Biolin Scientific
[Progress Together]

KSV NIMA | [Application Overview] 1

Fabricating Highly Organized Nanoparticle Thin Films

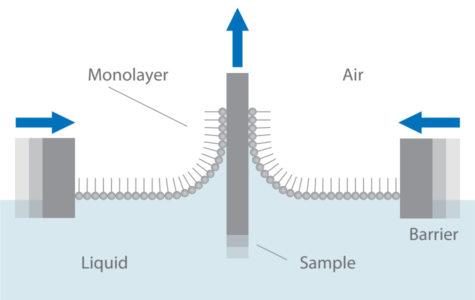
This Application Overview describes how the Langmuir-Blodgett (LB) technology is used to fabricate highly organized mono- and multilayer nanoparticle films.

Introduction

Nanoparticles and thin films made from nanoparticles are gaining recognition and use in various products and applications including displays, sensors and energy storage. These types of products often require well-controlled particle organization, density and film thickness to achieve optimal performance and efficiency.

Techniques that enable such control and precision during thin film formation are critically important in the development of new nanoparticle-based materials. Common methods to fabricate these types of thin films include transfer printing and spin, spray and dip-coating methods. However, these methods do not enable the necessary control over packing density or particle organization on the surface. Additionally, vacuum based methods, such as chemical vapor deposition and atomic layer deposition enable control over particle organization but are often limited to specific substrates and carry a high cost due to the required ultra-high vacuum conditions.

The Langmuir-Blodgett deposition method offers a combination of controlled deposition, a wide range of substrates and usability in ambient conditions. In an LB deposition process (Figure 1), a nanoparticle suspension is first deposited at the air/water interface, then, the resulting film is compressed to the desired surface pressure and particle density and then transferred onto a solid substrate by dipping the substrate into and through the particle layer. The deposition can then be repeated to fabricate alternating layer structures or performed at different speeds and temperatures.



[Figure 1]: Langmuir-Blodgett Deposition.

Application Examples

Graphene

Graphene is an attractive material in a number of different applications, primarily because of its flexibility and its unique electron transport properties, but also for applications that require high layer integrity, such as protective layers for molecular electronics [1-3].

One specific example describes how multilayers of graphene oxide sheets can be deposited on silicon, glass, quartz and mica substrates using the LB technology [3]. Detailed characterization showed that the films were relatively smooth, had a uniform graphitic structure with low defects, a transparency of 90%, and presented low sheet resistances of 460 ohm/square. The results were better than those obtained using other deposition techniques such as chemical vapor deposition, transfer printing and spin, spray or dip coating. The deposition parameters and application areas are summarized in Table 1.

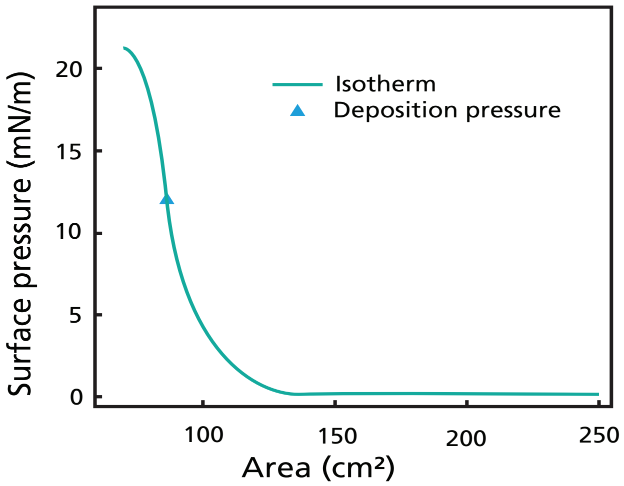
Type	Speed [mm/min]	SP [mN/m]	GO Structure	Applications
Small GO	0.1-1.0	any	flat	nanoelectronics
Large GO	0.1	0-15	flat	nanoelectronics
Large GO	0.1	>20	wrinkled	GO nanoribbons
Large GO	1.0	>20	wrinkled	H_2 storage

[Table 1]: Various graphene oxide (GO) structures obtained at different pulling speeds and surface pressures. Small GO = several square micrometers, Large GO = 1 to 10 000 μm^2. Adapted with permission from ACS Nano 2011, 5 (7), pp 6039-6051. Copyright 2011 American Chemical Society.

