example, for neutron diffraction. In this case, the crystals rarely withstand the treatment.

[5] Another conventional solution consists in depositing a film around the substrate to be protected using a composition comprising an ionic surfactant. This conventional solution is described in patent application WO 2007/132089 and involves liquid compositions in which the concentration of ionic surfactant is greater than or equal to the critical micelle concentration (CMC) of said surfactant. This conventional solution has been used to deposit a film comprising graphene and an ionic surfactant onto various types of substrates (Azevedo *et al.* ACS Applied Materials & Interfaces **7**(38) 21270-21277 (2015)), and in particular onto protein crystals (Wierman *et al.* Journal of Applied Crystallography **46**, 1501-1507 (2013)). Although the film of graphene and ionic surfactant can protect the protein crystal against air, it is not sufficiently reliable since it may comprise holes.

Technical problem

[6] There is thus still a need for an effective solution for preserving protein crystals in order to be able to place them in an X-ray beam to study their three-dimensional structure.

[7] The inventors have, to their credit, found that this need can be met by means of a liquid composition comprising a neutral surfactant and a charged lamellar compound.

Summary

[7a] In one aspect, there is provided a process for depositing a film onto a substrate using a liquid composition, comprising the following steps:

a) formation of a film using the liquid composition,

b) placing the film in contact with the substrate, and

c) depositing the film on the substrate,

characterized in that

the liquid composition comprises a neutral surfactant and a charged lamellar compound,

the liquid composition is obtained by mixing the charged lamellar compound with the neutral surfactant, and

the concentration of neutral surfactant before mixing with the charged lamellar compound is less than the critical micelle concentration (CMC) of said surfactant.

[7b] In another aspect, there is provided a process for analyzing a substrate onto which a film is deposited, comprising the steps of the process of depositing a film as defined above and a step d) of analyzing the substrate onto which a film is deposited.

[7c] In another aspect, there is provided a liquid composition comprising a neutral surfactant and a charged lamellar compound is provided, in which:

- the neutral surfactant is chosen from a nonionic surfactant, a zwitterionic surfactant, an amphoteric surfactant and mixtures thereof, and
- the charged lamellar compound is chosen from a lamellar clay, a lamellar hydroxide, a lamellar double hydroxide, $H_{3(1-x-y-z)}Li_{3x}Na_{3y}K_{3z}Sb_3P_2O_{14}$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, $H_{(1-x-y-z)}Li_xNa_yK_zSbP_2O_8$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, a lamellar oxide, a lamellar perovskite, a lamellar phosphate, a lamellar sulfide, a lamellar halide, a lamellar carbide and mixtures thereof,

the liquid composition being obtainable by mixing the charged lamellar compound with a solution comprising the neutral surfactant, the concentration of neutral surfactant in this solution being less than the critical micelle concentration (CMC) of said neutral surfactant.

[8] Thus, a first example of the disclosure is a process for depositing a film onto a substrate using a liquid composition, comprising the following steps:

a) formation of a film using the liquid composition,

b) placing the film in contact with the substrate, and

c) depositing the film on the substrate,

characterized in that

the liquid composition comprises a neutral surfactant and a charged lamellar compound.

[9] Advantageously, the liquid composition comprising a neutral surfactant and a charged lamellar compound makes it possible to form a film which effectively protects the substrate, in particular a protein crystal, onto which said film is deposited via the process according to the disclosure. Indeed, a protein crystal onto which a film is deposited via the process

according to the disclosure does not degrade in the open air for a period of more than one month, whereas a protein crystal onto which no film is deposited degrades within a few minutes.

[10] In contrast with cryogenics, the film deposited onto a protein crystal via the process according to the disclosure does not change the solubility of said protein crystal, does not destroy said protein crystal and does not change either the structure or the conformation of the protein.

[11] Furthermore, the film deposited onto a protein crystal via the process according to the disclosure does not impair the quality of the analyses that can be performed on said crystal. For example, the film does not give rise to background noise which reduces the quality of the data recorded during these analyses.

[12] The process of the disclosure is also suitable for protecting large protein crystals, which, once the film has been deposited, can be analyzed by neutron diffraction.

[13] According to another example, a process is provided for analyzing a substrate onto which a film is deposited, comprising the steps of the process of depositing a film onto a substrate using a liquid composition and a step d) of analyzing the substrate onto which a film is deposited.

[14] According to another example, a liquid composition comprising a neutral surfactant and a charged lamellar compound is provided, in which:

- the neutral surfactant is chosen from a nonionic surfactant, a zwitterionic surfactant, an amphoteric surfactant and mixtures thereof, and
- the charged lamellar compound is chosen from a lamellar clay, a lamellar hydroxide, a lamellar double hydroxide, $H_{3(1-x-y-z)}Li_{3x}Na_{3y}K_{3z}Sb_3P_2O_{14}$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, $H_{(1-x-y-z)}Li_xNa_yK_zSbP_2O_8$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, a lamellar oxide, a lamellar perovskite, a lamellar phosphate, a lamellar sulfide, a lamellar halide, a lamellar carbide and mixtures thereof.

Brief description of the drawings

Fig. 1

[15] [Fig. 1] shows a device for performing the process according to the invention.

