Ultrasmall Inorganic Cages directed by Surfactant Micelles

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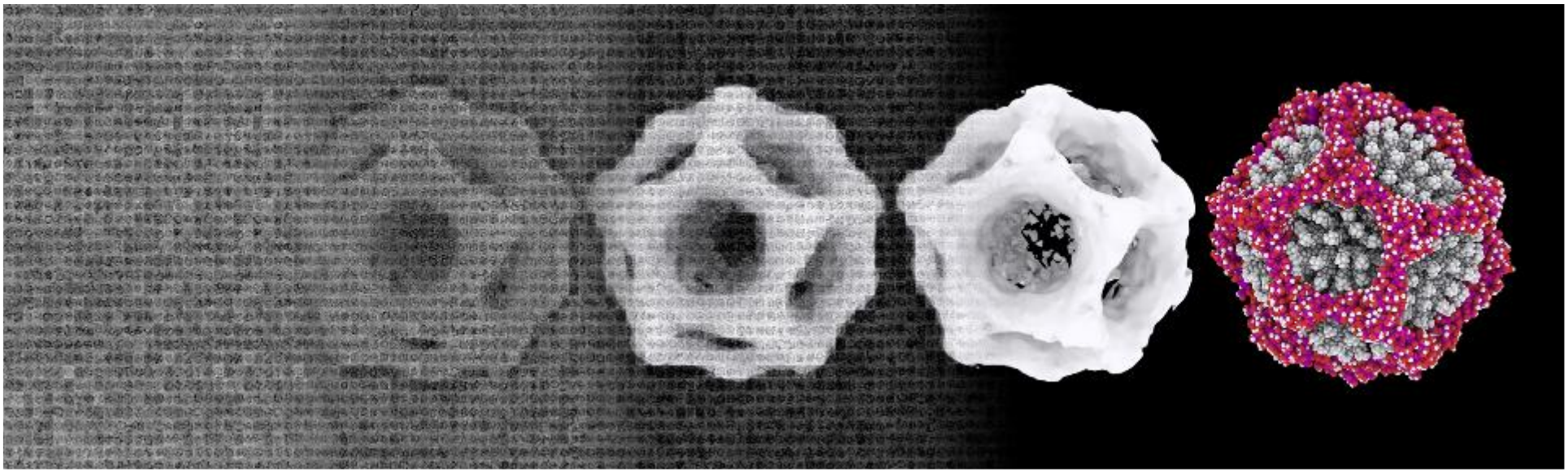
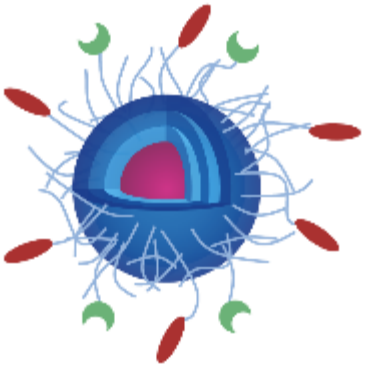
Wiesner Group, Cornell University, United States



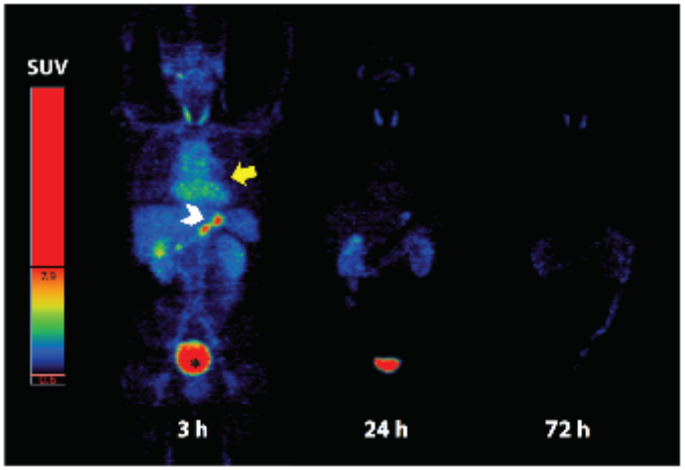
Cdots: Nanoparticles Targeting Cancer

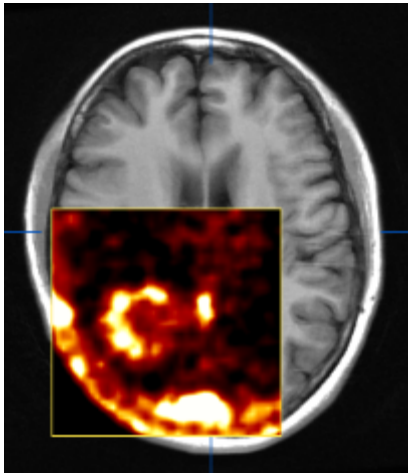
ultrasmall hybrid silica nanoparticles with organic dyes rich cores

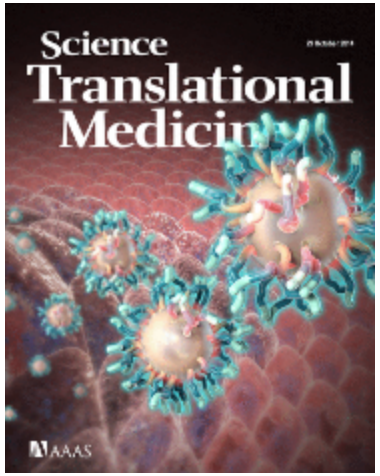


< 10 nm

suitable for renal clearance and multimodal imaging







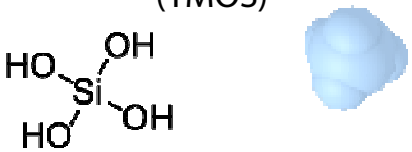
→ **phase 2 of clinical trials for cancer diagnostics**

- M. Benezra, U. Wiesner, M. S. Bradbury et al., *J. Clin. Invest.* **2011**, 121, 2768–2780.
- E. Phillips, U. Wiesner, M. S. Bradbury et al., *Sci. Trans. Med.* **2014**, 6 (260), 260ra149.

