

## Supporting Information

### Structural insights into magnetic clusters grown inside virus capsids

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## 1. Co-VLPs on SiO<sub>2</sub>

Figure S1 compares both the heights obtained after drying of CPMV virus on HOPG and SiO<sub>2</sub>, measured by AFM. Interestingly, a clear effect is observed in the height of the dried CPMV depending on the surface used: the dried Co-VLP are higher when deposited on SiO<sub>2</sub>. While eVLPs collapse wall-to-wall on HOPG; when dried in SiO<sub>2</sub> capsids appear, on average, 8 nm higher. A similar case is observed for Co-VLP, which is 6 nm higher on SiO<sub>2</sub> compared with heights observed on HOPG. From these results, we can conclude that the interaction between the wall of the capsid and the surface modulate the process of collapse. Apparently, hydrophobic CPMV-HOPG interactions act as a driving force in the collapsing process. Notably, the CPMV-SiO<sub>2</sub> interaction is much weaker, so it cannot compensate the thermodynamic cost necessary for wall-to-wall collapse. If we compare the results obtained for eVLPs and Co-VLP on SiO<sub>2</sub>, a mechanical reinforcement of the virus is observed by the presence of cobalt. In fact, the Co-VLP keeps almost the same height as that observed in solution (23 nm), while on HOPG, a decrease in the height (14 nm) was observed due to increased CPMV-surface interaction. Adsorption results on SiO<sub>2</sub> are less sensitive to the differences between eVLPs and Co-VLP than the results of adsorption on HOPG. Since HOPG elicits a larger collapse it is a better surface than SiO<sub>2</sub> to explore the amount of inner cobalt within the capsid. HOPG shows more restrictive conditions for estimating a top limit of Co inside virus particles.

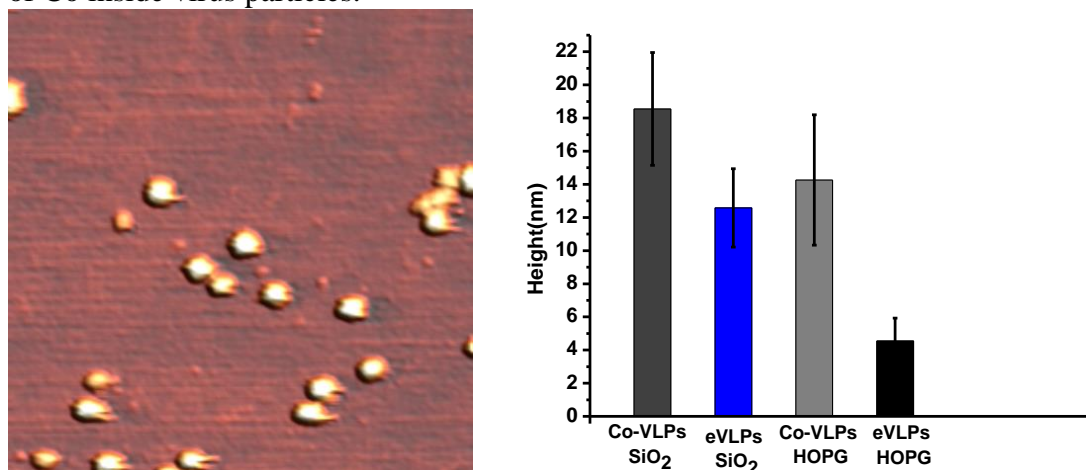


Figure S1: Histograms (right) corresponding to the heights observed by AFM for empty and full particles (left,  $1.5 \times 1.5 \mu\text{m}^2$ ) on SiO<sub>2</sub> and HOPG after the drying process.

## 2 Calculation of Virus Volume and Weight Ratios

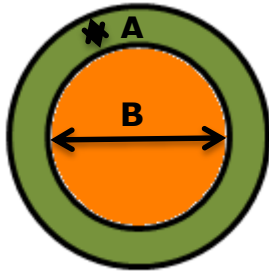


Figure S2

eVLP are protein shells with a total diameter of ~28 nm, and internal cavity diameter of 24 nm, i.e. thickness of the protein shell is 2 nm. With these dimensions and the known density values of the eVLP and cobalt the loading weight ratio of eVLP : Co can be predicted.

Density of cobalt = 8.9 g/cm<sup>3</sup>  
 Density of eVLP = 1.32 g/cm<sup>3</sup>

Volume of a sphere =  $\frac{4}{3}\pi r^3$

$$\begin{aligned} \text{Total Volume of eVLP} &= A + B = \frac{4}{3}\pi r^3 \quad \text{where } r = 14 \text{ nm} \\ &= 11494.0672 \text{ nm}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of inner sphere B} &= \frac{4}{3}\pi r^3 \quad \text{where } r = 12 \text{ nm} \\ &= 7238.2464 \text{ nm}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of Virus shell coating} &= \text{Total Volume} - \text{Volume of Inner Sphere B} \\ &= 4255.8208 \text{ nm}^3 \end{aligned}$$

If volume is converted into weight:

$$\begin{aligned} \text{Co: } 1 \text{ cm}^3 &= 1 \times 10^{21} \text{ nm}^3 = 8.9 \text{ g} \\ 7238.2464 \text{ nm}^3 &= x \\ \text{Weight of Co} &= 6.442 \times 10^{-17} \text{ g} \end{aligned}$$

$$\begin{aligned} \text{eVLP } 1 \text{ cm}^3 &= 1 \times 10^{21} \text{ nm}^3 = 1.32 \text{ g} \\ 4255.8208 \text{ nm}^3 &= x \\ \text{Weight of eVLP} &= 0.5518 \times 10^{-17} \text{ g} \end{aligned}$$

$$\text{Total Weight} = \text{Co} + \text{eVLP} = 7.0 \times 10^{-17} \text{ g}$$

For 100% Co loaded eVLP, weight % values should be:

eVLP:	8.7 %	ratio = 0.087
Co :	92 %	

For the TGV data (figure 5)

eVLP:	55%	ratio = 1.2
Co:	45%	

This supports the AFM data that the Co load does not fill the entire virus cavity.

## 1.2 Dessicated Co-VLPs decrease to 14 nm in height, 9 nm top limit cobalt

If we consider the AFM studies of the dessicated eVLP and Co-VLPs :

Height of flattened eVLP = 2 nm

Height of Co-VLP = 14 nm where 4 nm corresponds to VLP wall thickness.

Co diameter can be no greater than 5 nm.

1. Assume that the desiccated Co-VLP will have the same VLP content as an eVLP but that it is denser over a smaller area, i.e. density and volume of material has changed but the same weight as calculated above can be expected.

Weight of eVLP=  **$5.518 \times 10^{-18}$  g**

Co volume where $r = 2.5$ nm =	$523.6 \text{ nm}^3$
Co weight in volume =	<b><math>4.66 \times 10^{-18}</math> g</b>
Total weight =	$10.178 \times 10^{-18}$ g

For this loading weight % values:

eVLP:	54.7%	Ratio 54.7/45.3 = 1.2
Co :	45.3 %	

Similar result to TGV experiments

Considering the mass of solid filling and the AFM/TGV results, the amount of space filled by Co is roughly  $0.5 \times 100 / 6.4 \sim 10$  % of the internal cavity.