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Fabrication of Supports for Carbon Fullerenes Hard Disk Unit

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Abstract

We prepared nanostructured films of fullerenes C_{60} in different thicknesses by assembling 1 to 3 monolayers by means of Langmuir-Schaefer technique. We obtained the stock solutions by dissolving the fullerenes C_{60} in toluene and then spreading at the air/water interface. The study of pressure-area isotherms showed a surface pressure of 40 mN/m as the best value for the deposition of monolayers. We also used the isotherms to determine the area per molecule parameter during the compression process; at the condensation point on packaging the C_{60} molecules we reached a value of 50 Å^2/molecule, highlighting the formation of agglomerates of fullerenes upon compressing, confirmed by the study of scanning electron microscope acquisitions. We deposited monolayers on different substrates in order to characterize the morphology, and the conductivity of fullerenes C_{60} nanoassembled with the future goal to construct hard disk units.

Keywords: SSD memories; Surface morphology; Scanning electron microscope; Conductivity

Introduction

Flash memories are nowadays widely used in electronics devices due to their versatile features such as non-volatility, solid-state reliability, low power consumption, and shock resistance [1].

The most popular types of flash memory are NOR and NAND, respectively. Even though NOR flash memory offers random access capability and high read performance, it has the disadvantage of low write and erase performance along with more expensive prices per MB than NAND flash memory. On the contrary, NAND flash memory are able to provide high cell densities and lower cost per MB besides more performed write and erase capability than NOR flash memory. On taking into account the properties so far described, NOR flash memory matches the requirements for code storage and execute-in-place (XIP) applications, while NAND flash memory is more suitable for data storage [2].

Nowadays any mobile devices such as MP3 players, PDAs (personal digital assistants), PMPs (portable media players), high-resolution digital cameras, and mobile phones, need large capacity and high-performance storage systems in order to store, retrieve, and process large multimedia data quickly and in these devices, NAND flash memory is already becoming a common storage medium. Furthermore, solid-state disks (SSDs) based on NAND flash memory technology, such as M-System's FFDs (Fast Flash Disks) and BiTMICRO's E-Disks, are gradually replacing mechanical hard disks under mission-critical and/or rugged operating conditions, above all in military and aerospace industries. Since NAND flash technology development continues to double density growth on an average of every 12 months [1], it is expected that sub-notebook computers or tablet PCs equipped with more than tens of Gigabytes of NAND flash memory-based storage system will be available to ordinary users in the near future.

Although the use of hard disks with NAND flash memory is advantageous in terms of size, weight, reliability, and energy use, it is not easy to obtain the maximum performance from this kind of devices due to its unique operational characteristics since in NAND flash memory, the write operation requires a relatively long latency compared to the read operation. Furthermore, the previous data must undergo an erasing process in order to write another data in the same physical area. The worst problem is that the erasing operation cannot be performed on the particular data selectively, but on the larger unit containing the original data with much longer latency. The MLC (Multi-Level Cell) technology, which has been introduced recently to multiply the capacity of a NAND flash memory chip, causes a decrement in the operation speed [3]. Thus, the development of a high-performance NAND flash-based storage system remains a technically challenging area.

The main idea of our work is therefore the possibility of using "molecular" material for the fabrication of substrates to use in the field of SSDs flash memories. As "molecular" material, we took into account fullerenes C_{60} molecules to employ such molecules as single cell transistors, studied and characterized with different methods of investigation in order to assess their possible application for the fabrication of SSDs NAND flash-based storage systems [4]. Among the different kind of available molecules, we used fullerenes C_{60} since they are the most common and studied along with their easy possible functionalization, important characteristics that make them the best candidates for the development in the light of their possible applications for hard disk unit [5].

