Impact of nanoparticles on stabilisation of lattices of topological defects in smectic A ordering

U. Jagodič[1], S. Kralj[1,2], G. Cordoyiannis[2,3], Z. Kutjak[2], and E. Lacaze[4]

1 Faculty of Natural Sciences and Mathematics, University of Maribor, 2000 Maribor, Slovenia
2 Jožef Stefan Institute,1000 Ljubljana, Slovenia
3 Department of Physics, National and Kapodistrian University of Athens, 15784 Zografou, Greece
4 INSP, CNRS UMR-7588, UPMC University Paris 06, Paris, France

Topological defects (TDs) are ubiquitous in phases reached via continuous symmetry breaking phase transitions. Physics of TDs exhibits several universal phenomena because their origin is driven by topology which is independent of systems' microscopic details. For example, the first theory on coarsening dynamics of TDs following a quenched phase transition was developed in cosmology in order to study evolution of TDs in the early universe[1]. Furthermore, pioneering studies of stable (i.e. Abrikosov) lattices[2] of TDs were carried out in type-II superconductors. Latter, these phenomena have been studied (coarsening dynamics[3,4], lattices[5,6] of TDs) also in various liquid crystal (LC) phases.

In our contribution we study impact of nanoparticles on stability of various lattices of TDs in smectic A LCs stressing universal phenomena. We consider lattices of screw[7] and edge[8] dislocations using Landau-de Gennes-Ginzburg – type phenomenological approach[7,8]. Type I and type II smectics are analyzed for 1st order and 2nd order nematic-smectic A phase transitions. In studying edge dislocations we consider a herringbone[9] pattern of smectic layers, where we vary the angle characterizing the bend-type smectic distortion. In studying screw dislocations we consider twist-grain-boundary SmA (TGB_A) phase. For both cases we determine critical conditions for which lattices of TDs are stabilized. Furthermore, we analyze impact of appropriate trapped nanoparticles on stability of these patterns, emphasizing the role of the *Defect Core Replacement* (DCR) mechanism[7] and LC elastic properties. The former mechanism describes the reduction of relatively costly condensation free energy penalty by partially replacing the defect core with the nonsingular volume of a trapped nanoparticle. This mechanism is efficient if NPs do not significantly disrupt the defect core structure. We show that in case of screw dislocation the so called saddle-splay elasticity also plays significant role.

References:

[1] T. W. B. Kibble, *Topology of cosmic domains and strings*, J. Phys. A **9**: 1387 (1976).

[2] A. A. Abrikosov, *The magnetic properties of superconducting alloys*, J. Phys. Chem. Solids **2**: 199 (1957).

[3] I. Chuang *et al.*, *Cosmology in the Laboratory: Defect Dynamics in Liquid Crystals,* Science **251**: 1336 (1991).

[4] R. Repnik *et al.*, *Symmetry breaking in nematic liquid crystals: analogy with cosmology and magnetism*, J. Phys.: Condens. Matter, **25**: 404201 (2013).

[5] S.R. Renn, and T.C. Lubensky, *Abrikosov dislocation lattice in a model of the cholesteric to smectic-A transition*, Phys. Rev. A **38**, 2132 (1988).

[6] G. Cordoyiannis *et al*, *Different modulated structures of topological defects stabilized by adaptive targeting nanoparticles*, Soft Matter, **9**: 3956 (2013).

[7] S. Kralj and T.J. Sluckin, *Core structure of a screw disclination in smectic A liquid crystals*, Phys. Rev. E **49**: R3244 (1993).

[8] M. Slavinec *et al.*, *Surface depinning of smectic A edge dislocations*, Phys. Rev. E **63**: 031705 (2001).

[9] R. Wang *et al*, *Bend-Induced Melting of the Smectic-A Phase: Analogy to a Type-I Superconductor* Phys. Rev. Lett. **97**: 167802 (2006).

---

* presenting author; E-mail: uros.jagi@gmail.com