Claims

[Claim 1] A process for depositing a film onto a substrate using a liquid composition, comprising the following steps:

a) formation of a film using the liquid composition,

b) placing the film in contact with the substrate, and

c) depositing the film on the substrate,

characterized in that

the liquid composition comprises a neutral surfactant and a charged lamellar compound,

the liquid composition is obtained by mixing the charged lamellar compound with the neutral surfactant, and

the concentration of neutral surfactant before mixing with the charged lamellar compound is less than the critical micelle concentration (CMC) of said surfactant.

[Claim 2] The deposition process as claimed in claim 1, in which the neutral surfactant is chosen from a nonionic surfactant, a zwitterionic surfactant, an amphoteric surfactant and mixtures thereof.

[Claim 3] The deposition process as claimed in claim 2, in which the neutral surfactant is a nonionic surfactant chosen from an ethoxylated alcohol, an ethoxylated alkylphenol, an ethoxylated fatty acid, an ethoxylated monoalkanolamide, an ethoxylated sorbitan ester, an ethoxylated amine, a glycol ester, a glycerol ester, a polyglycerol ester, a sorbitol ester, a glucoside, a polyglucoside, a sucrose ester, an amine oxide, a block copolymer including at least one amphiphilic block, and mixtures thereof.

[Claim 4] The deposition process as claimed in claim 3, in which the nonionic surfactant is a block copolymer including at least one amphiphilic block chosen from fluoro unit blocks, biological unit blocks, dendrimer unit blocks and poly(alkylene oxide) unit blocks.

[Claim 5] The deposition process as claimed in any one of claims 1 to 4, in which the charged lamellar compound is chosen from a lamellar clay, a lamellar hydroxide, a lamellar double hydroxide, $H_{3(1-x-y-z)}Li_{3x}Na_{3y}K_{3z}Sb_3P_2O_{14}$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, $H_{(1-x-y-z)}Li_xNa_yK_zSbP_2O_8$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, a lamellar oxide, a lamellar perovskite, a lamellar phosphate, a lamellar sulfide, a lamellar halide, a lamellar carbide and mixtures thereof.

[Claim 6] The deposition process as claimed in any one of claims 1 to 5, in which the substrate is an organic substrate or an inorganic substrate.

[Claim 7] The deposition process as claimed in claim 6, in which the organic substrate is chosen from a polymer, biological material, an organic semiconductor and an organic light-emitting diode.

[Claim 8] The deposition process as claimed in claim 6, in which the inorganic substrate is chosen from a ceramic, an aluminum oxide, a silicon substrate, a semiconductor material, a metal and a light-emitting diode.

[Claim 9] The deposition process as claimed in any one of claims 1 to 8, in which the neutral surfactant is a compound of formula $(PEO)_w$-$(PPO)_y$-$(PEO)_z$ in which w is between 5 and 300 and y is between 33 and 300 and z is between 5 and 300, the charged lamellar compound is $H_{3(1-x-y-z)}Li_{3x}Na_{3y}K_{3z}Sb_3P_2O_{14}$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $x+y+z = 1$ and the substrate is a protein crystal.

[Claim 10] The deposition process as claimed in any one of claims 1 to 9, in which steps a) to c) are repeated.

[Claim 11] A process for analyzing a substrate onto which a film is deposited, comprising the steps of the process of depositing a film as defined in any one of claims 1 to 10 and a step d) of analyzing the substrate onto which a film is deposited.

[Claim 12] A liquid composition comprising a neutral surfactant and a charged lamellar compound, in which:

- the neutral surfactant is chosen from a nonionic surfactant, a zwitterionic surfactant, an amphoteric surfactant and mixtures thereof, and
- the charged lamellar compound is chosen from a lamellar clay, a lamellar hydroxide, a lamellar double hydroxide, $H_{3(1-x-y-z)}Li_{3x}Na_{3y}K_{3z}Sb_3P_2O_{14}$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, $H_{(1-x-y-z)}Li_xNa_yK_zSbP_2O_8$ with $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 0.5$ and $0 \leq x+y+z \leq 1$, a lamellar oxide, a lamellar perovskite, a lamellar phosphate, a lamellar sulfide, a lamellar halide, a lamellar carbide and mixtures thereof,

the liquid composition being obtainable by mixing the charged lamellar compound with a solution comprising the neutral surfactant, the concentration of neutral surfactant in this solution being less than the critical micelle concentration (CMC) of said neutral surfactant.

[Claim 13] The liquid composition as claimed in claim 12, in which the neutral surfactant is a nonionic surfactant chosen from an ethoxylated alcohol, an ethoxylated alkylphenol, an ethoxylated fatty acid, an ethoxylated monoalkanolamide, an ethoxylated sorbitan ester, an ethoxylated amine, a glycol ester, a glycerol ester, a polyglycerol ester, a sorbitol ester, a

glucoside, a polyglucoside such as an alkyl polyglucoside, a sucrose ester, an amine oxide such as lauryldimethylamine oxide, or a block copolymer including at least one amphiphilic block.

[Claim 14] The liquid composition as claimed in claim 13, in which the nonionic surfactant is a block copolymer including at least one amphiphilic block chosen from fluoro unit blocks, biological unit blocks, dendrimer unit blocks and poly(alkylene oxide) unit blocks.