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The shape of the orientation distribution of carbon nanotubes in aligned arrays

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Recent simulations of vertically aligned carbon nanotube arrays have shown that the shape of the orientation distribution of nanotubes within the array has a drastic effect on the electrical properties of the array. Orienting of shape-anisotropic objects can be carried out in several different ways such as shearing, magnetically steering, or by vibrating the objects. Nevertheless, perfect orientation is difficult if not impossible to achieve. In the case of the growth of carbon nanotube arrays, self-confinement can occur affecting the resultant orientation distribution. Yet so far the shape of the orientation distribution has not been quantified in great detail and it has been mostly assumed to be Gaussian or Lorentzian. In the present work, multi-walled carbon nanotube arrays were grown via aerosol-assisted chemical vapour deposition with iron catalyst and investigated using small-angle X-ray scattering, a method perfectly suited to characterizing the orientation of carbon nanotubes. Using a microfocused X-ray beam of 24 µm x 17 µm in size at beamline P03 of the PETRA III synchrotron storage ring in Hamburg, we determined the orientation distribution of the vertically aligned carbon nanotubes along the film height. Remarkably, the packing density of the carbon nanotubes seems to correlate not only with the width of the distribution but also its shape. The shape of the orientation distribution was then compared to that from different oriented systems. These findings indicate that by using alignment methods that are based on steric interaction between particles, such as shearing or self-confinement during particle growth, the system will reach an alignment with an orientation distribution closer to the Laplace distribution than to the normal distribution. Such a finding has profound implications for simulation studies of mechanical, electrical and other properties of many hierarchical materials.

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