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Large-scale electrohydrodynamic organic nanowire printing, lithography, and electronics

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Although the many merits of organic nanowires (NWs), a reliable process for controllable and large-scale assembly of highly-aligned NW parallel arrays based on "individual control (IC)" of NWs must be developed since inorganic NWs are mainly grown vertically on substrates and thus have been transferred to the target substrates by any of several non-individually controlled (non-IC) methods such as contact-printing technologies with unidirectional massive alignment, and the random dispersion method with disordered alignment. Controlled alignment and patterning of individual semiconducting NWs at a desired position in a large area is a major requirement for practical electronic device applications. Large-area, high-speed printing of highly-aligned individual NWs that allows control of the exact numbers of wires, and dimensions and their orientations, and its use in high-speed large-area nanolithography is a significant challenge for practical applications. Here we use a high-speed electrohydrodynamic organic nanowire printer to print large-area organic semiconducting nanowire arrays directly on device substrates in an accurately individually-controlled manner; this method also enables sophisticated large-area nanowire lithography for nano-electronics. We achieve an unprecedented high maximum field-effect mobility up to 9.7 $cm^2 \cdot V^{-1} \cdot s^{-1}$ with extremely low contact resistance ($<5.53\ \Omega \cdot$ cm) even in nano-channel transistors based on single-stranded semiconducting NWs. We also demonstrate complementary inverter circuit arrays consist of well-aligned p-type and n-type organic semiconducting NWs. Extremely fast nanolithography using printed semiconducting nanowire arrays provide a very simple, reliable method of fabricating large-area and flexible nano-electronics.