Silver Coordination Polymers: Relationships Between Structure and Antibacterial Properties

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Silver Coordination Polymers as Antibacterial Agents

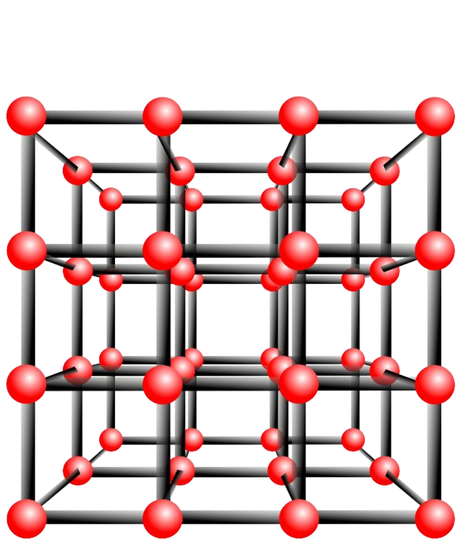
Ionic silver is an effective cytotoxic agent against bacteria, including multi-drug resistant species[1].

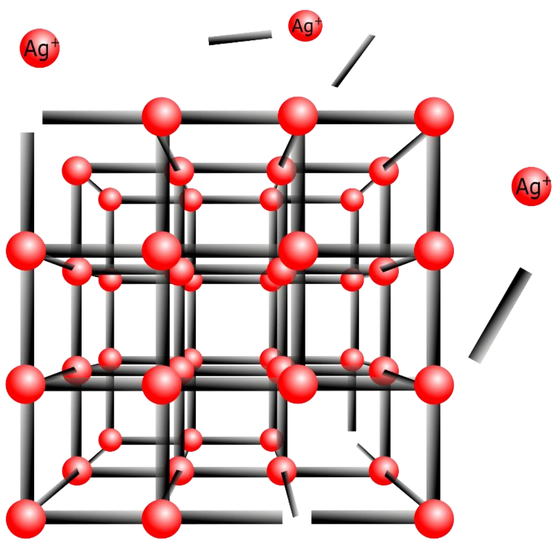
It is proposed that silver containing materials may be used in coatings of implants and medical instruments to prevent infections.

Silver coordination polymers provide the opportunity to control and tune the release of bactericidal Ag^+ ions through the framework decomposition[2].

Strategies to Control Ag^+ Release from Silver Coordination Polymers

1. Chemical bond strength can be influenced through the choice of ligand used to construct the coordination polymer.
2. Topology can be varied by the method of synthesis, leading to differences in porosity, allowing for dissolution to occur from additional surfaces.
3. Diffusion rate of ions out of coordination polymers inserted into inert matrices can be regulated by choice of matrix and embedding method.