Experimental Section

Study of pressure-area isotherms

We fabricated Langmuir-Schaefer (LS) films in a Langmuir–Blodgett trough (MDT Corp., Russia) 240 mm×100 mm in size and 300 ml in volume at a compression speed of 0.50 mm/s, maintaining a surface pressure of 40 mN/m at the air–liquid interface. We obtained the fullerenes C_{60} spreading solutions by dissolving 20 mg of materials in 20 ml of toluene, and for the deposition, we used distilled water as sub-phase. We also utilized the Langmuir–Blodgett trough to study the

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surface pressure-area isotherms of fullerenes C_{60} by spreading on the liquid sub-phase previously described. Surface pressure-area isotherms, π-A isotherms or simply isotherms can be defined as a measurement, at constant temperature, of the surface pressure as a function of the available area per each molecule in a floating monolayer (Langmuir film). We thus employed the surface pressure-area isotherms to calculate the related area per molecule value in order to verify the possible formation of agglomerates (clusters) by the condensation of several C_{60} molecules during the compression process.

Study of the morphology of deposited films

We used a scanning electron microscope FESEM-Carl Zeiss model SUPRA 40 VP, operating with an electronic beam at a 5 KV in order to achieve a resolution of 20 nm. For the analysis of the morphology of the nanoassembled we deposited three monolayers on apposite cupper-graphite substrates having a diameter of 2 mm. We performed the deposition process by using the same experimental parameters described in the previous section.

Figure 1: Illustration of the set up device obtained from a substrate of glass with gold contacts on both sides. The gold contacts were directly connected to the electrometer to collect V/I characteristics of fullerenes C_{60} nanoassembled.

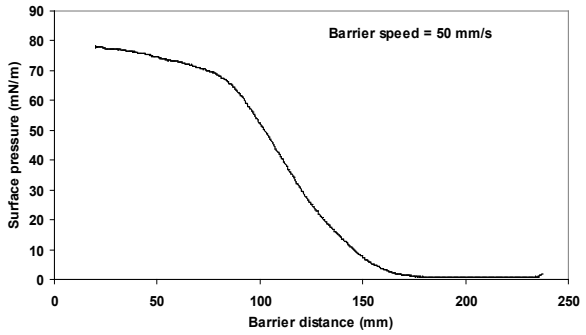

Figure 2: The π-A isotherm obtained by spreading a solution of fullerenes C_{60} in toluene having a concentration of 1000 ppm at the air/water interface, barrier speed 0.50 mm/s.

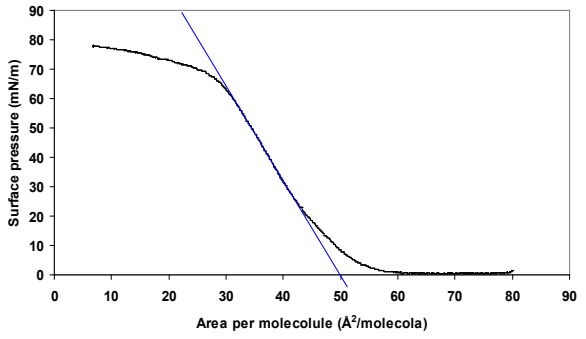

Figure 3: Calculation of the area per molecule for a solution of fullerenes C_{60} in toluene having a concentration of 1000 ppm, obtained by considering the intercept on the abscissa of the best fitting of the compression curve.

Measurement of conductivity

We carried out conductivity tests on fullerenes C_{60} nanoassembled by using an experimental set up obtained from a substrate of glass with gold contact on both sides as shown in Figure 1. The distance between gold contacts was 2 cm and each contact had a length of 1 cm. Therefore, the total area of the deposited films was 2 cm^2.

We carried out the measurements of conductivity by basing on voltage/current (V/I) characteristics measured with an electrometer Keitley model 6517 connected to the gold contacts, driven by computer. For these measurements, we deposited 1 and 5 monolayers of nanocomposites onto the substrate and we collected the experimental data of current by applying a potential ranging between −10 V and 10 V at a sweeping rate of 0.1 V/s.

Results and Discussions

Study of pressure-area isotherms

The study of π-A isotherms was important to obtained the best surface pressure of deposition in order to fabricate nanoassembled from different number of monolayers of fullerenes C_{60}. The experimental data highlighted a surface pressure of 40 mN/m as the optimum for the deposition of monolayers as illustrated in Figure 2, where it is possible to observe the behavior of the fullerenes C_{60} molecules spread at the air/water interface during the compression process.

