Controlled-release of carvacrol oil from stimuli-responsive copper doped mesoporous silica particles

M. Argaiz[a*], L. Fiore[b], A.M Goitandia[a], F. Arduini[b], M. Blanco[a*], B. Coto[a]

[a] Química de Superficies y Nanotecnología , Tekniker, Eibar, Spain

[b]Department of chemical science and technologies, University of Rome Tor vergata, Rome, Italy

*maialen.argaiz@tekniker.es; *miren.blanco@tekniker.es

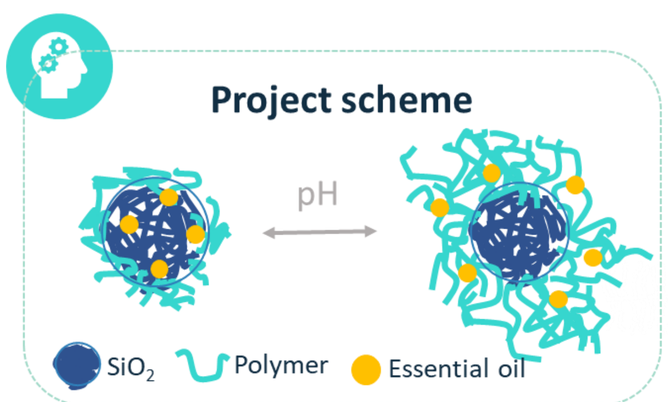
CONTEXT

- Microbial colonisation of surfaces forms a **dangerous reservoir for pathogens** contributing to spread of infections causing significant cost in human life and economic terms.
- It is estimated that **antimicrobial resistance infections are responsible for 110,000 deaths and EUR 1.5 billion per year in healthcare costs and productivity losses.**
- Several antimicrobial coatings exist in the market; however, they are **based mainly on the leaching of non-environmentally friendly chemicals** (i. e. non-biobased antimicrobial molecules such as antibiotics, phenolic biocides, or quaternary ammonium compounds) and are **formulated considering synthetic, non-biobased polymers as binders.**
- These antimicrobial coatings frequently show **serious concerns** linked to antibiotic resistance, complex chemical synthesis, environmental pollution, non-biodegradability, low product performance, toxicity and extremely low sustainability.
- Hence, there is a **real need of innovative high performance antimicrobial coatings** and also a significant market opportunity because the antimicrobial coatings market size exceeded USD 3.2 billion in 2019 and **is estimated to grow at over 10.4% CAGR between 2020 and 2026.**

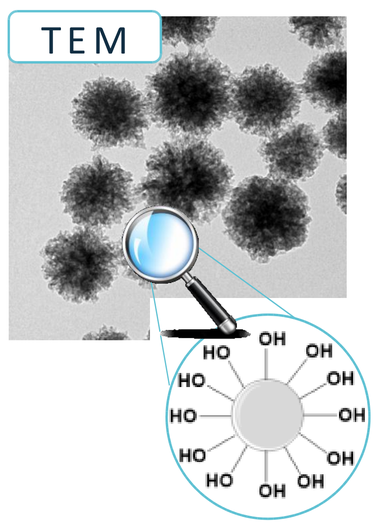
RELIANCE — Addressing the growing need for an innovative holistic antimicrobial solution for different surfaces that is highly effective, safe and sustainable by design

The main objective of RELIANCE is to design and develop smart response s**elf-disinfectant antimicrobial nanocoatings** based on a new range of **antimicrobial copper doped mesoporous silica nanoparticles (Cu-SMIN) modified with non-toxic bioactives**, such as **essential oils (EOs) coming from non-edible plants**, incorporated into the porous particles for a controlled release to the environment.

FUNCTIONALIZATION of CuSMIN



CuSMIN synthesis

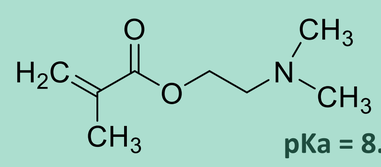


Monomers for functionalization

pH and T responsive

2-(dimethylamino)ethyl methacrylate)