Metals and semiconductors

Nanoparticles of metal oxides, carbon nanotubes and quantum dots are used in various applications, such as photovoltaics, displays and sensors. The efficient use of these materials in electronic applications requires their assembly into well-defined mono- or multilayer films and the LB technique has been successfully demonstrated in such film formation [4-5].

An example study describes the deposition of CdSe-nanocrystals that were compressed to a surface pressure of 12 mN/m for deposition and transferred onto glass/silicon substrates using horizontal Langmuir-Shaefer deposition as mono- and multilayers of Fe_3O_4/CdSe [5]. Figure 2 displays the surface pressure - area isotherm obtained during compression. The transferred monolayers were found to be homogenous and free of microscopic voids over their entire area and presented high structural integrity in that the resulting films did not rearrange or crack.

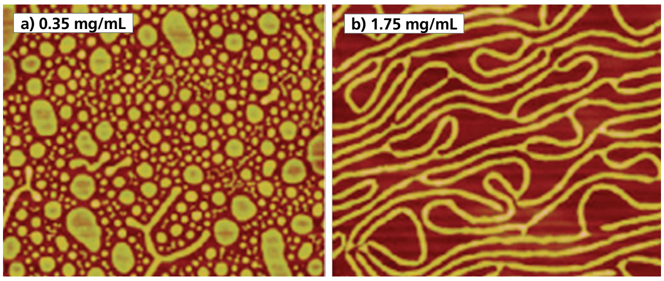


[Figure 2]: The isotherm of CdSe quantum dot suspension spread on a water surface. Adapted with permission from Langmuir 2010, 26 (11), pp 7732-7736. Copyright 2010 American Chemical Society.

Polymers and silica

Polymers, nanoparticles and nanocomposite materials are widely used in numerous products in industry, coatings, filtration devices, etc. Transferring a Langmuir film of polymers and silica onto a desired substrate has been used to fabricate for example porous structures, close-packed dense silica layers and resists for nanolithographic patterning [6].

An example study describes the deposition of block copolymers of polystyrene-b-poly(4-vinyl pyridine)/3-n-pentadecylphenol (PS-P4VP/PDP) in different solvents on hydrophilic mica substrates using the LB technique [6]. Depending on the deposition conditions, the nanostructured polymers were found to organize in long elongated ribbons. Figure 3 presents the nanostrand formation for low spreading concentrations (Figure 3a) and high spreading concentrations (Figure 3b). Higher concentrations resulted in an ordered nanostrand network.



[Figure 3]: AFM height images of LB monolayers of PS-P4VP/PDP formed at 20°C from chloroform solutions at copolymer concentrations of a) 0.35 mg/ml and b) 1.75 mg/ml and transferred to mica at a surface pressure of 10 mN/m. Adapted with permission from ACS Nano 2010, 4 (11), pp 6825-6835. Copyright 2010 American Chemical Society.

Summary

Langmuir-Blodgett and Langmuir-Schaefer deposition has been shown to be an excellent way to deposit nanoparticles onto substrates. For more information on the available Langmuir-Blodgett Troughs, visit www.biolinscientific.com/ksvnima.

References:

[1] Li, X., et al. Nature Nanotech. 2008, 3, 538-542
[2] Kim, J., et al. J. Am. Chem. Soc. 2010, 132, 8180-8186
[3] Zheng, Q., et al. ACS Nano 2011, 5, 6039-6051
[4] Giancane, G., et al. Adv. Funct. Mater. 2010, 20, 2481-2488
[5] Lambert, K., et al. Langmuir 2010, 26, 7732-7736
[6] Perepichka, I. I., et al. ACS Nano 2010, 4, 6825-6835.

Biolin Scientific
[Progress Together]

E-mail:info@biolinscientific.com
biolinscientific.com