The π-A isotherms also allowed to assess the area per molecule value at the condensation point upon compressing. We obtained this value by considering the intercept on the abscissa of the best fitting of the compression curve, as shown in Figure 3.

We obtained a value of 50 $Å^2$/molecule (5 nm^2 per molecule), widely above the size of a fullerene C60 molecule estimated around 1.0 nm. The experimental data proved the fullerene C_{60} molecules tend to agglomerate in clusters during the compression process, probably due to an "overlapping" favored by the spherical shape with a nanometer-size diameter and the behavior of the solvent itself when spread at the air-liquid interface. These conclusions are supported by recent works demonstrating the aggregation trend of functionalized fullerene C_{60} molecules in relation to their peculiar size and shape, and the solvents used for the dissolution. This result suggests the compression process as well as the concentration of the spreading solution and the related solvent can play an important role to prevent the formation of clusters. In other words, the quality of fullerenes C_{60} substrates can be "tuned" by modulating the parameters of deposition.

Study of the morphology of deposited films

We carried out the morphology study after scanning the surface of a three monolayers thin film with an electron microscope, as shown in Figure 4.

The analysis of scansions at a resolution of 20 nm highlighted a highly globular-like homogeneous surface supporting the goodness of the deposition parameters previously described. Furthermore, from the observation of the scansion appears clearly visible the presence of agglomerations having a size approximately 5 to 8 nm, fully corroborating the experimental results obtained from the π-A isotherms. The analysis of films morphology suggests the possibility of using "tunable" chemical agent to obtain a better separation of fullerenes C_{60} molecules in order to achieve the best homogeneity in the globular-like feature of the deposited films surface.

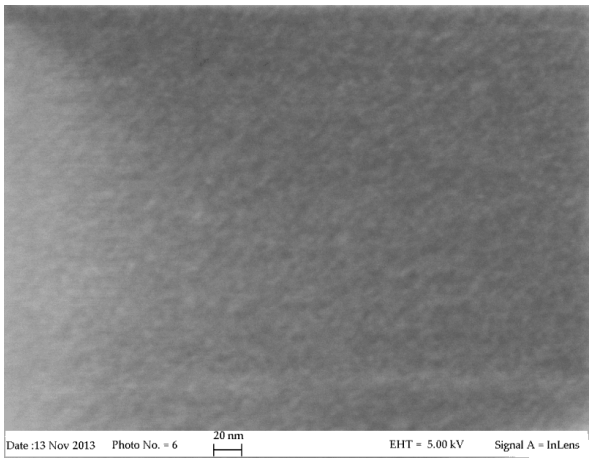

Figure 4: Study of the morphology from electron microscope FESEM scanning at 5.00 KV. The picture shows the formation of fullerenes C_{60} molecules clusters having a size varying 5 to 8 nm.

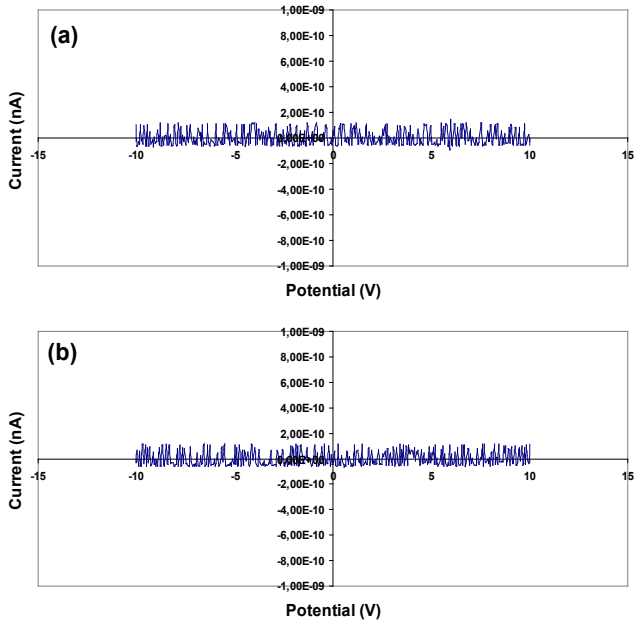

Figure 5: Fullerenes C_{60} thin films voltage/current (V/I) characteristics obtained for: a) 1 monolayer and b) 5 monolayers.