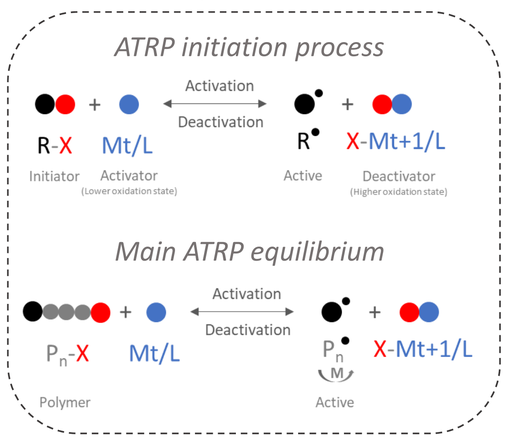
DMAEMA



pKa = 8.5

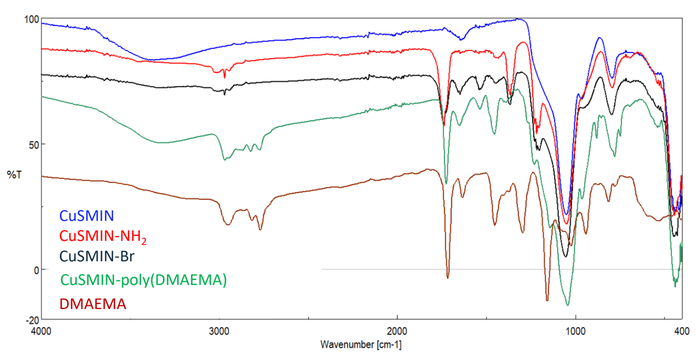
Synthesis path

ATRP (Atom Transfer Radical Polymerization)

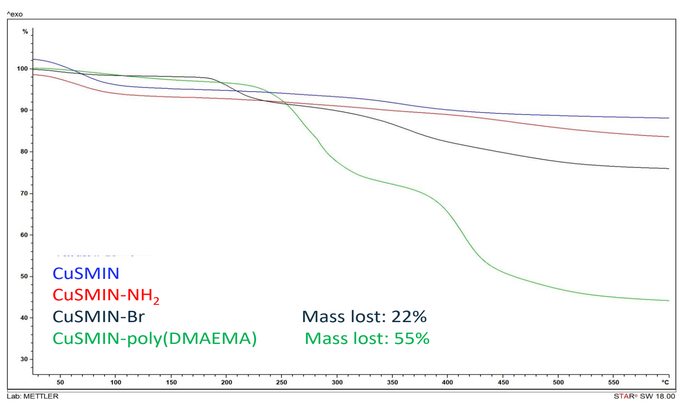


CHARACTERIZATION of CuSMINpolyDMAEMA

Fourier Transfer Infrared Spectroscopy (FTIR)



Thermogravimetry (TGA)

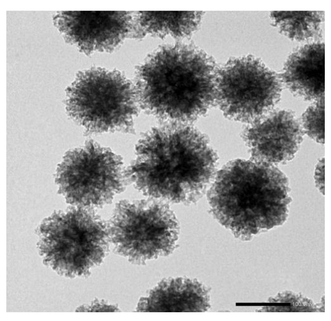


Absorption analysis (N quantification)

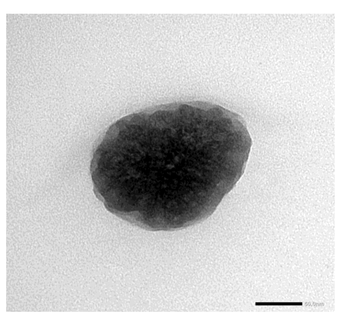
CuSMIN	0.22 %N
CuSMIN-NH_2	2.0 %N
CuSMIN-Br	2.3 %N
CuSMIN-poly(DMAEMA)	5.2 %N

Transmission electron microscopy (TEM)

CuSMIN



CuSMINpolyDMAEMA

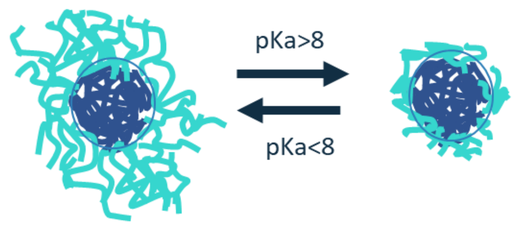


CuSMINpolyDMAEMA shows an **organic layer** around the tree branch-shaped shell, **likely related to the polymer brushes** grown from the CuSMIN surface.

