# Colloidal Rods in Irregular Spatial Confinement

**Authors:** Pouya Moghimian (1), Ludger Harnau (2), Vesna Srot (1), Francisco de la Peña (3), Nima Farahmand Bafi (4, 5), Sandra J. Facey (6), Peter A. van Aken (1)
1. Stuttgart Center for Electron Microscopy, Max Planck Institute for Solid State Research, Stuttgart, GERMANY
2. Bernhäuserstraße 75, 70771 Leinfelden-Echterdingen, Stuttgart, GERMANY
3. Department of Materials Science and Metallurgy, University of Cambridge, Cambridge, UK
4. , Max Planck Institute for Intelligent Systems, Stuttgart, GERMANY
5. Institute for Theoretical Physics, University of Stuttgart, Stuttgart, GERMANY
6. Institute of Technical Biochemistry, University of Stuttgart, Stuttgart, GERMANY

**DOI: 10.1002/9783527808465.EMC2016.6271**
**Corresponding email:** V.Srot@fkf.mpg.de
**Keywords:** liquid crystals, confinement, self-assembly

Spontaneous assembly of anisometric colloidal particles, such as rod-like particles, in two-dimensions (2D) can be carried out via incubation of colloid-containing suspensions on solid surfaces [1]. Rod-like particles having a high aspect ratio (e.g. very long inoviruses) show liquid crystal (LC) behavior in suspensions. An ordered medium of liquid crystals often possesses a variety of defects, at which the director *n(r)* of the liquid crystal undergoes an abrupt change. Experimental research on these effects has remained challenging and has not been performed, to our knowledge, on confined rod-like colloidal particles on irregularly structured substrates. Therefore, we studied semi-flexible M13 phages in contact with irregular stranded webs of thin amorphous carbon (a-C) films (Figure 1a,b) using transmission electron microscopy (TEM) and theoretical considerations. In this work, we show that on the structureless and wide amorphous carbon (a-C) surface areas, far from the surface edges, the phages exhibited random orientations (Figure 1c). However, close to the surface edges the orientation of M13 phages in two-dimensional nematic films was controlled by the orientation and curvature of the edges. When constrained to surface strands, the M13 phages adopted a configuration that matched the confining boundary conditions (Figure 2). An annulus sector was superimposed on these oriented phage bundles that allowed us to derive analytic expressions for the bending energy of such oriented bundles. Our theoretical approach provides an explanation for the different number of phages orienting close to the surface edges with different local curvatures. By comparing the self-assembly on differently shaped carbon substrates, it was demonstrated that the alignment of the phages can be controlled by choosing appropriate substrate shapes [2]. This offers a convenient means to fabricate designed structures of orientationally ordered M13 phages. The understanding of such systems opens up new possibilities for defect engineering of liquid crystals, which can be beneficial for applications of liquid crystals in the presence of microscopic surface pores and irregularities.

**Acknowledgements:**
The financial support by the DFG is gratefully acknowledged. The research leading to these results has received funding from the European Union Seventh Framework Programme [FP7/2007-2013] under grant agreement no. 312483 (ESTEEM2). P. M. thanks Dr. M. Bier (MPI-IS, Stuttgart, Germany) for discussions.

