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Research on Organic Resistive Memory Devices: Integration and Mechanism

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Abstract

Organic resistive memory devices in which active organic materials hold at least two stable resistance states have been extensively investigated. In this talk, I will present our group's recent research results on organic resistive memory devices. Specifically, I will explain orthogonal lithography which enables microscale integration of organic memory cells in the cross-bar architecture, and noise characteristics in relation with memory mechanism.

1. Introduction

Recently, polymer-based organic memory device has been considered to be promising candidate as next-information storage due to its advantages such as low cost, ease of fabrication, large-area processibility, material variety, flexibility, and printability of organic-based materials [1]. Although a lot of research progresses such as architectural advancement or enhancement of memory performance have been made [2,3], there are still several challenges in this field, for example, microscale integration with high memory cell density is required, memory performances need to be further improved, and memory mechanism needs to be understood better. In this talk, I will present a summary on our group research results on these topics. Specifically, I will explain (1) orthogonal lithography which enables microscale integration of organic memory cells in the cross-bar architecture and (2) noise characteristics in relation with memory mechanism.

2. Results and Discussion

2.1. Microscale integration of organic resistive memory

Organic memory devices have often been fabricated in a cross-bar structure, which can realize high integration of memory cells [2]. However, the cross-bar structured organic memory devices have usually been limited to be less than a hundred bits integration with the individual cell size of several hundreds of microns (μm). The conventional photolithographic patterning technique to scale down the devices is difficult to apply to organic electronics because of the chemical incompatibility between organic electronic materials and organic solvents for photolithographic processing. Organic solvents (e.g., the developer used in lithography or acetone) dissolve not only the photoresist but also the organic electronic materials. To overcome the lithographic problem in organic electronics, some groups, including ours, have demonstrated a chemically non-damaging orthogonal photolithographic method that allows to protect the underlying polymer organic films from the action of lithographic chemicals. One possible solution is to use fluorinated photoresist (such as semi-perfluoroalkyl resorcinarene) and solvents (such as hydrofluoroethers) which are miscible to each other and orthogonal to most organic materials. These materials allow organic electronic devices to be fabricated at the microscale using the photolithography process [4]. With this method, we demonstrated the microfabrication of highly-integrated 4K-bit (64 × 64 array) organic nonvolatile resistive memory devices with a 10 ×10 μm^2 cell size, made possible by using fluorinated photoresist and solvents to avoid damaging the underlying organic memory materials (see Figure 1) [5]. The fabricated organic memory devices exhibited a high ON/OFF ratio, stable switching characteristics, and excellent durability in terms of retention and endurance characteristics. Our devices showed a desirable operational uniformity and high device yield of operative memory distribution over the 4K-bit integration of organic memory devices. Furthermore, we demonstrated vertically stacked microscale organic memory devices [6].

2.2. Noise characteristics in organic nanocomposite resistive memory

Many studies on organic memory have focused on scientific and technical issues of the materials, device structures, switching mechanisms, and performance enhancement. However, because of the strongly disordered polymer structures, a consensus on the mechanisms of organic resistive memory has not been achieved. We studied noise properties

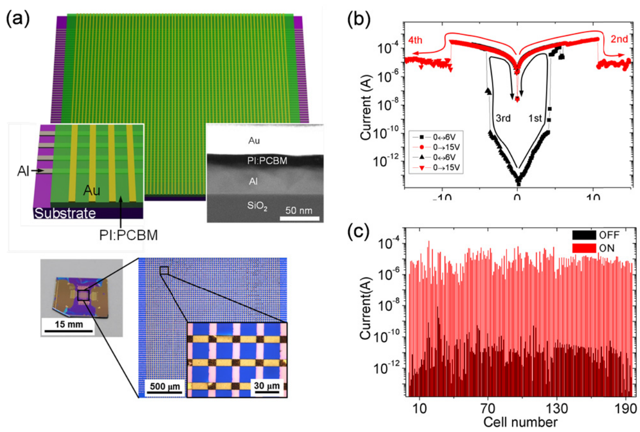

Fig. 1. (a) Schematic and images of 64 ×64 array (4 Kbit) microscale organic memory devices. (b) Representative memory data. (c) Cumulative probability of ON and OFF states from 195 measured memory cells. Results from Ref. [5].

of a nanocomposite of polyimide (PI) and phenyl-C61-butyric acid methyl ester (PCBM) (denoted as PI:PCBM), a composite for the organic nonvolatile resistive memory material [7]. The current fluctuations were investigated over a bias range that covers various intermediate resistive states and negative differential resistance (NDR) in organic nanocomposite unipolar resistive memory devices. From the analysis of the 1/f type noises, scaling behavior between the relative noise power spectral density and resistance R was observed, indicating a percolating behavior. Considering a linear rate equation of the charge trapping-detrapping at traps, the percolation behavior and NDR could be understood by the modulation of the conductive phase fraction with an external bias. This study can enhance the understanding of the NDR phenomena in organic nanocomposite unipolar resistive memory devices in terms of the current path formation and the memory switching. Furthermore, the noise scaling behavior from the intermediate resistance states (IRSs) and the telegraphic noise in NDR were investigated at a range of temperatures from 80 K to 300 K to observe the electronic dynamics, thereby enabling a better understanding of NDR and the IRSs in organic nanocomposite memory systems [8].

3. Conclusions

In this talk, I present our group research results on organic resistive nonvolatile memory devices, focusing on two topics: orthogonal lithography which enables microscale integration of organic memory cells in the cross-bar architecture. And, noise characteristics in relation with memory mechanism.

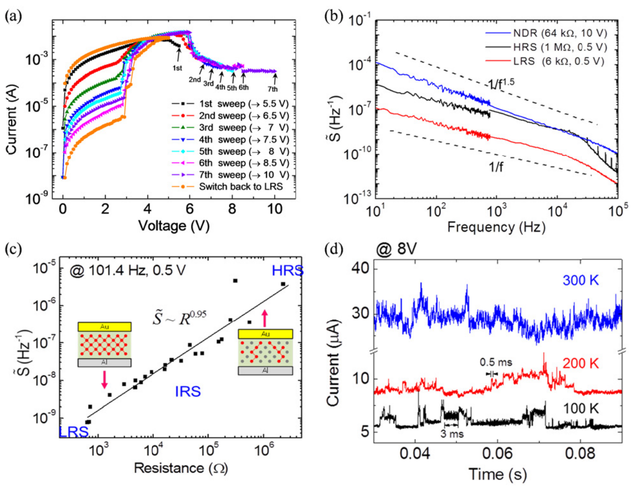

Fig. 2. (a) Intermediate resistance states. (b) 1/f noise analysis of organic nanocomposite memory. (c) Scaling behavior between relative power spectral density and resistance. (d) Telegraphic fluctuation is reduced at lower temperature and lower applied bias. Results from Ref. [7,8].

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