Low-Dimensional Structured Materials

silica precursor

tetramethyl orthosilicate (TMOS)

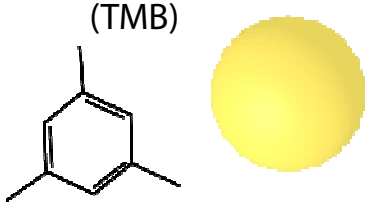


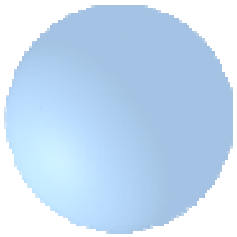
cationic surfactant

cetyltrimethylammonium bromide (CTAB)

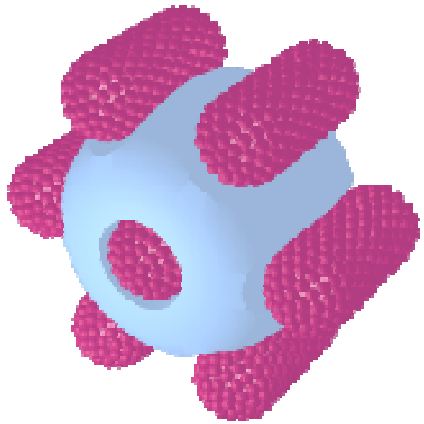
pore expander

mesitylene (TMB)

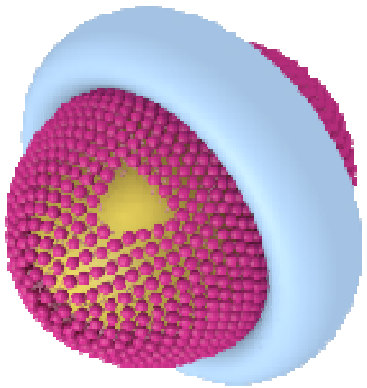




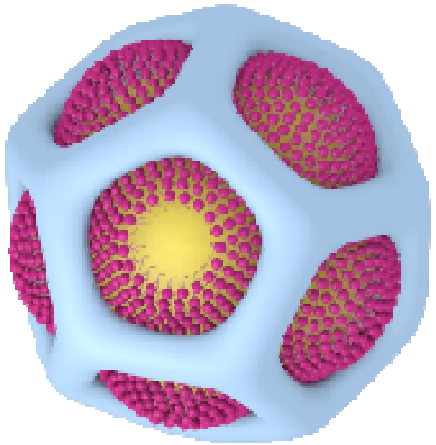
Silica nanoparticle **(Cdot) [1]**



Mesoporous silica nanoparticle **(mCdot) [2]**



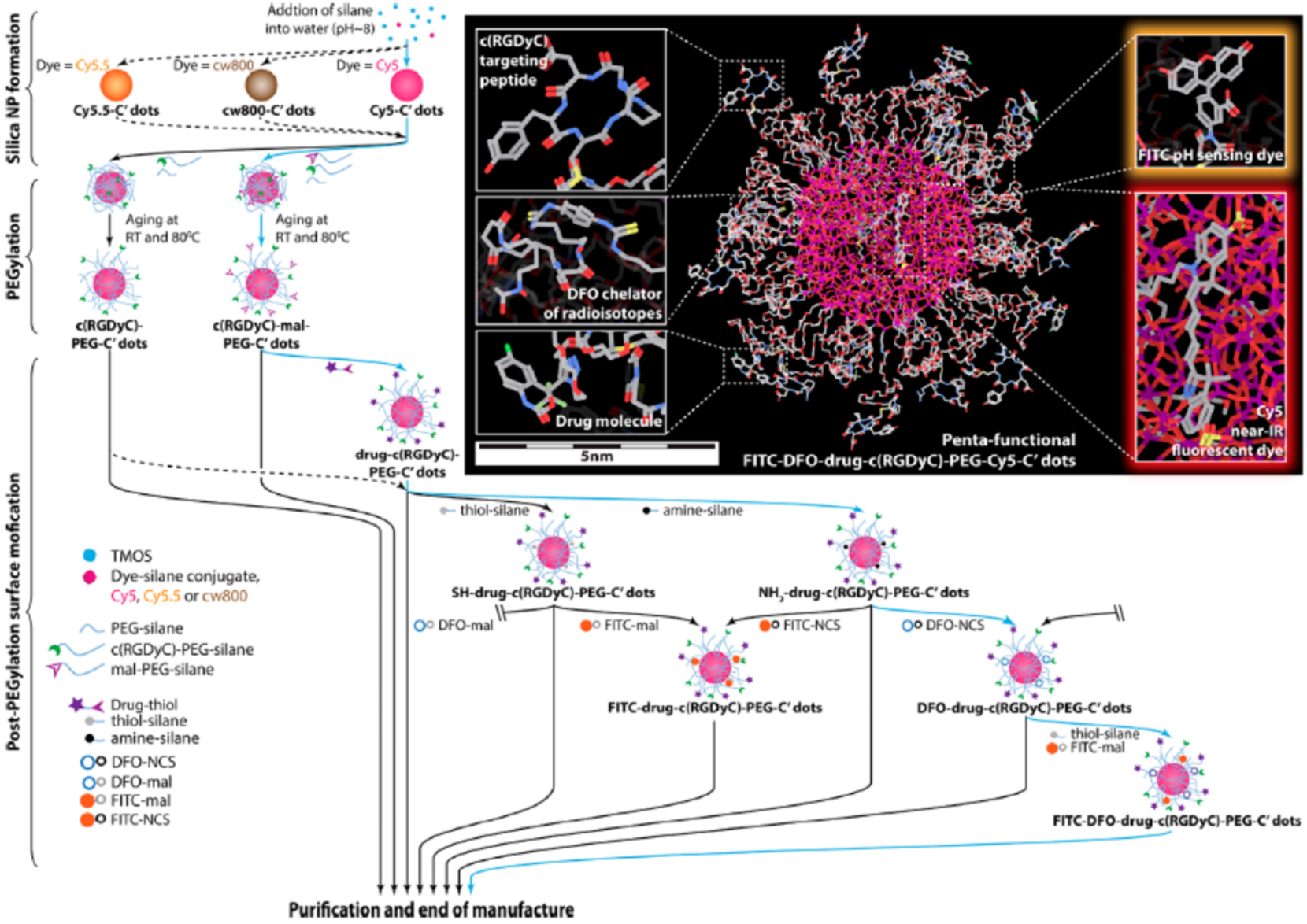
Silica nanoring **(Cring) [3]**



Silica nanocage **(Silicage) [4]**

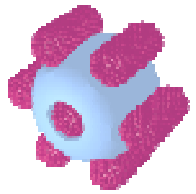
[1] K. Ma, C. Mendoza, M. Hanson, U. Werner-Zwanziger, J. Zwanziger, U. Wiesner, *Chem. Mater.* **2015**, 27, 4119-4133.
[2] K. Ma, H. Sai, U. Wiesner, *J. Am. Chem. Soc.* **2012**, 134, 13180−13183.
[3] K. Ma, K. A. Spoth, Y. Cong, D. Zhang, T. Aubert, M. Z. Turker, L. F. Kourkoutis, E. Mendes, U. Wiesner, *JACS*, **2018**, DOI: 10.1021/jacs.8b08802.
[4] K. Ma, Y. Gong, T. Aubert, M. Z. Turker, T. Kao, P. C. Doerschuk, U. Wiesner, *Nature* **2018**, 558 (7711), 577-580.

