THIN COLLOIDAL CRYSTALS: STRUCTURES AND OPTICAL PROPERTIES

B. Pansu, P. Piera_ski

To cite this version:


HAL Id: jpa-00224643
https://hal.archives-ouvertes.fr/jpa-00224643
Submitted on 1 Jan 1985

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
THIN COLLOIDAL CRYSTALS: STRUCTURES AND OPTICAL PROPERTIES

B. Pansu and P. Pierański

Laboratoire de Physique des Solides, Université de Paris-Sud, Bât. 510, 91405 Orsay, France

Résumé - Quand on confine des cristaux colloïdaux dans un coin de faible épaisseur, on observe une série de transitions structurelles : le nombre de couches mais aussi leur structure cristalline varient. Parce que l'indice de réfraction varie dans l'espace, les cristaux colloïdaux minces se comportent optiquement comme des réseaux de phase et présentent des couleurs vives.

Abstract - When colloidal crystals are confined in a narrow wedge shaped gap between a pair of glass flats, we observe a series of structural transitions. These transitions consist in a change in the number of layers and also in their crystalline structure. Because the refractive index varies in space, thin colloidal crystals optically act as phase gratings and show very bright colors.

Colloidal crystals present many advantages for research on two-dimensional systems. Thanks to specific interactions of the polymeric particles with glass surfaces, it is possible to trap one or a few layers of these particles, in aqueous suspension, in a narrow wedge shaped gap between a pair of glass flats. The observation of the microscopic structure of thin colloidal crystals is easy with an optical microscope and scattering of a laser beam is a good tool to study local order /1/.

In our experiments /2/, a three dimensional reservoir of colloidal suspension imposed in the wedge a high enough pressure so that the spheres were organized into crystalline layers parallel to the glass surfaces. We used suspensions of monodisperse polystyrene balls of diameter \( \phi = 1.1 \) \( \mu \)m in water purified by ionic exchange resins. For these balls, the three dimensional crystalline structure is fcc. The available thickness D of the wedge varied linearly in space from a few to \( 10^5 \) \( \AA \). Samples were lit with white, non polarized parallel light and observed using a transmission optical microscope. We observed a series of colored strips parallel to the edge of the wedge /2/. The first strip corresponded to a monolayer of spheres organized in a 2D hexagonal network. As the gap thickness increased, new strips appeared. Their structure was determined with higher magnification objectives. The second strip corresponded to a stack of two layers with a 2D square structure. The third one corresponded to a stack of two layers with a 2D hexagonal structure. As the gap thickness increased, the series of structures we observed was:

\[ 1\Delta - 2\Theta - 2\Delta - 3\Theta - 3\Delta - 4\Theta - 4\Delta - 5\Theta - 5\Delta - \ldots \]

where a stack of n square (resp hexagonal) layers is written \( n\Theta \) (resp \( n\Delta \)). The existence of such a series has been explained in terms of packing efficiency /3/ : the pressure at the bottom of the tube imposed in the wedge structures of maximum volume density. For some intervals of the gap thickness, the square packing (\( \Theta \)) becomes more dense than the hexagonal one (\( \Delta \)).

Using a low aperture objective, each strip associated with each structure showed very bright colors (a color photograph is shown in ref /4/ figure 43). The color was uniform in the strips \( n\Theta \), \( 1\Delta \) and \( 2\Delta \). On the contrary the strips \( n\Delta \) (\( n \geq 3 \)) were composed of domains of m different colors : \( m = 2 \) for \( 3\Delta \), 3 for \( 4\Delta \) ... We noticed that in all the samples one of the color of the strip \( n\Delta \) is similar to the unique color of the strip \( n\Theta \). The existence of these colors may be explained by the difference in the refractive index of polystyrene (\( n_2 = 1.59 \)) and water (\( n_1 = 1.33 \)). Because...
the difference between $n_2$ and $n_1$ is small, light rays are supposed to propagate without deviation. An optical ray which crosses a sphere suffers a phase shift compared to a ray which propagates only through water. The spectrum (therefore the color) of the transmitted light depends on the phase shifts suffered by the rays. The strip $3\Delta$ for instance is composed of two types of domains: ABA and ABC. In these stacks, the number of spheres crossed by the light is different: the colors are different. On the contrary there is only one type of stack in the strip $3\Box (ABA)$ then its color is the uniform. As we are concerned with forward scattering and normal incidence, this color is similar to the color of the domains ABA in the strip $3\Delta$.

In conclusion, this experiment has revealed that in a wedge geometry thin colloidal crystals show a series of structural transitions which consists in a change in the number of crystalline layers and in their bidimensional structure. From an optical point of view, they act as phase gratings.

REFERENCES

/1/ RUTH J., Oral communication at the Workshop on Colloidal Crystals, Les Houches (1984)
/2/ PANSU B., PIERAŃSKI P., STRZELECKI L., J. Physique 44 (1983)