Particle shape transformation in colloidal crystals under sintering conditions

A.V. Zozulya[1*], J.-M. Meijer[2], I. Zaluzhnyy[1,3], N. Mukhamarova[1], E. Sulyanova[1], S. Lazarev[1], M. Sprung[1], A.V. Petukhov[4], I.A. Vartanyants[1,3]

[1]*Photon Science DESY, Hamburg, Germany*
[2]*Division of Physical Chemistry, Department of Chemistry, Lund University, Sweden*
[3] *National Research Nuclear University MEPhI, Moscow, Russia*
[4] *van 't Hoff laboratory for Physical and Colloid Chemistry, Debye Institute for Nanomaterials Science, University of Utrecht, The Netherlands*

**alexey.zozulya@desy.de*

Colloidal crystals formed by self-assembly of sub-micron colloidal spherical particles represent a new class of nanomaterials with promising applications as photonic crystals [1,2]. For these applications colloidal crystals are especially attractive materials due to large surface area, a wide range of particle sizes and low fabrication costs.

The band gap properties of colloidal crystals can be tailored by thermal treatment [3]. The physical mechanism responsible for this phenomenon is not well understood. The annealing treatment of low-order spin-coated polystyrene (PS) colloidal films has provided only a rough picture of structural evolution [4]. Our recent X-ray diffraction studies of high-quality PS colloidal crystals [5] upon incremental heating have revealed detailed scenario of colloidal crystal melting [6, 7]. X-ray diffraction studies of PS colloidal crystals have been carried out in transmission and reflection geometries using high resolution X-ray scattering setup at the P10 coherence beamline of the PETRA III synchrotron at DESY Hamburg. Bragg peak parameters, such as q-values, integrated peak intensities, the radial and azimuthal widths, were analysed as a function of temperature [7]. Temperature dependencies of in-plane components of lattice distortions and mosaic spread as well as the size of coherently scattering domain (CSD) were evaluated by Williamson-Hall method. In this method the peak widths are analysed as a function of scattering vector magnitude, which enables to determine the sizes of CSD and lattice distortion parameters. Based on the performed analysis we identified four stages of structural evolution in a PS crystal film upon heating: steady-state, pre-melting, particle shape transformation and crystal melting. The observed peculiarities of temperature dependences indicated that the evolution of particle shape and induced strains play a central role in the mechanism of colloidal crystal melting.

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