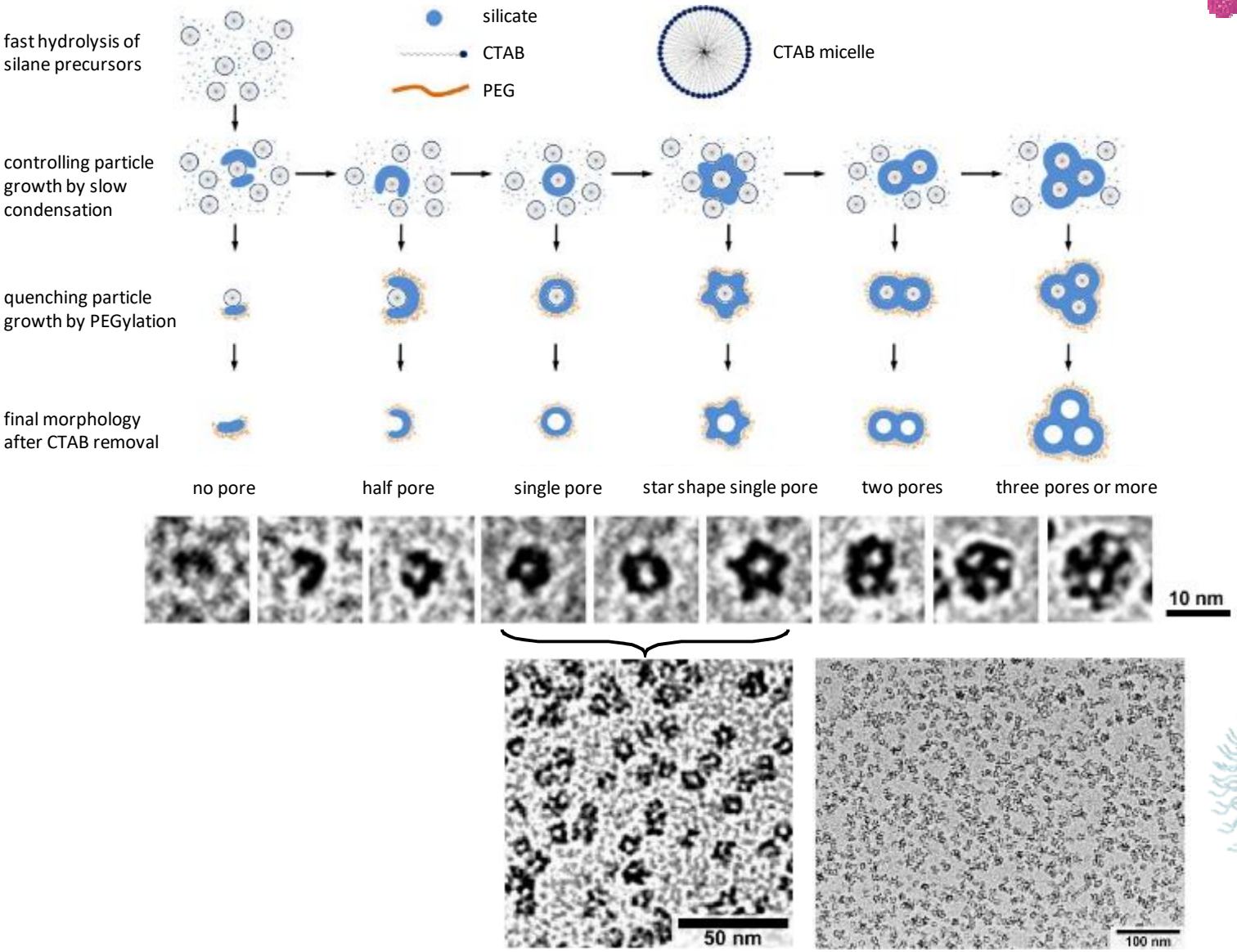
Multifunctional Nanoparticles



K. Ma and U. Wiesner, *Chem. Mater.* **2017**, 29, 6840−6855.

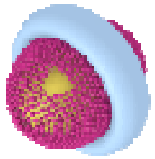
mCdots: Single Pore Nanoparticles





K. Ma, H. Sai, U. Wiesner, *J. Am. Chem. Soc.* **2012**, 134, 13180−13183.
K. Ma, U. Werner-Zwanziger, J. Zwanziger, U. Wiesner, *Chem. Mater.* **2013**, 25, 677−691.

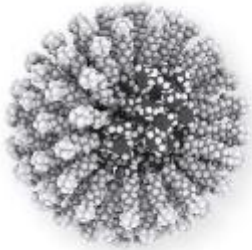
Silica Nano-Rings



tetramethyl orthosilicate (TMOS)

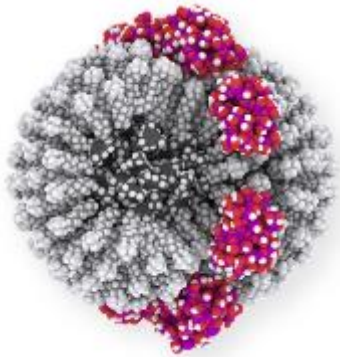
mesitylene (TMB)

cetyltrimethylammonium bromide (CTAB)