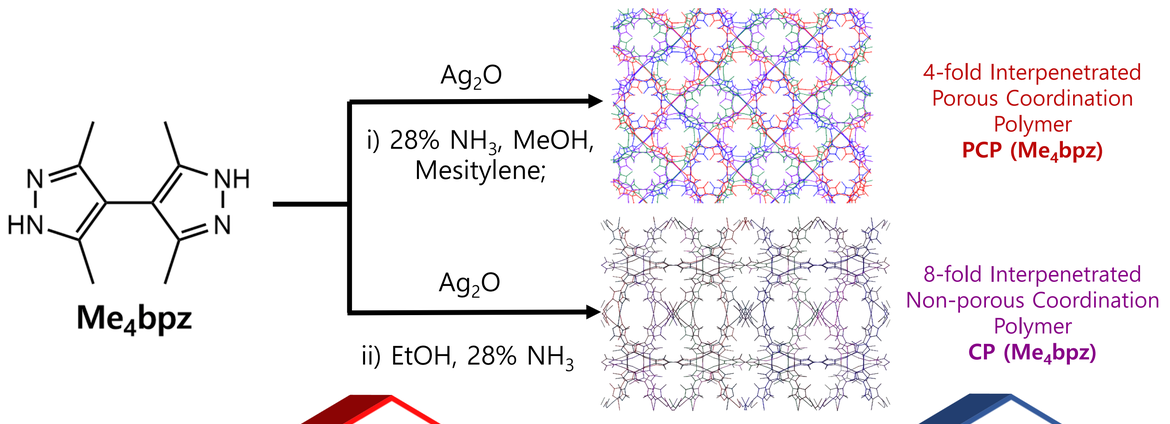




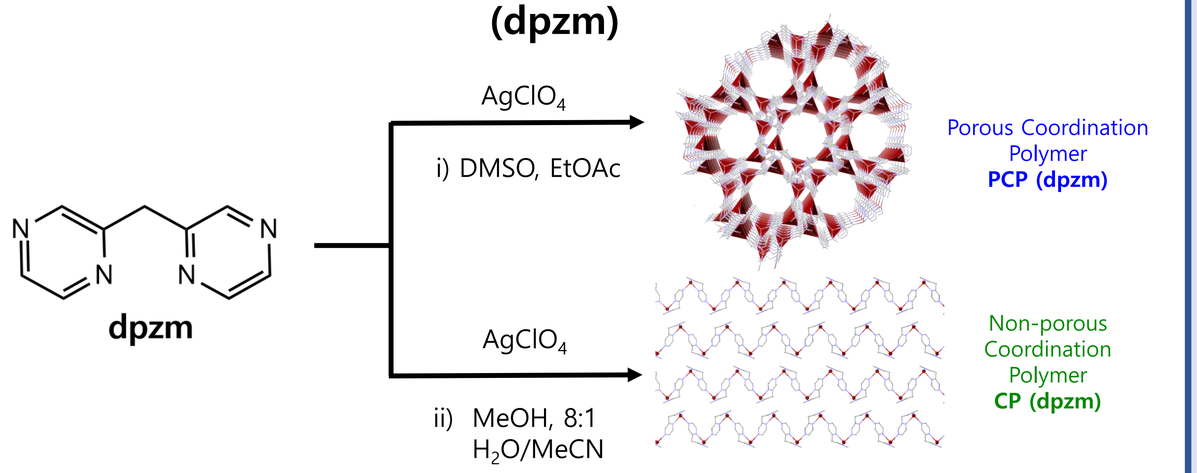
Silver coordination polymers can decompose to release bactericidal Ag^+ ions.

Before these materials may be considered for medicinal applications, the factors governing Ag^+ release must be determined.

System 1: Coordination polymers with *3,3′-5,5′-tetra-4,4′-methyl bipyrazole* (**Me_4bpz**)



System 2: Coordination polymers with *di-2-pyrazinylmethane* (**dpzm**)



