healing

PLASTICIZING EFFECT

to contrast the brittle nature of chitosan film and better adhere to the wound

1



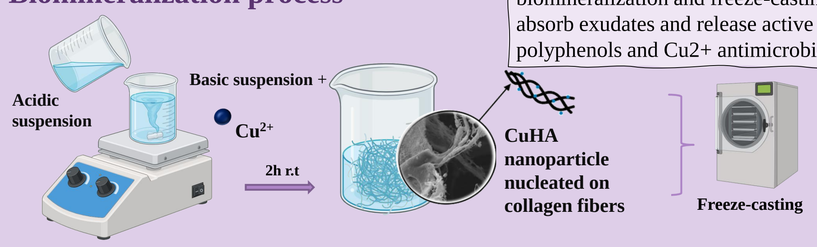
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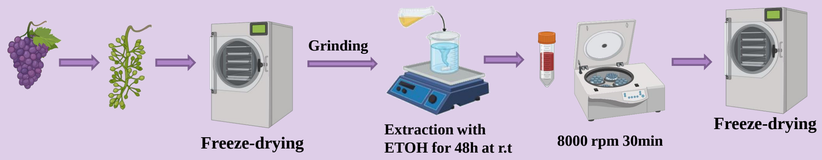
Upper compact layer acting as a protective barrier against external contamination

Biomineralization process

Hybrid porous **lower layer**, produced by biomineralization and freeze-casting, designed to absorb exudates and release active agents: polyphenols and Cu2+ antimicrobial ions



Polyphenol extraction



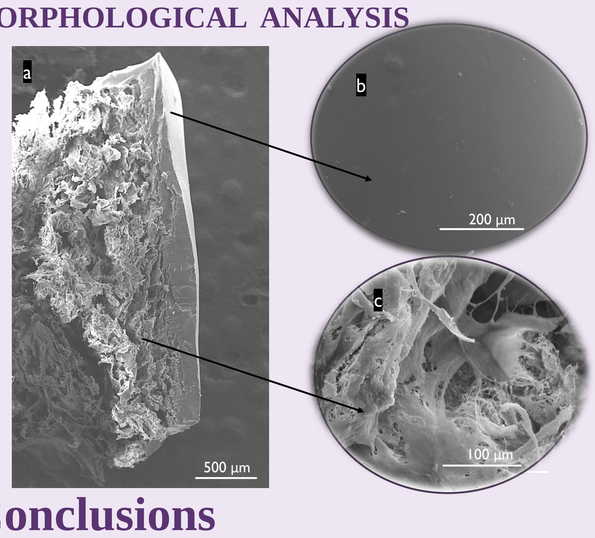
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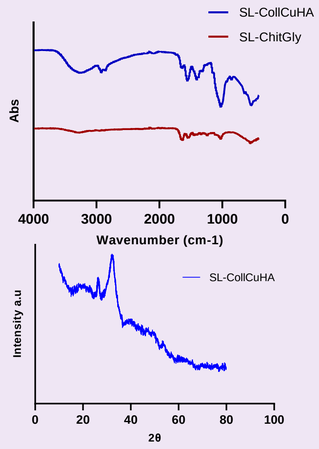
Assembly of the **bilayer structure** for local drug delivery and tissue regeneration:

1. **Upper protective layer** of chitosan and glycerol by air-drying [ChitGly]
2. **Hybrid porous regenerative and antimicrobial lower layer** of collagen biomineralized with CuHA by freeze-drying [CollCuHA]

MORPHOLOGICAL ANALYSIS

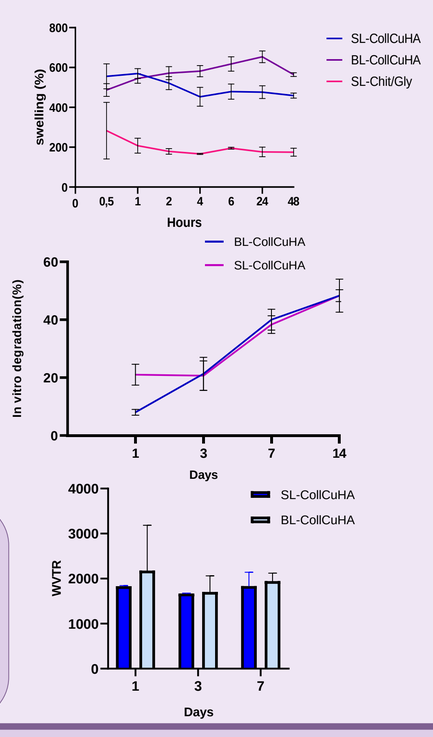


CHEMICAL ANALYSIS

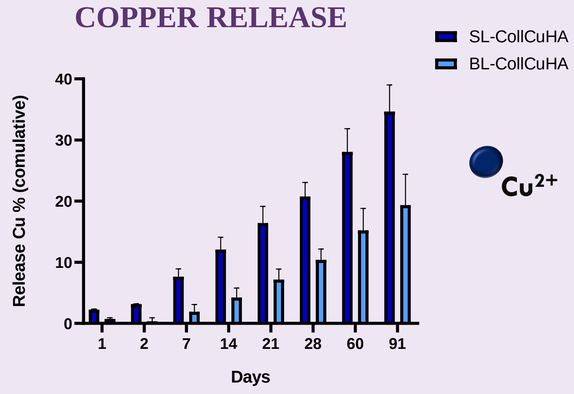


Sample	Ca/P	Std.Dev.	Cu/Ca	Std.Dev
SL-CollCuHA	1,35	± 0,01	1,35%	± 0,01

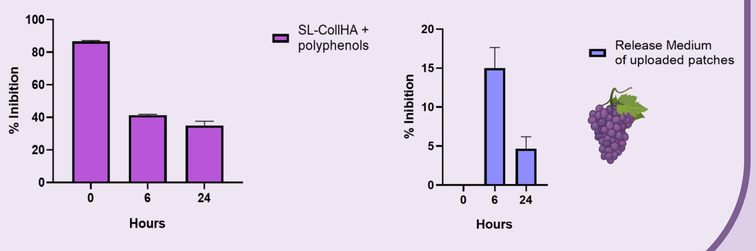
PHYSICAL ANALYSIS



COPPER RELEASE



ANTIOXIDANT ACTIVITY- DPPH assay



Conclusions

Biomimetic bilayer scaffolds with optimal porosity, swelling, vapor permeability and controlled degradation, was successfully developed and characterized, meeting essential requirements for wound healing. The dual-layer design, featuring a protective and a regenerative layer, enhanced with CuHA nanoparticles and antibiotics, provides multifunctional activity, offering a promising platform for advanced chronic wound management. Ongoing cellular and microbial in vivo evaluations are further assessing the scaffolds' potential.

1. Bernardoni S., Campodoni E., Vicinelli G., Sandri M. *From wound dressing to tissue regeneration: bilayer medicated patches for personalized treatment of chronic wounds.* ACS Applied Materials & Interfaces 2025, 17, 35240−3526
2. Bernardoni S., Campodoni E., Gentilomi G.A., Tolomelli A., Sandri M. *Multiple-layer chitosan-based patches medicated with LTX-109 antimicrobial peptide for modulated local therapy in the management of chronic wounds.* Macromolecular Bioscience 2024, 2400375

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