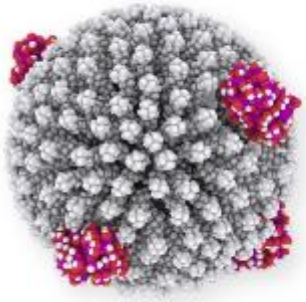


TMB swollen CTAB micelle

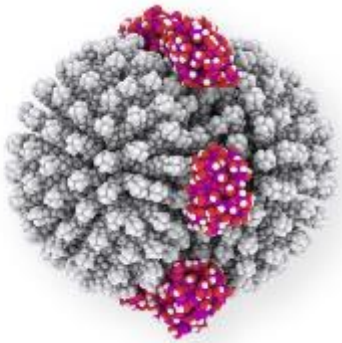
TMOS



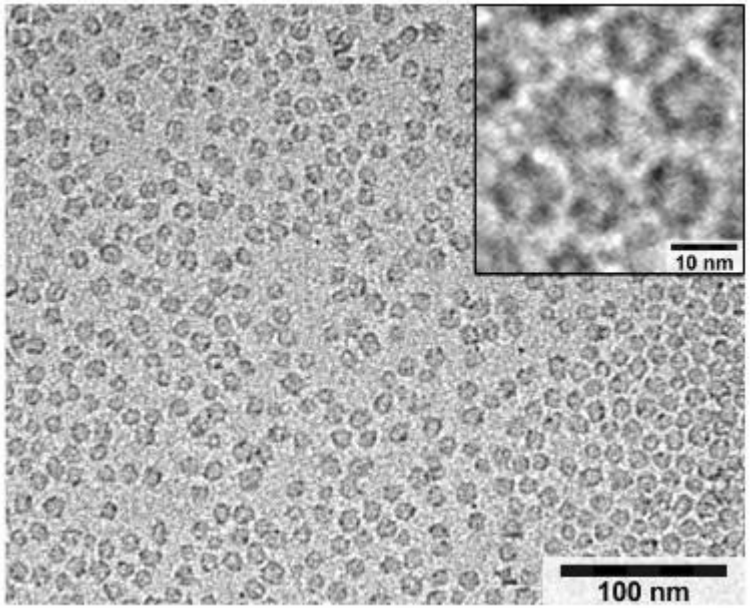
silica ring

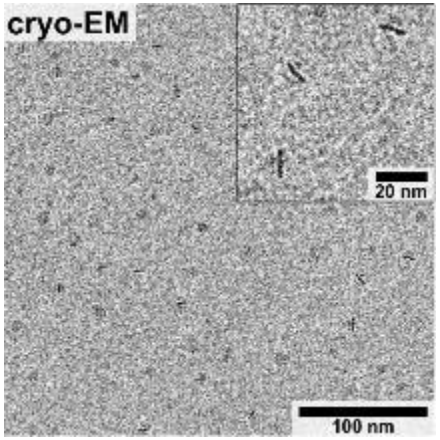


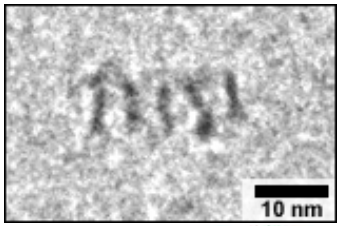
random silica clusters distribution

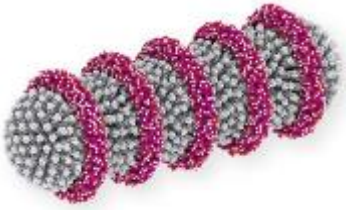


silica clusters self-assembly



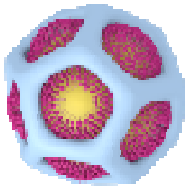




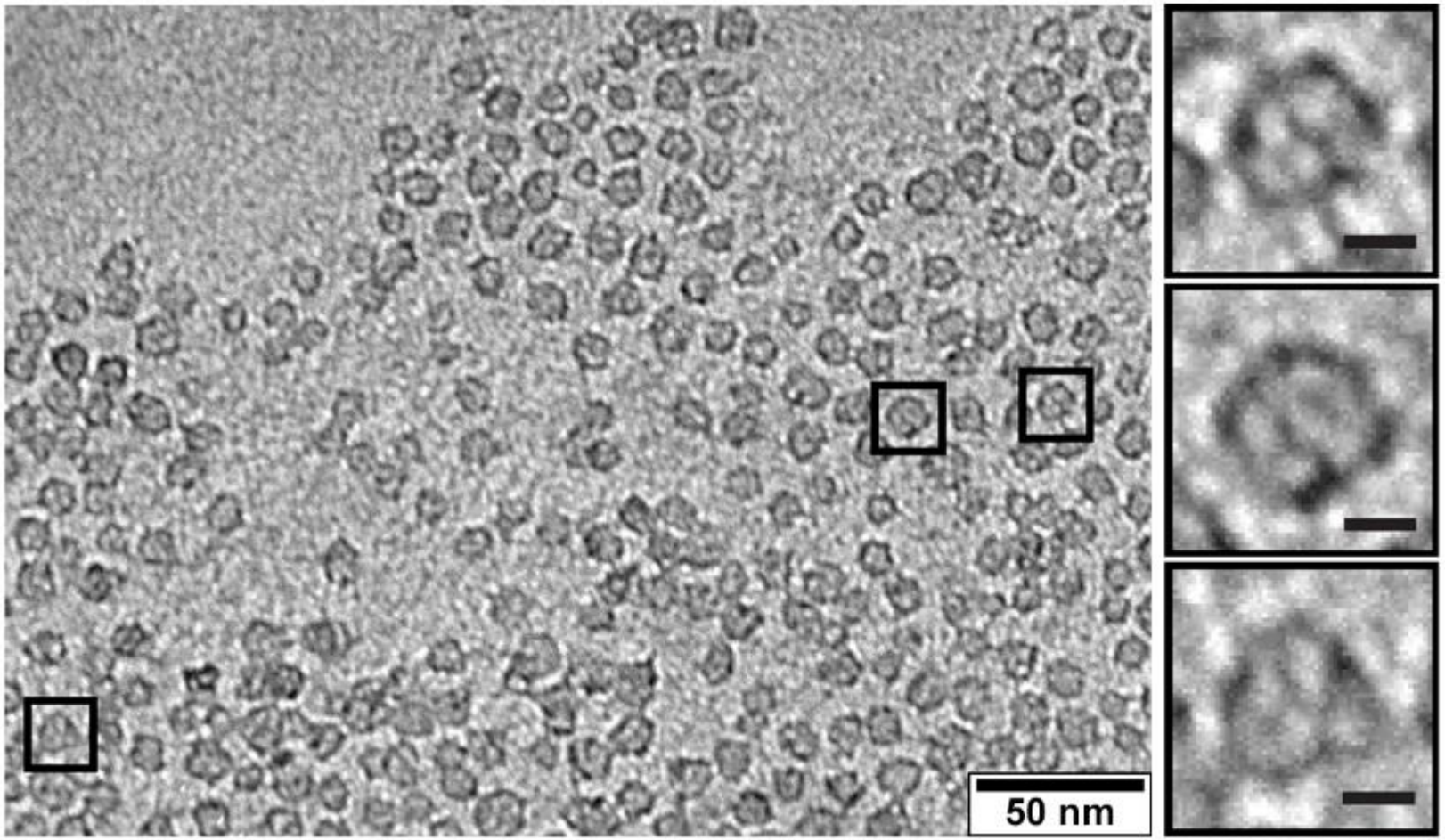


K. Ma, K. A. Spoth, Y. Cong, D. Zhang, T. Aubert, M. Z. Turker, L. F. Kourkoutis, E. Mendes, U. Wiesner, *J. Am. Chem. Soc.* **2018**, DOI: 10.1021/jacs.8b08802.

