Ph.D. in Information Technology: Thesis Defense

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Bianca PASSARELLA – XXXIII Cycle

Transistors Based on Printed Polymers Operating at Radio-Frequencies

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Abstract:

Organic electronics has gained increasing attention from both the scientific community and industries, becoming a valuable enabler for new applications designed to satisfy the continuous demand for quality-of-life improvements and for the implementation of the "Internet of Things". Such a development is only possible thanks to the unique properties of organic materials, whose molecular structure can be tailored to fulfil desired electronic properties. In addition, high solubility of organic materials in a wide spectrum of common solvents is convenient since it allows the possibility to deposit them at low temperature on many different substrates and by techniques already exploited in the field of graphical arts, i.e. printing or coating. Thanks to their solution processability, indeed, the manufacturing processes become easier, less expensive and compatible with the use of flexible substrates and with large area fabrication techniques, a fundamental requirement for a cost- and energy-efficient production schemes. To employ organic materials in the production of complex circuits, the performances of the main building block, such as the transistor, have to be optimized. Many efforts have been spent to improve organic field-effect transistors performances, mainly in terms of charge mobility in polymer semiconductors. Thanks to these improvements in organics, also higher organic transistors' operational speed has been feasible. Improving transistors' operational speed would enable a wide spectrum of applications such as wireless sensors and Radio-Frequency Identification (RFID) based systems or the driving of high-resolution flexible displays. Transistor's operational speed can be estimated through several figures of merit, among which the transition frequency that is defined as the frequency at which the current gain, in short circuit condition, is equal to 1. As of now, the highest demonstrated transition frequency is 160 MHz, using an n-type organic field-effect transistor, fabricated on a rigid substrate by a combination of solution-processed and direct-writing techniques. Indeed, along with high operating frequency, cheap and energy efficient fabrication schemes are demanded to minimize production costs and enable mass production. To this aim, printing and direct-writing techniques represent ideal candidates, allowing ambient temperature, large area, sheet-to-sheet continuous production lines. In this work, n-type and p-type organic field-effect transistors have been fabricated on flexible substrates by a combination of solution-processed and a large-area compatible direct-writing techniques. This approach resulted in micron-scale patterning resolution, allowing transistor channel miniaturization, down to 1.2 µm. This up-scalable fabrication scheme yields a transition frequency of 11 MHz and 22 MHz for n-type and p-type organic field-effect transistors fabricated on flexible and transparent substrates. The frequency value obtained for the p-type polymer transistors makes this the fastest p-type solution-processed device fabricated on flexible substrates so far. The possibility to have both n-type and p-type OFETs working in the same range of frequency gives access to the fabrication of complementary electronics, which require low power consumption.

In spite of producing complementary electronics, a method to fabricate both p- and n-type OFETs on the same chip, sharing the same ambipolar organic semiconductor has been proposed. This was possible through contacts functionalization by different self-assembled monolayers (SAMs) and proper doping the ambipolar organic semiconductor by p- and n-type dopants, both deposited by directly inkjet-printing SAMs and dopants solutions on the desired contacts area. We demonstrated both n- and p- unipolarized devices with mobilities exceeding 0.1 cm2V-1s-1.

PhD Committee

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