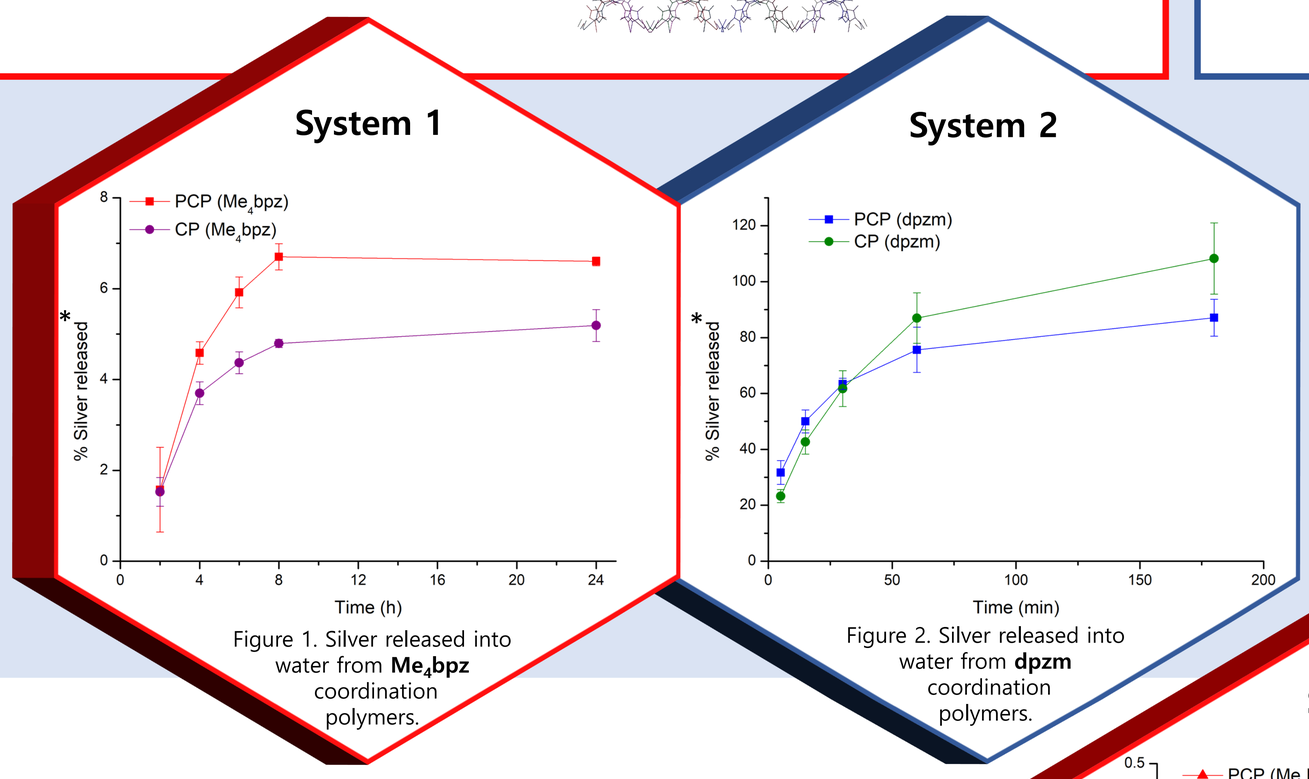


Figure 1. Silver released into water from **Me_4bpz** coordination polymers.

Figure 2. Silver released into water from **dpzm** coordination polymers.

Silver Release Studies

* All y-axes for silver release studies are normalised against the total mass of silver in material

System 1: PCP (**Me_4bpz**) and CP (**Me_4bpz**) are highly stable to light, heat and dissolution due to their anionic ligand and interpenetrated networks. Equilibrium was reached after 8 hrs leading to low overall release of silver ions.

System 2: The coordination polymers constructed from neutral ligand, **dpzm**, are unstable to light, heat and dissolution. Near complete dissolution was achieved after 3 hrs.

Release of Ag^+ from Coordination Polymers Embedded into Inert Polymer Matrices

Polyethylene (PE) is currently used to coat medical implants, while polycaprolactone (PCL) is proposed for use in degradable, drug releasing implants and devices[3].

Both polymer matrices were found to greatly retard the release of ions.

Embedding PCP (**dpzm**) and CP (**dpzm**) into PE caused structural changes resulting in significantly lower release rates.

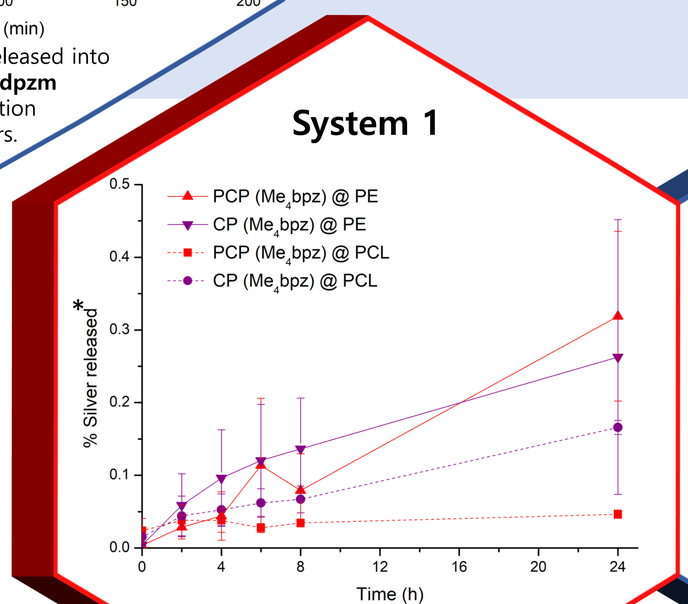


Figure 3. Silver released into water from **Me_4bpz** coordination polymers embedded in polymer.

