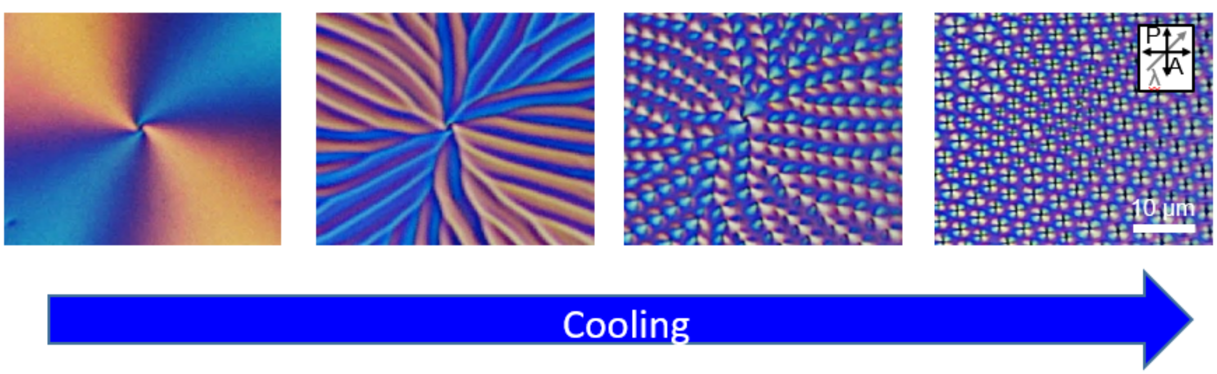
Observation of the phase transition of liquid crystal defects for the first time

June 2 2017



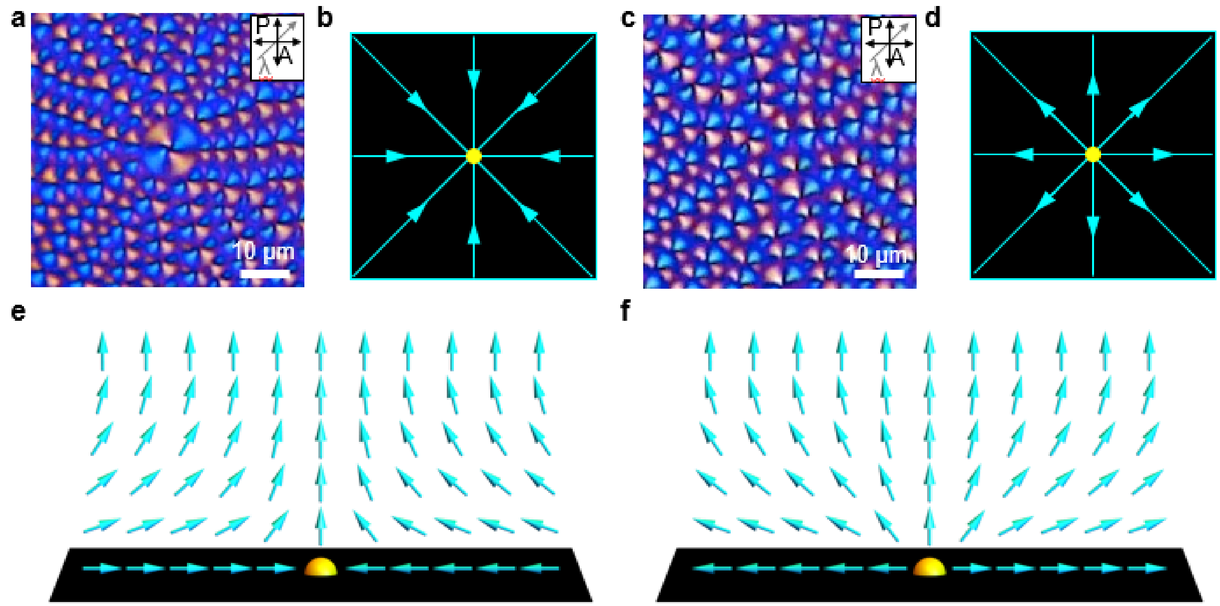
Phase transition of the LC topological defect on cooling. Credit: KAIST

KAIST researchers observed the phase transition of topological defects formed by liquid crystal (LC) materials for the first time.

The phase transition of topological defects, which was also the theme of the Nobel Prize for Physics in 2016, can be difficult to understand for a layperson but it needs to be studied to understand the mysteries of the universe or the underlying physics of skyrmions, which have intrinsic topological defects.

If the galaxy is taken as an example in the universe, it is difficult to observe the topological defects because the system is too large to observe some changes over a limited period of time. In the case of defect structures formed by LC molecules, they are not only a suitable size to observe with an optical microscope, but also the time period in which the phase transition of a defect occurring can be directly observed over a few seconds, which can be extended to a few minutes. The defect structures formed by LC material have radial, circular, or spiral shapes centering on a singularity (defect core), like the singularity that was already introduced in the famous movie "Interstellar," which is the center point of black hole.

In general, LC materials are mainly used in liquid crystal displays (LCDs) and optical sensors because it is easy to control their specific orientation and they have fast response characteristics and huge anisotropic optical properties. It is advantageous in terms of the performance of LCDs that the defects of the LC materials are minimized. The research team led by Professor Dong Ki Yoon in the Graduate School of Nanoscience and Technology did not simply minimize such defects but actively tried to use the LC defects as building blocks to make micro- and nanostructures for the patterning applications. During these efforts, they found the way to directly study the phase transition of topological defects under in-situ conditions.



Polarizing optical microscopy images of topological defects depending on the strength of the director field. (a,b,e) Convergent director field arrangements of LC molecules and corresponding schematic images; (c,d,f) Divergent director field arrangements of LC molecules and corresponding schematic images. Credit: KAIST

Considering the LC material from the viewpoint of a device like a LCD, robustness is important. Therefore, the LC material is injected through the capillary phenomenon between a rigid two-glass plate and the orientation of the LCs can be followed by the surface anchoring condition of the glass substrate. However, in this conventional case, it is difficult to observe the phase transition of the LC defect due to this strong surface anchoring force induced by the solid substrate.

In order to solve this problem, the research team designed a platform, in which the movement of the LC molecules was not restricted, by forming a thin film of LC material on water, which is like oil floating on water.

For this, a droplet of LC material was dripped onto water and spread to form a thin film. The topological defects formed under this circumstance could show the thermal phase transition when the temperature was changed. In addition, this approach can trace back the morphology of the original defect structure from the sequential changes during the temperature changes, which can give hints to the study of the formation of topological defects in the cosmos or skyrmions.

Prof. Yoon said, "The study of LC crystal defects itself has been extensively studied by physicists and mathematicians for about 100 years. However, this is the first time that we have observed the phase transition of LC defects directly." He also added, "Korea is leading in the LCD industry, but our basic research on LCs is not at the world's research level."

More information: Min-Jun Gim et al, Morphogenesis of liquid crystal topological defects during the nematic-smectic A phase transition, *Nature Communications* (2017). DOI: 10.1038/ncomms15453

Provided by The Korea Advanced Institute of Science and Technology (KAIST)