Silica Nano-Cages



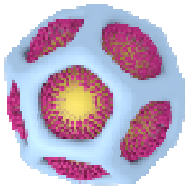
dry-state TEM



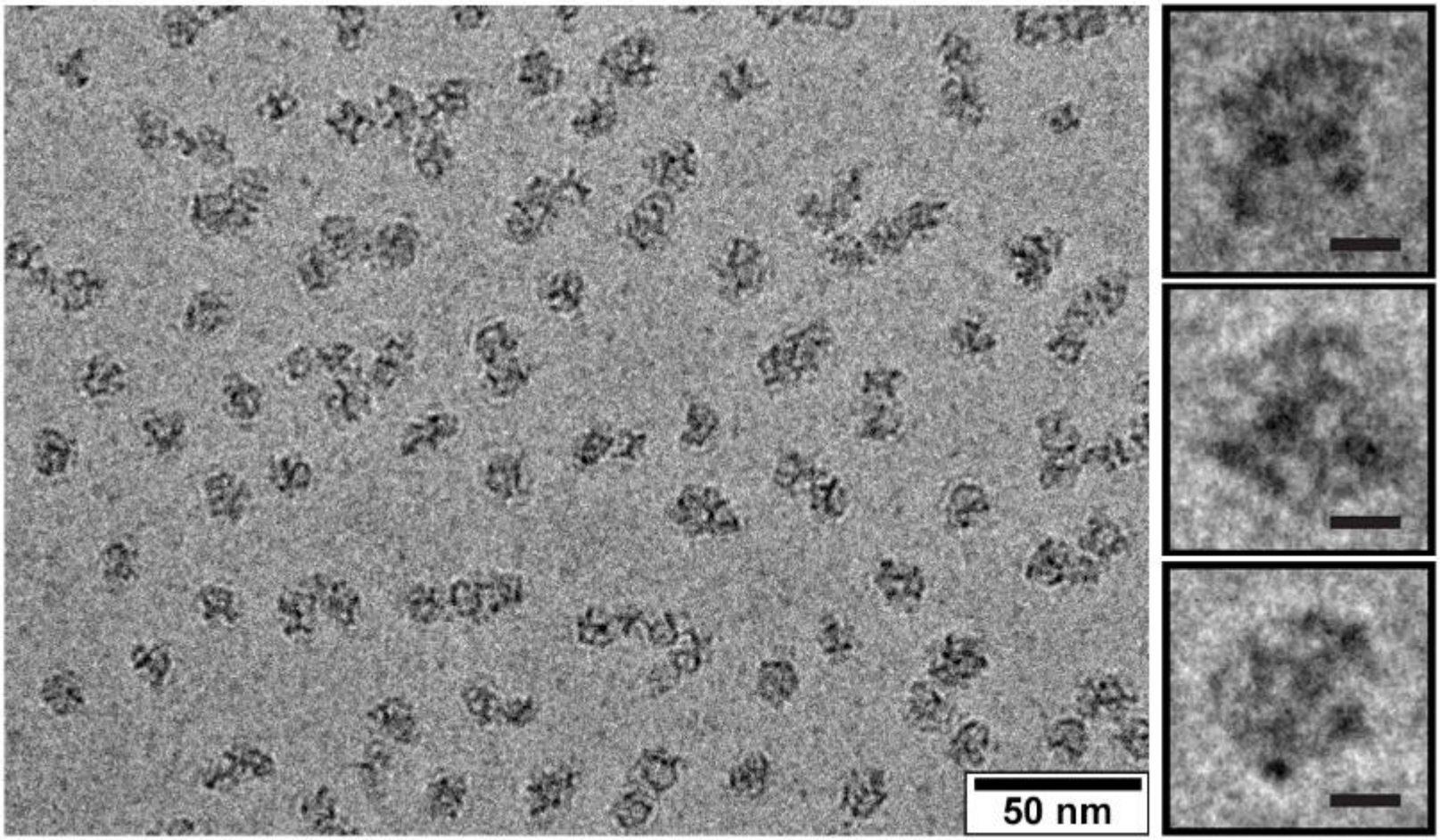
→ detailed particle structure cannot be solved by this technique

K. Ma, Y. Gong, T. Aubert, M. Z. Turker, T. Kao, P. C. Doerschuk, U. Wiesner, *Nature* **2018**, 558 (7711), 577-580.

Silica Nano-Cages



Cryo-electron microscopy



→ improved background, structure preservation and random orientation

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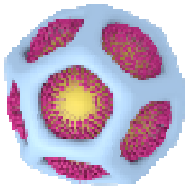
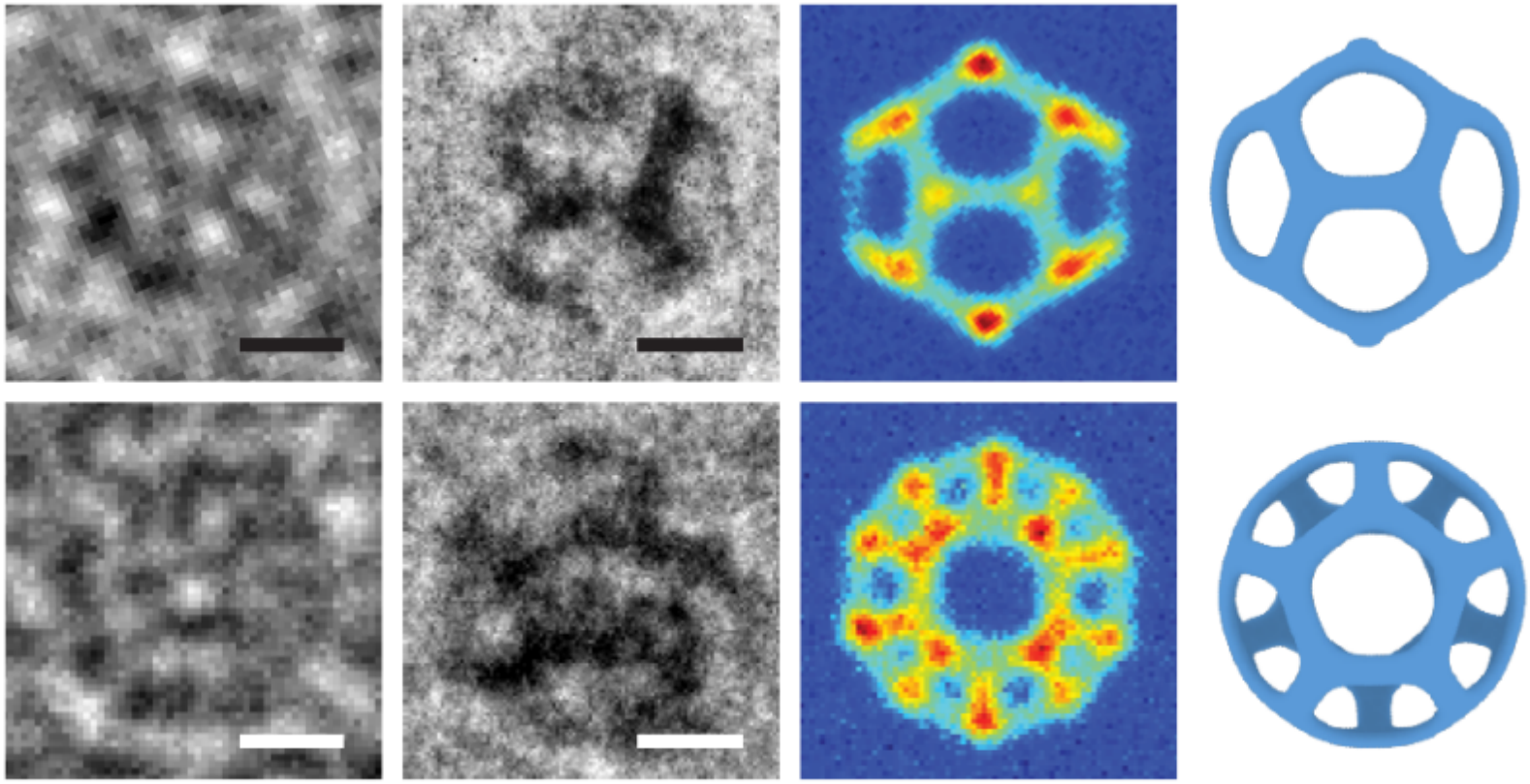
Silica Nano-Cages



