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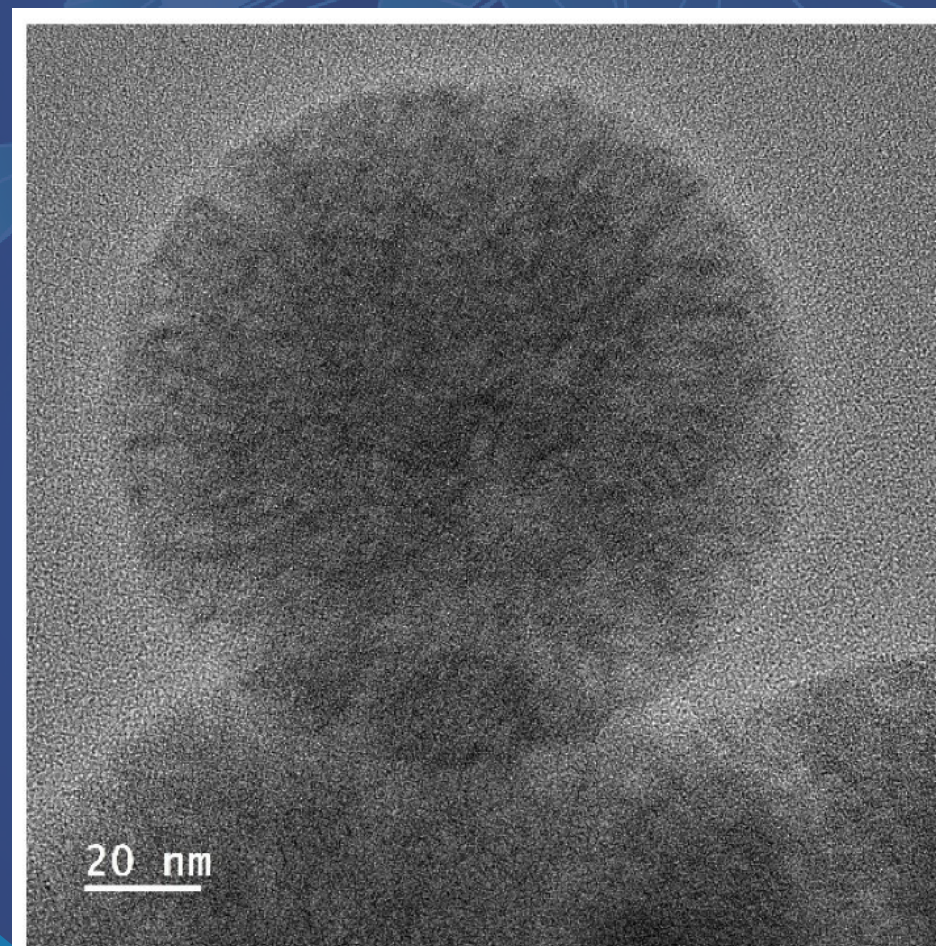
Copper-doped silica mesoporous nanoparticles loaded with essential oils

Copper-loaded silica nanoparticles enable long-lasting antimicrobial protection through controlled and responsive release of essential oils.

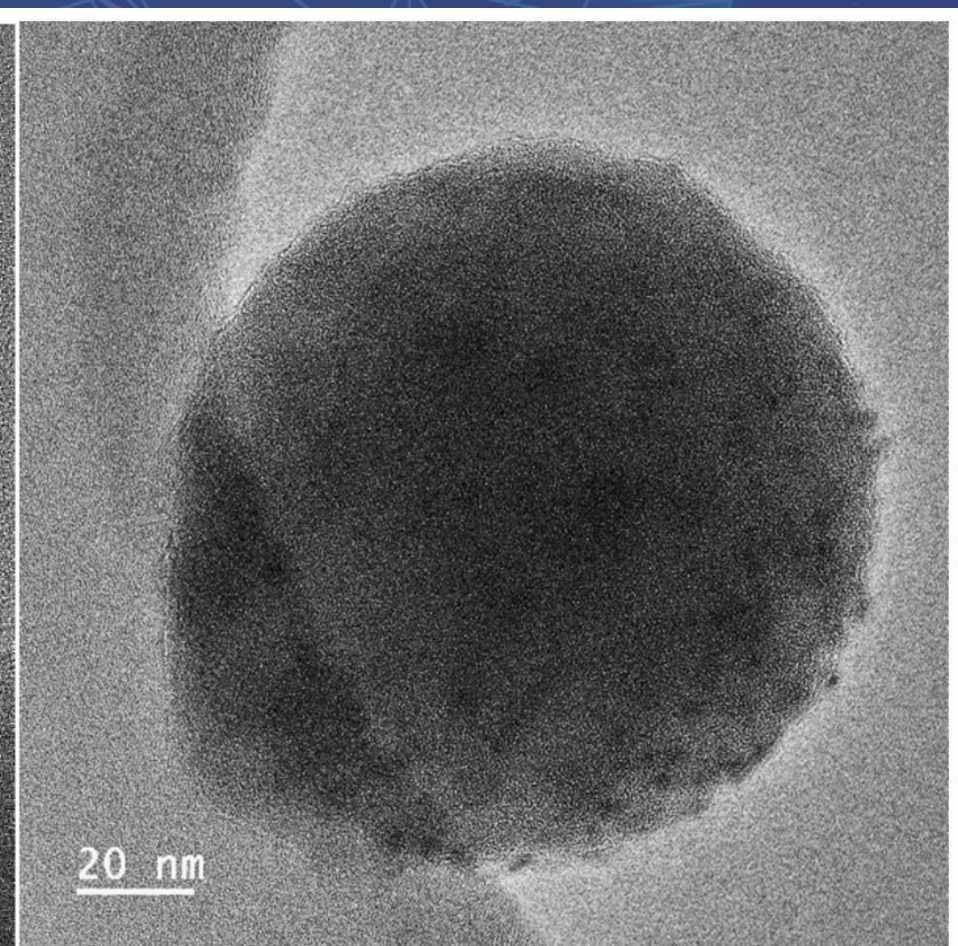
The Challenge

Many antimicrobial products lose effectiveness rapidly or rely on high biocide doses.

Industry needs safer, durable antimicrobial solutions effective against diverse microorganisms.



(a)



(b)

The Achievements

- Mesoporous silica nanoparticles successfully modified with copper
- Production scaled at semi industrial level
- Effective inhibition of bacteria and fungi over extended periods



Key Conclusions

- **Antimicrobial performance can be tuned through material design**
- **Copper-modified mesoporous silica provides broad-spectrum antimicrobial activity**
- **Reduced ecotoxicity of developed particles in comparison with conventional antimicrobial such as triclosan**

Recommendations



Industry: Incorporate these nanoparticles into coatings and polymers



Policymakers: Promote safer antimicrobial materials with controlled release



Who is this result for?

- **Coating and surface treatment manufacturers**
- **Healthcare and hygiene product developers**
- **Materials science researchers**



Long-term Impact



This approach supports safer antimicrobial strategies, reduces biocide overuse and enables durable protection, improving sustainability and market acceptance under increasing regulatory pressure.



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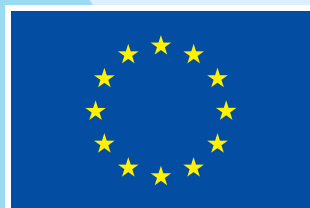
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