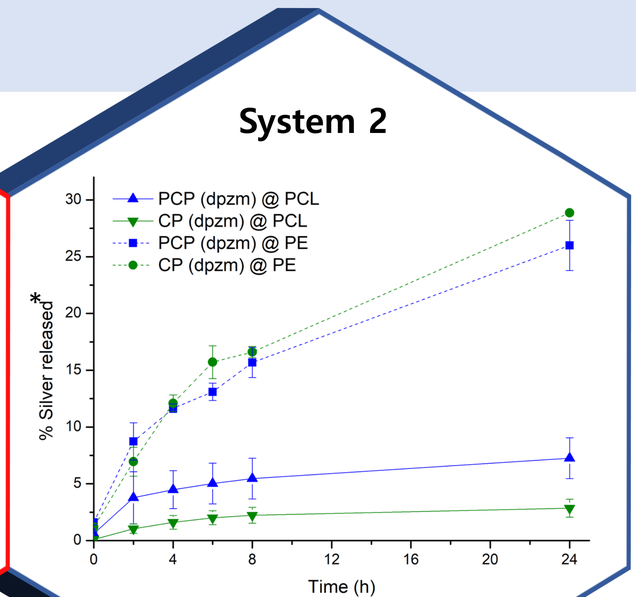


Figure 4. Silver released into water from **dpzm** coordination polymers embedded in polymer.

Antibacterial Assays

PCP (**dpzm**) was bactericidal against both Gram positive *(S. Aureus)* and Gram negative *(E. coli)* strains of bacteria.

CP (**dpzm**) caused a reduction in bacterial growth in *E coli.*

System 1 was not effective.

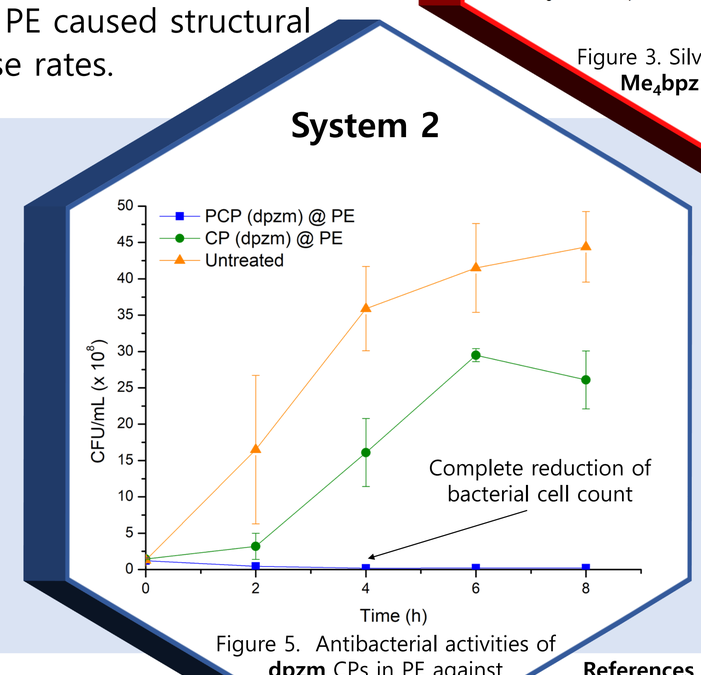


Figure 5. Antibacterial activities of **dpzm** CPs in PE against *E. coli.*

Conclusions

- The determining variable for the release rate of silver ions is the metal-ligand bond strength.
- Although small variations were observed due to topology, porosity had little impact on the release rate compared to other variables.
- Ag^+ release rate is dependent on both the matrix polymer and embedding conditions. Both matrices cause significant reduction in release rate compared to the pure coordination polymer.

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References

1. M. Berchel, T. Le Gall, C Denis, S. Le Hir, F. Quentel, C. Elleouet, T. Montier, J. Rueff, J Salaun, J. Haelters, G. Hix, P. Lehnb, P. Jaffres, *New J. Chem.*, **2011**, 35, 1000–1003
2. M. Rai, A. Yadav, A. Gade, *Biotechnol. Adv.* **2009**, *27*, 76-83
3. M.A. Woodruff, D.W. Hutmacher, *Prog. Polym. Sci.*, **2010**, *35*, 1217–1256

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