

Hematite cubes in a static magnetic field form kinked chains. This is an entropic effect and two cube alignments with the same minimal energy plays the key role.

Hematite cube chains in static magnetic fields

Mārtiņš Bricis, Viesturs Šints, and Andrejs Cēbers
 University of Latvia, Lab of Magnetic Soft Materials

Intro

Hematite from a physical viewpoint is a weak ferromagnetic material. Thus, hematite colloids allow us to explore a different physical particle interaction parameter range compared to ordinary ferromagnetic particle colloids. Here we explore and explain structures in static magnetic fields.

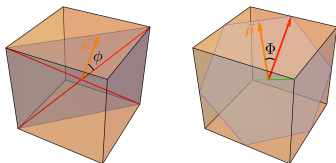


FIGURE: Momenta orientation in a hem. cube [1,2].

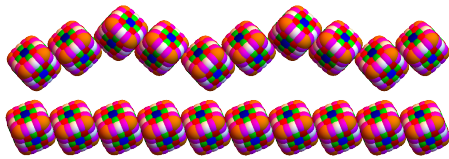


FIGURE: Chain with kinks (top) vs straight chain.

Theoretical methods

- Energy minimization

$$\vec{E} = \sum_{i,j>i} \frac{\vec{\mu}_i \cdot \vec{\mu}_j}{r_{ij}^3} - \frac{3(\vec{\mu}_i \cdot \vec{r}_{ij})(\vec{\mu}_j \cdot \vec{r}_{ij})}{r_{ij}^5} - \vec{\mu}_i \cdot \vec{B}$$

- MD with simulated annealing

$$m \frac{d\mathbf{v}}{dt} = -\nabla(E_{tot} + V_{LJ}) - \gamma \mathbf{v} + \sqrt{2\gamma k_B T} \xi(t)$$

Results

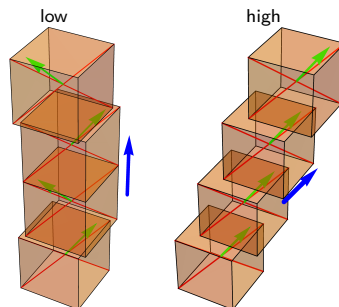


FIGURE: Energetically favorable cube chains at low and high magnetic fields without gravity.

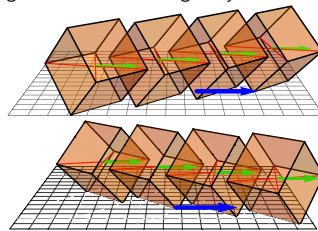


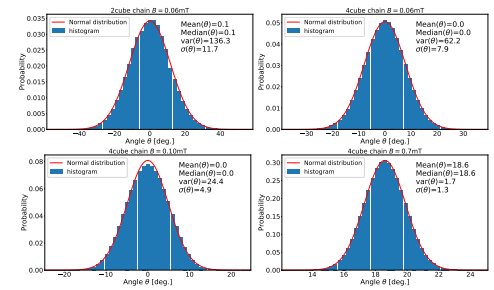
FIGURE: Two alignments of energetically favorable configuration with the same energy in the presence of gravity, $\phi = 12^\circ$, and strong magnetic fields.

Conclusions

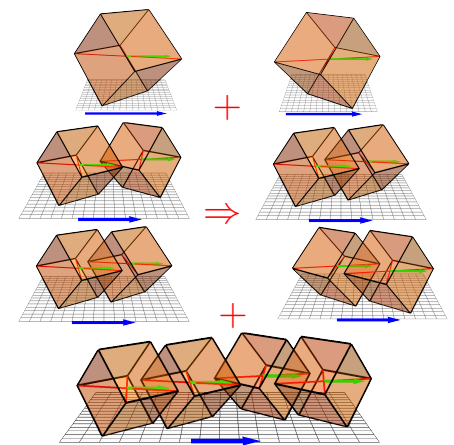
- Energy minimization \Rightarrow 2 different chain types
- Energy minimization \nexists kink formation
- Kinks formed during assembly
- Kinks form when two cube chains ($N > 2$) with different alignment attach
- Entropy effect

Extra figures

Chain orientation distributions at room temperature, calculated using MD simulations, which were initialized with energetically favorable straight chain solution



Kink formation

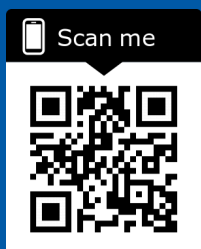


References

- [1] L. Rossi, et. al., *Soft Matter* **14**, 1080 (2018).
- [2] M. Ozaki, et. al., *J. Col. Int. Sci.* **113**, 76 (1986).

Acknowledgment

The authors appreciate the financial support from PostDocLatvia grant No. 1.1.1.2/VIAA/3/19/562 and M.era-net project FMF No.1.1.1.5./ERANET/18/04



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