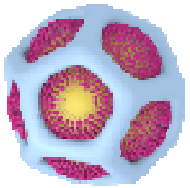


scale bar: 5 nm

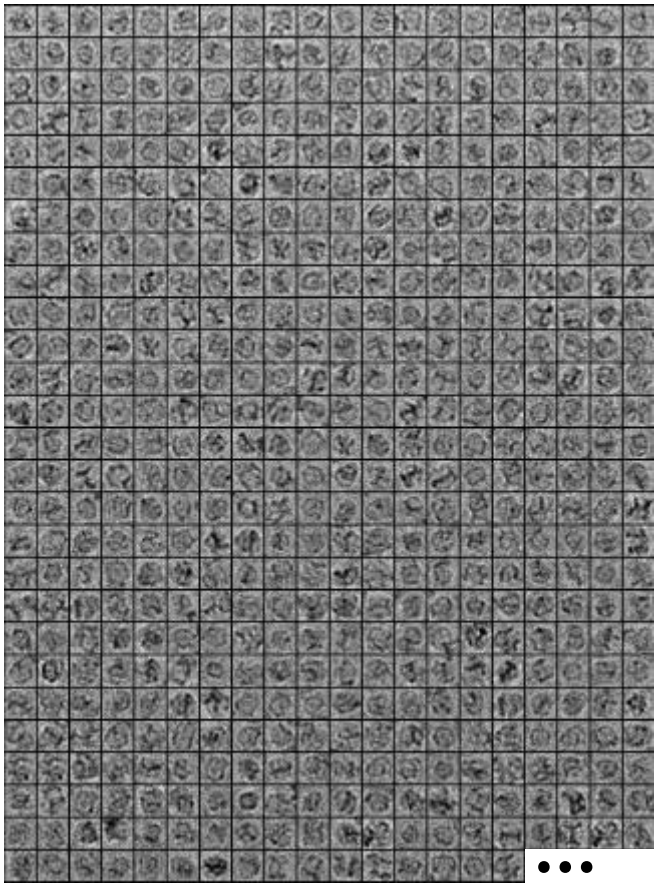
→ some of the images are consistent with projections of a dodecahedron

K. Ma, Y. Gong, T. Aubert, M. Z. Turker, T. Kao, P. C. Doerschuk, U. Wiesner, *Nature* **2018**, 558 (7711), 577-580.

Silica Nano-Cages

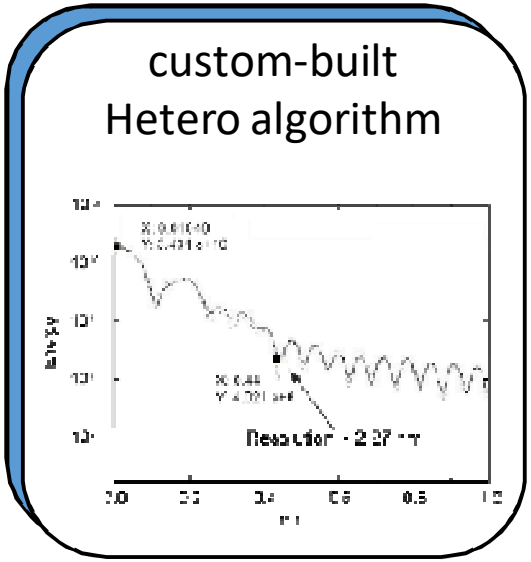


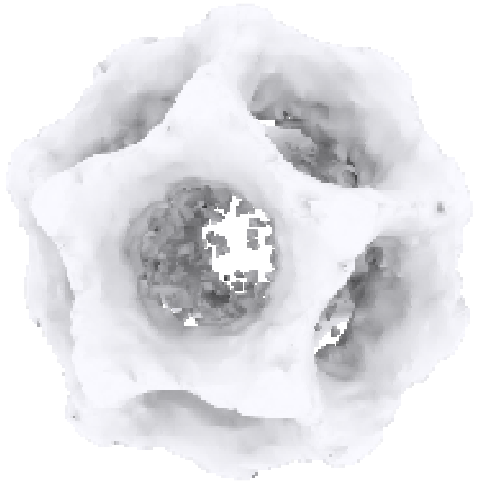
Single-particle 3D reconstruction of cryo-electron microscopy images using a machine learning algorithm



~ 19,000 single particle images

custom-built Hetero algorithm

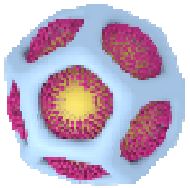




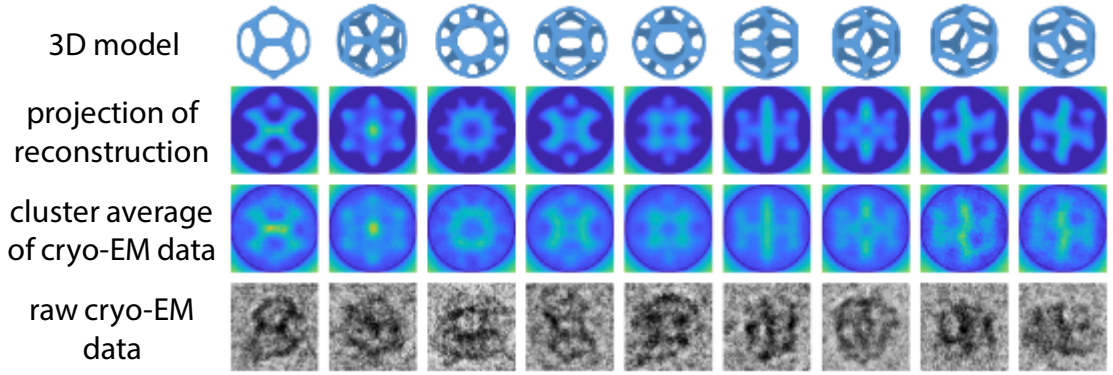
silica dodecahedron

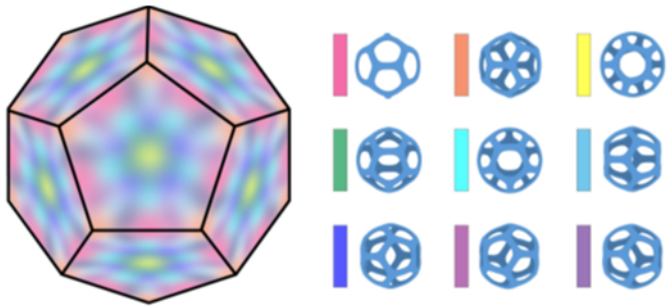
K. Ma, Y. Gong, T. Aubert, M. Z. Turker, T. Kao, P. C. Doerschuk, U. Wiesner, *Nature* **2018**, 558 (7711), 577-580.