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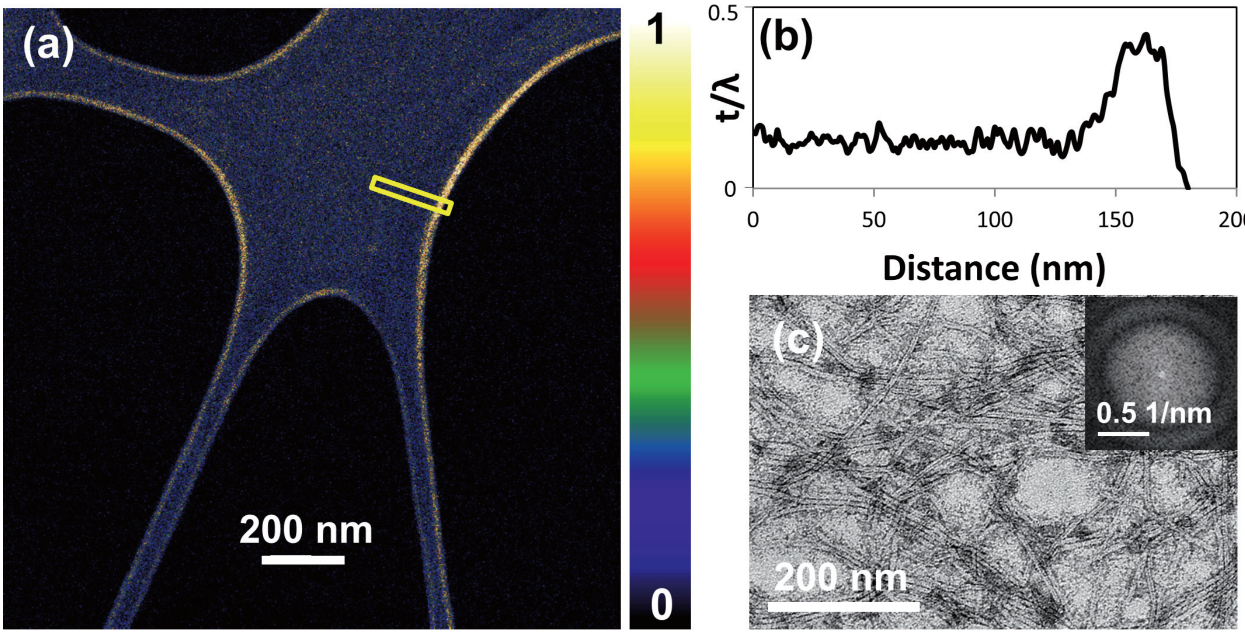


Figure 1. (a) Energy-filtered TEM thickness map of the (a-C) web film. A line profile with an integration width of 40 nm (yellow rectangle) was taken from the area indicated to estimate the material's average thickness over the referred area. (b) The relative thickness profile (t/λ) along the length of the yellow rectangle in (a). (c) Bright-field TEM image of randomly oriented M13 particles on the a-C flat surface far from the surface edges and intersections. The inset shows the 2D Fourier transform image of the BF-TEM image.

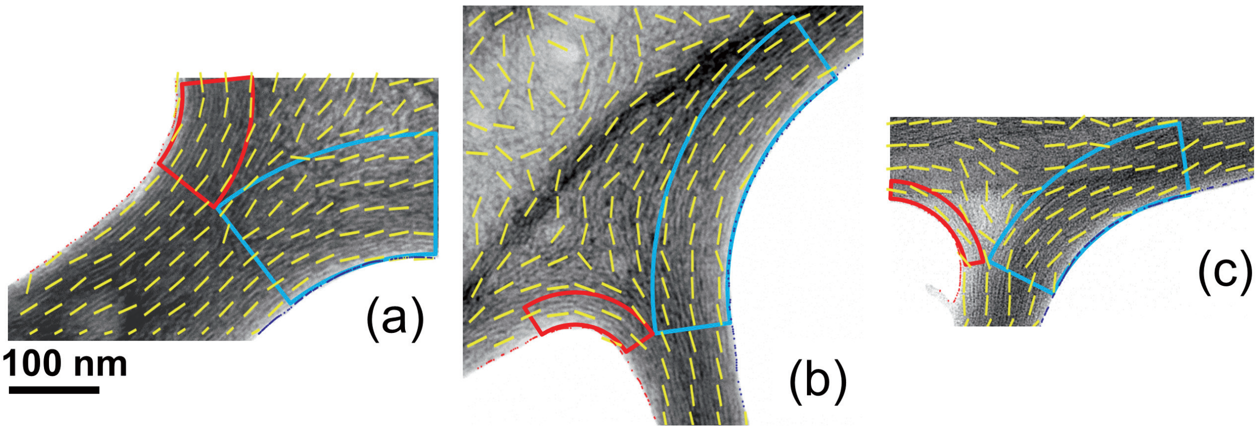


Figure 2. (a)-(c) Orientational orders (marked with yellow lines) extracted from analyses of the TEM images along with schematic representations of Y intersections showing two branching sections denoted by red and blue annulus sectors. The particle orientations, superimposed on the raw TEM images, show that within the assumed annulus sectors the molecules tend to align parallel to their closest surface edge.