Measurement of conductivity

The study of V/I characteristics illustrated in Figure 5a and 5b, obtained from 1 and 5 monolayers, highlighted the non-conducting properties of fullerenes C_{60} molecules when assembled in thin films. Taking into account the thickness of films and its geometry, we calculated the specific conductivity (calculation not shown) by using the following equations:

$$V = R\,I \quad (1)$$

$$R = \rho\, l\, s^{-1} \quad (2)$$

Where the potential 'V', the current 'I' and the resistance 'R' is determined experimentally, 'l' is the length of the deposited film and s is the related section.

We determined a specific conductivity of 2.0×10^{-3} s/cm for 1 monolayer and 1.8×10^{-3} s/cm for 5 monolayers, respectively.

The experimental data always showed that the increment of the number of monolayers deposited upon the substrate slightly decreased the specific conductivity. This result can be attributed to the insulator properties of the fullerenes C_{60} molecules. In fact, for very thin films (1 nm in thickness), the close vicinity to the substrate can determine the slight increment of the conductivity due to the presence of some defects resulted from the interaction of the monolayers with the substrates.

Conclusion

We utilized the Langmuir-Schaefer technique to fabricate nanostructured films by spreading at the air/water interface stock solutions of fullerenes C_{60} in toluene. We carried out pressure-area isotherms in order to optimize the value of surface pressure for the deposition of monolayers, turned out to be 40 mN/m, and to determine the behavior of the area per molecule parameter during the compression process. We found at the condensation point on packaging the C_{60} molecules a value of 50 $Å^2$/molecule (5 nm^2/molecule), five times above the average size of fullerene C_{60} molecule. This result is consistent with the formation of agglomerates (clusters) of fullerene molecules upon compressing. We also deposited monolayers on different substrates in order to characterize the morphology, and the conductivity of fullerenes C_{60} nanoassembled. The experimental data obtained from the FESEM acquisitions of films morphology corroborated the results from the area/molecule investigation since the surface highlighted the formation of globular-like areas 5 to nm in size. The V/I characteristics investigations highlighted non-conducting properties of fullerenes C_{60} films, also observing a small decrement in conductivity on increasing the number of monolayers on the substrate. We attributed this behavior to the insulator properties of the fullerenes C_{60} molecules and the close vicinity to the substrate for 1 monolayer, which determined the slight increment in conductivity due to the presence of some defects resulted from the interaction of the monolayer with the substrate itself. On considering these fullerenes C_{60} molecules for the fabrication of SSD memories as the final goal, the preliminary experimental data obtained from the characterization of these molecules sound very promising. It will be our future goal the "treatment" of fullerenes C_{60} molecules in order to make them "more tunable" during the deposition/compression process in order to avoid phenomena of clusters formation and reach the required smoothness for the fabrication of prototype SSD memories.

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References

1. Douglis F, Caceres R, Kaashoek F, Li K, Marsh B, et al. (1994) Storage alternatives for mobile computers. Proceedings of the First Symposium on Operating Systems Design and Implementation (OSDI-1): 25-37.
2. Park C, Seo J, Seo D, Kim S, Kim B (2003) Cost-efficient memory architecture design of NAND flash memory embedded systems. Proceedings of the 21st International Conference on Computer Design (ICCD'03): 474-480.
3. http://www.intel.com/design/flash/isf/overview.pdf
4. Bavastrello V, Nicolini C (2014) Memory Unit (Hard Disk) Based on Carbon Fullerenes. Patent GE2014A00005.
5. Nicolini C (2014) Molecular Bioelectronics. 2nd edtn, World Scientific Singapore, New York, USA.