Silica Nano-Cages

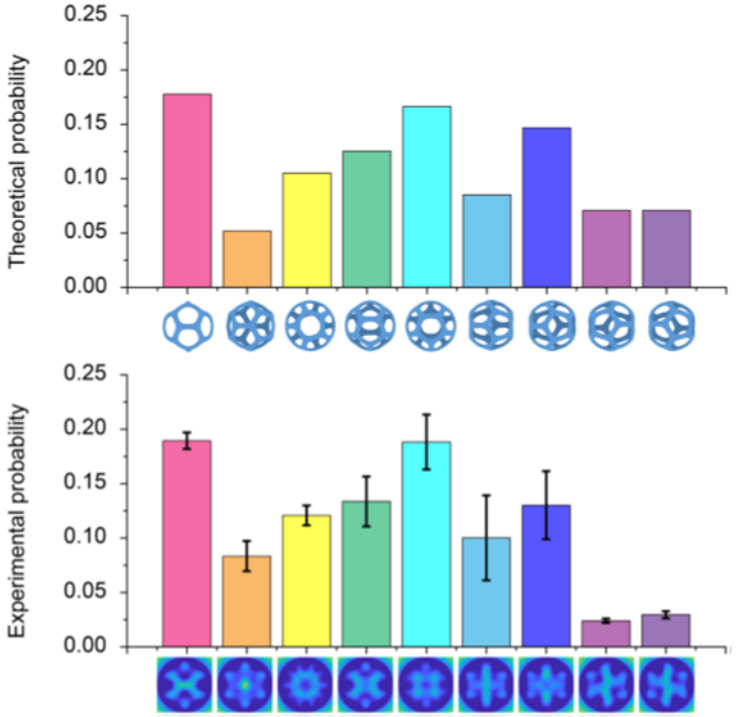


representative projections





→ good agreement between theoretical and experimental probability of each projection



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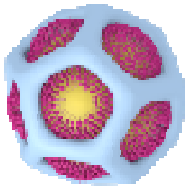
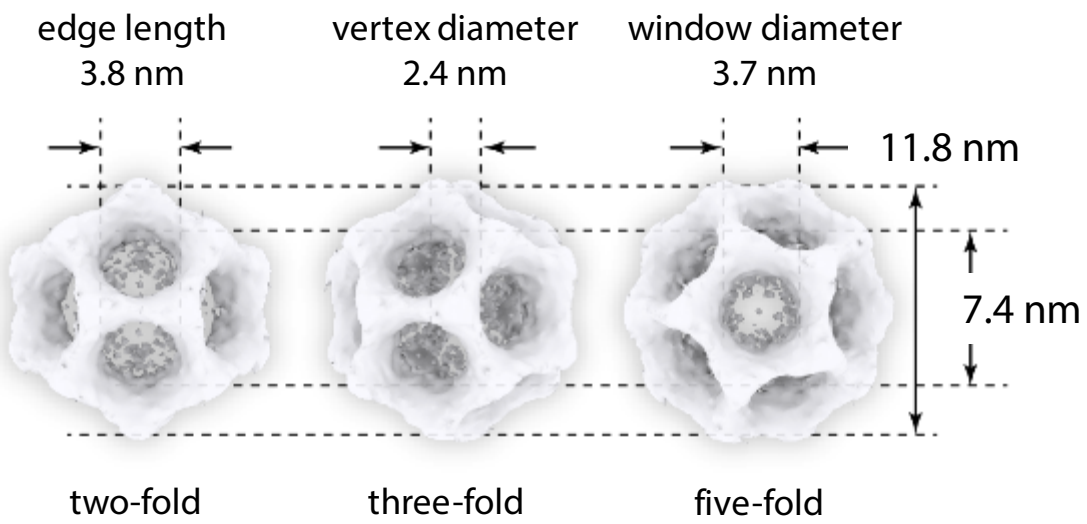
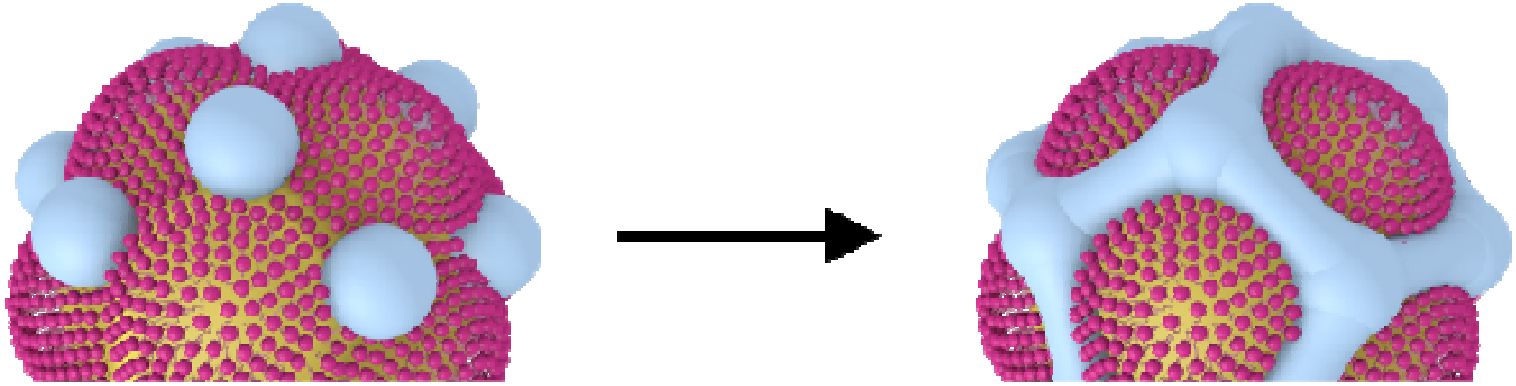
Silica Nano-Cages





→ edges are thinner than the typical primary silica cluster size (~ 2 nm)



adsorption of silica clusters
→ deformation of the micelle

further silica condensation
finishes to form the cage

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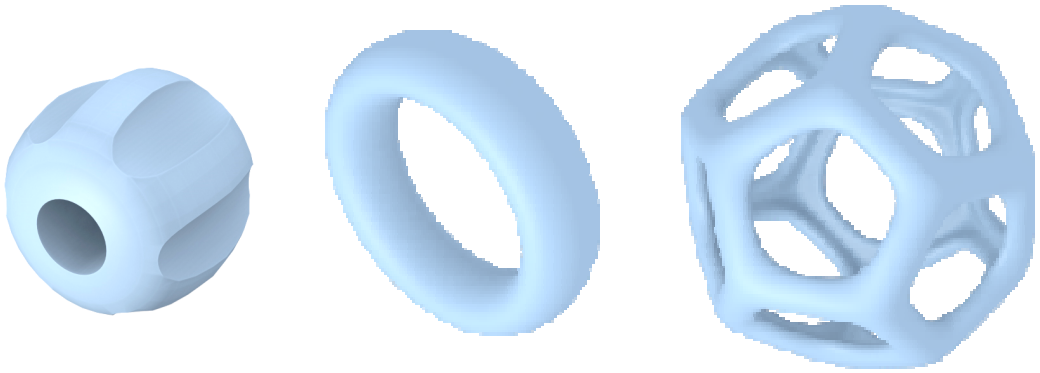
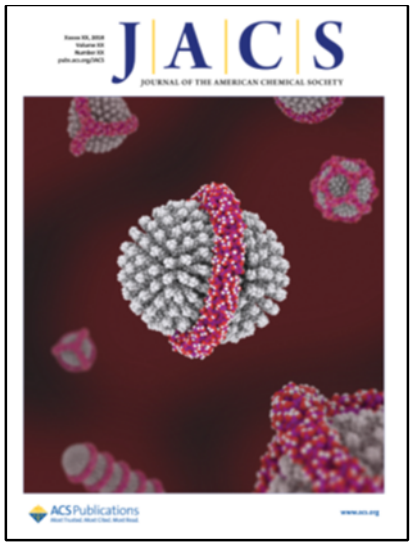
Perspectives