SMART response to pH and T

Particle size vs pH

CuSMIN-poly(DMAEMA)

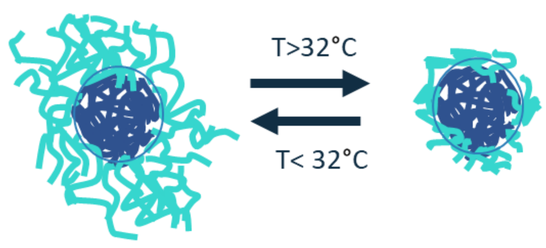


$dp_{Z\text{-}average}$: 432 nm

$dp_{Z\text{-}average}$: 225 nm

Particle size vs T

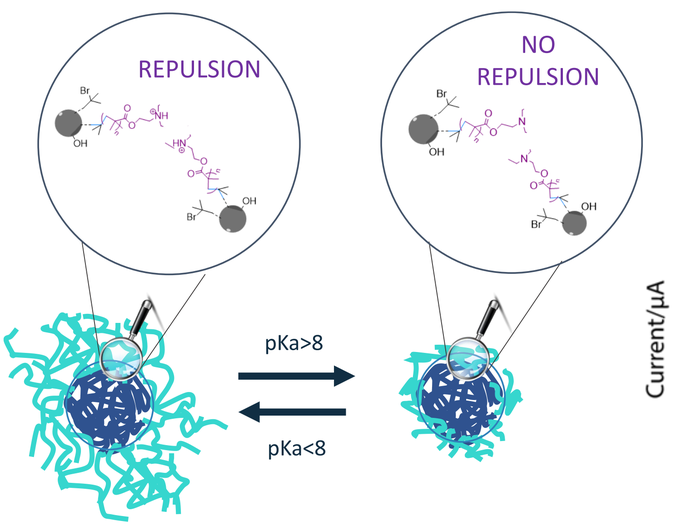
CuSMIN-poly(DMAEMA)

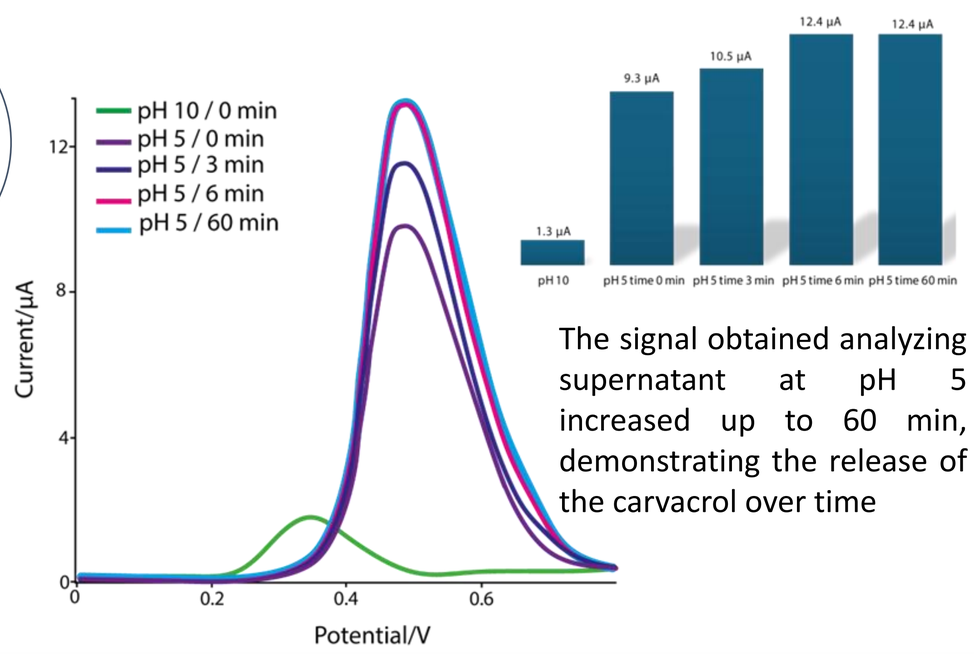


$dp_{Z\text{-}average}$: 440 nm

$dp_{Z\text{-}average}$: 320 nm

SMART RELEASE OF CARVACROL ESSENTIAL OIL





The signal obtained analyzing supernatant at pH 5 increased up to 60 min, demonstrating the release of the carvacrol over time

CONCLUSIONS

- **CuSMIN particles are susccessfully functionalized → Assessed by FTIR, TGA, Elemental Analysis, TEM and DLS**
- **The polymeric brushes are responsive to pH and T changes → Assessed by DLS**
- **The release of the essential oils is confirmed → Assessed by paper-based electrochemical sensor**

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No. 101058570 (RELIANCE). This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein