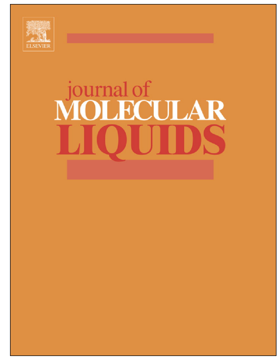

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Evaluation of Interactions between Liquid Crystal Films and Silane Monolayers by Atomic Force Microscopy

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Abstract

Atomic force microscopy (AFM) has been used to study forces of intermolecular interactions in two different types of liquid crystal (LC) systems (thermotropic and lanthanide-containing lyotropic ones) with different supramolecular organization and degrees of surface hydrophilization in relation to self-associated silane monolayers on a cantilever probe. Statistical analysis has been applied to the force curves to determine adhesion between liquid crystals and monoassociated layers of trichlorododecylsilane and (3-mercaptopropyl)trimethoxysilane on silicon. The results have been analyzed within the framework of hydrophilic and hydrophobic interactions and compared to the free surface energy values calculated by the Owens, Wendt, Rabel and Kaelble method. Lanthanide-containing liquid crystals demonstrate high value of adhesion work to monoassociated silane monolayers due to their considerable free surface energy. The method of chemical force microscopy (CFM) is found to be applicable to the direct determination of the adhesion force of liquid crystals.

Keywords: atomic force microscopy, liquid crystals, lanthanum ion, self-associated monolayers, adhesion

1. Introduction

Application of liquid crystal systems as molecularly organized matrices is an important approach to the synthesis of polyfunctional materials with controlled morphology [1-3]. Development of hybrid organic-inorganic materials is accompanied by the creation of nano- and mesoporous structures with the use of liquid crystal templates [4-6]. Lanthanide-based hybrid organic-inorganic materials with optic, magnetic and catalytic properties attracted strong interest for about a decade [7-9]. Lanthanide ions have narrow emission band and high luminescence quantum yield, their emission range covers electromagnetic spectrum from the UV area to the visible and near-infrared ranges. Lanthanide ions containing mesophases are attractive in this respect due to their unique magnetic and optical behavior [10-14]. In our studies, we developed an approach to the synthesis of hybrid lanthanide-containing materials with efficient luminescence. In our previous work, we discussed the relationship of luminescence and self-assembly of LLC [15]. On this basis, we developed hybrid luminescent films with red, green and yellow emission [16]. An important aspect of the synthesis of highly efficient hybrid luminescent materials is the characterization of intermolecular interactions between a silicate precursor and a lyotropic lanthanide-containing matrix. One of unique modern methods which allow estimating such interactions is the modified atomic force microscopy method: a chemical force microscopy. The key idea of this method is the chemical modification of a probe: formation of self-assembled monolayers (SAM) of organic molecules on a cantilever. It allows studying intermolecular interactions with a substrate surface (such as biomolecules or a polymer matrix) on a nanometer level, analyzing adhesion, and modeling mechanisms of various processes [17-21]. This method is used to a wide extent in cellular biology for studying cytological structures and their functioning mechanisms via physicochemical properties of their surfaces [22-23]. In general, AFM method is a fundamental tool for estimating intermolecular interactions between self-associated monolayers of silanes and the surface of liquid crystals as the models of self-organized intermolecular anisotropic media. At the same time, new data about intermolecular interactions in hybrid organic-inorganic systems is necessary to understand the mechanism of formation of luminescent hybrid materials.