→ **important fundamental and practical value**

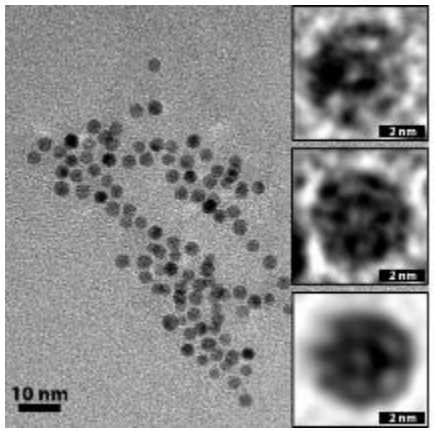




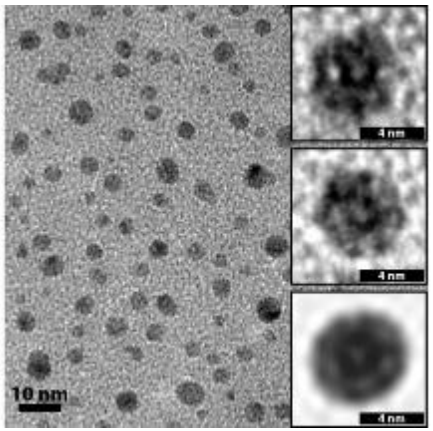
JACS **2018**, 10.1021/jacs.8b08802
Nature **2018**, 558, 577-580

→ **Extension of the same strategy to other materials**

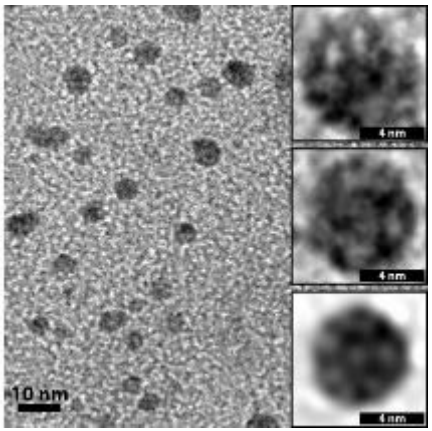
gold



silver



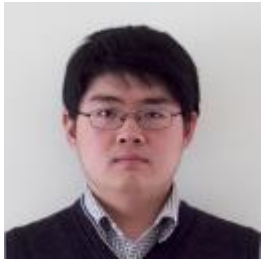
vanadium oxide



Acknowledgments

CornellEngineering
Materials Science and Engineering

- Prof. Ulrich Wiesner
- Melik Turker
- Teresa Kao
- Hiroaki Sai
- Ying Cong
- Duhan Zhang



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- Prof. Lena F. Kourkoutis
- Katherine A. Spoth

TU Delft - Prof. Eduardo Mendes

DALHOUSIE UNIVERSITY

- Prof. Josef Zwanziger
- Dr. Ulrike Werner-Zwanziger

Supports:

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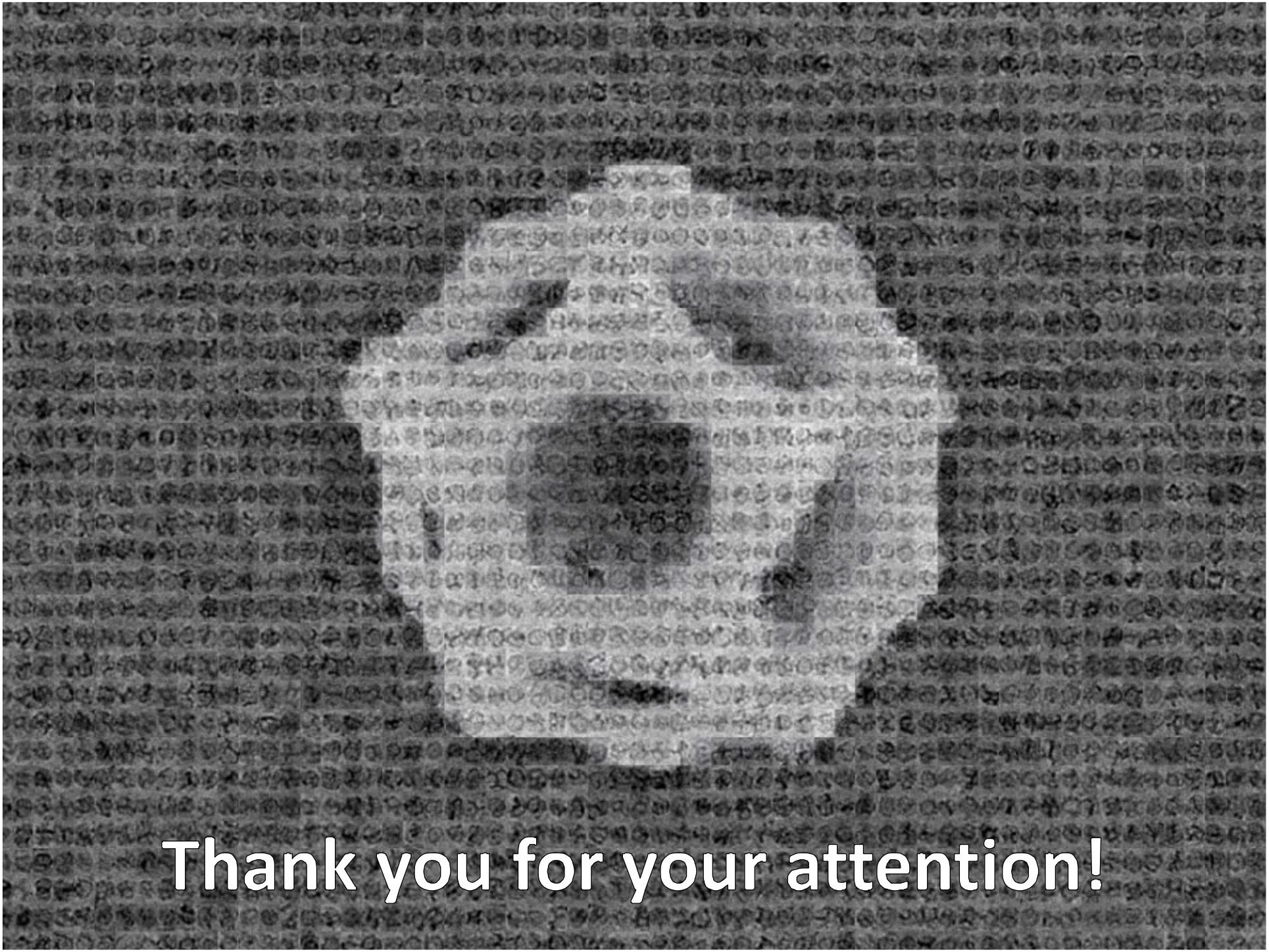
NSF

Memorial Sloan Kettering Cancer Center

European Commission


Thank you for your attention!