High Resolution E-skin System Based on Piezo-phototronic Effect

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Abstract: Functional tactile sensing device is a challenge for next-generation robotics and human-machine interfaces since the emulation of touching requires large-scale pressure sensor arrays with high-spatial resolution, high-sensitivity, and fast-response. Prof. Bao mainly studied the preparation of ultra-high resolution tactile sensor based on piezo-phototronic effect, and designed a real-time data acquisition and controlled feedback system of e-skin for intelligent robot applications. Her research on high resolution e-skin combine the advantages of organic-semiconductor and the piezo-phototronic effects of ZnO nanowires to solve the problem. The ZnO/p-polymer pn junction LED is used as the pixel point of pressure sensing. Obvious light emissions are observed from NW LEDs under pressure due to the piezo-phototronic effect. The pressure distribution on the whole device plane can be obtained by the light intensity distribution of nanowire arrays. Finely, a flexible pressure distribution sensor array with spatial resolution of 1.5 micron and optical signal sensing was fabricated. Meanwhile, replacing the pressure distribution of electrical signals with optical signals can instantaneously achieve large area and high integration of signal output and eliminate cross-interference. Moreover, in order to meet the needs of intelligent robots, she has studied the multi-function e-skin and designed a real-time reading/feedback controllable system for intelligent manipulator application. The prepared e-skin system applied to intelligent manipulator fingers, possess high sensitivity and a large range of detecting pressure. The sensors are located at different positions on the intelligent manipulator fingers to collect the force data at the pressure points. In the grip system, force distribution at each figure, different grip coefficient and material of the objects have been investigated and analyzed to achieve the intelligent operation of an artificial robotic manipulator. This type of intelligent manipulator with high-quality of the grip perception and grasping control will lead to stable and effective grasping and accomplishing the complex tasks.

1. Mapping Sensor Matrix by ZnO NW LED Array

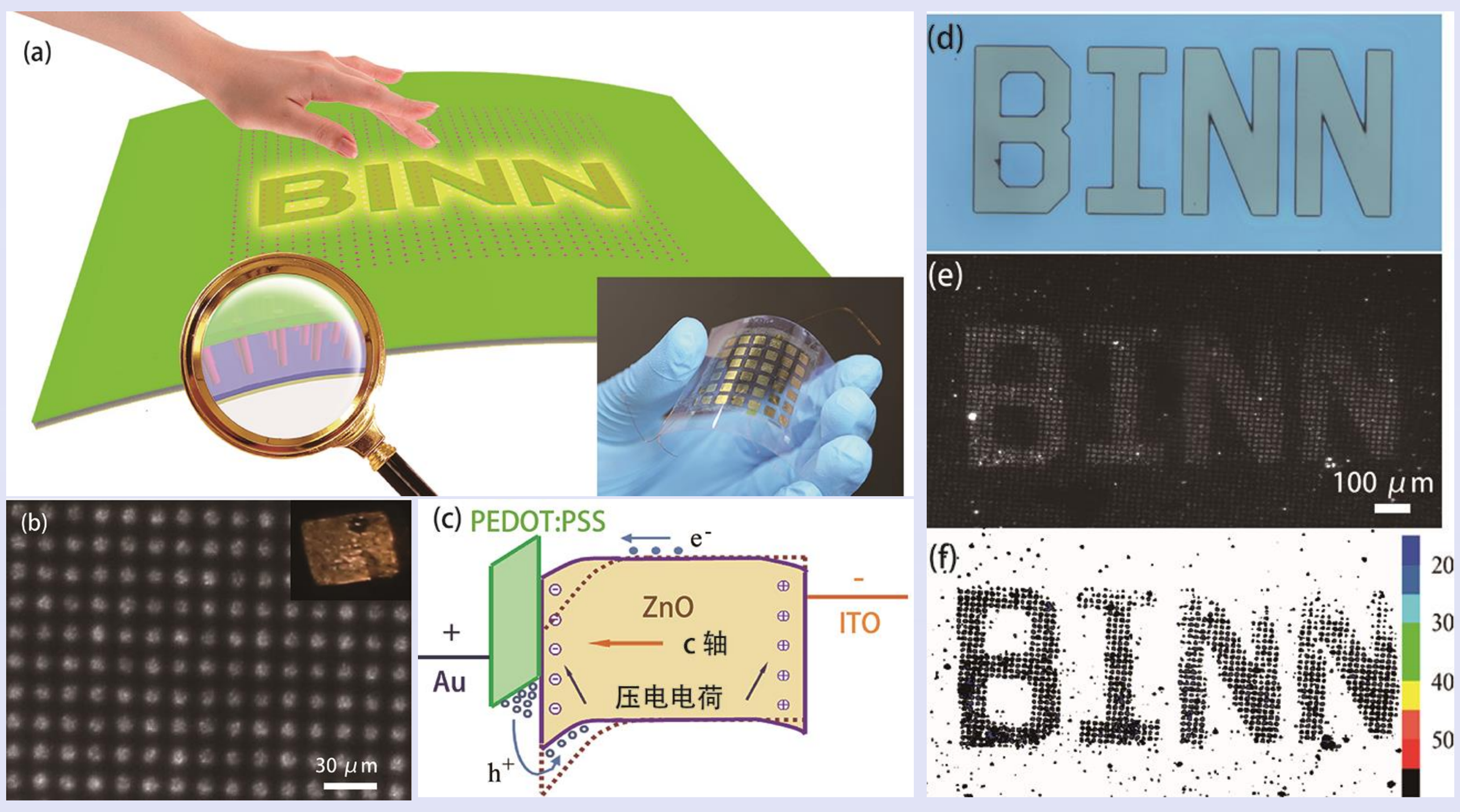

Figure 1. Mapping sensor matrix by ZnO NW LED array. (a) Schematic illustration of the flexible NW-LED-based pressure sensor array after applying a compressive strain. The device is based on a ZnO NW/p-polymer array. The inset is a photograph of the flexible device. (b) Optical images of a ZnO NW/p-polymer LEDs array device. The inset is optical image of a fabricated flexible was electrically lit up. (c) Schematic band diagram of an n-ZnO/p-polymer p–n junction before (top) and after (solid line in the bottom) applying a compressive strain. (d) Optical image of the convex character pattern of "BINN." (e) Electroluminescence image of the device at a stress of 80 MPa. The image clearly shows that a change in LED intensity occurred at the pixels that were compressed, whereas those away from the pattern on mask showed almost no change. (f) 2D contour map of the factor derived from the LED intensity images.

2. Mapping Sensor Matrix by CdS NW LEDs

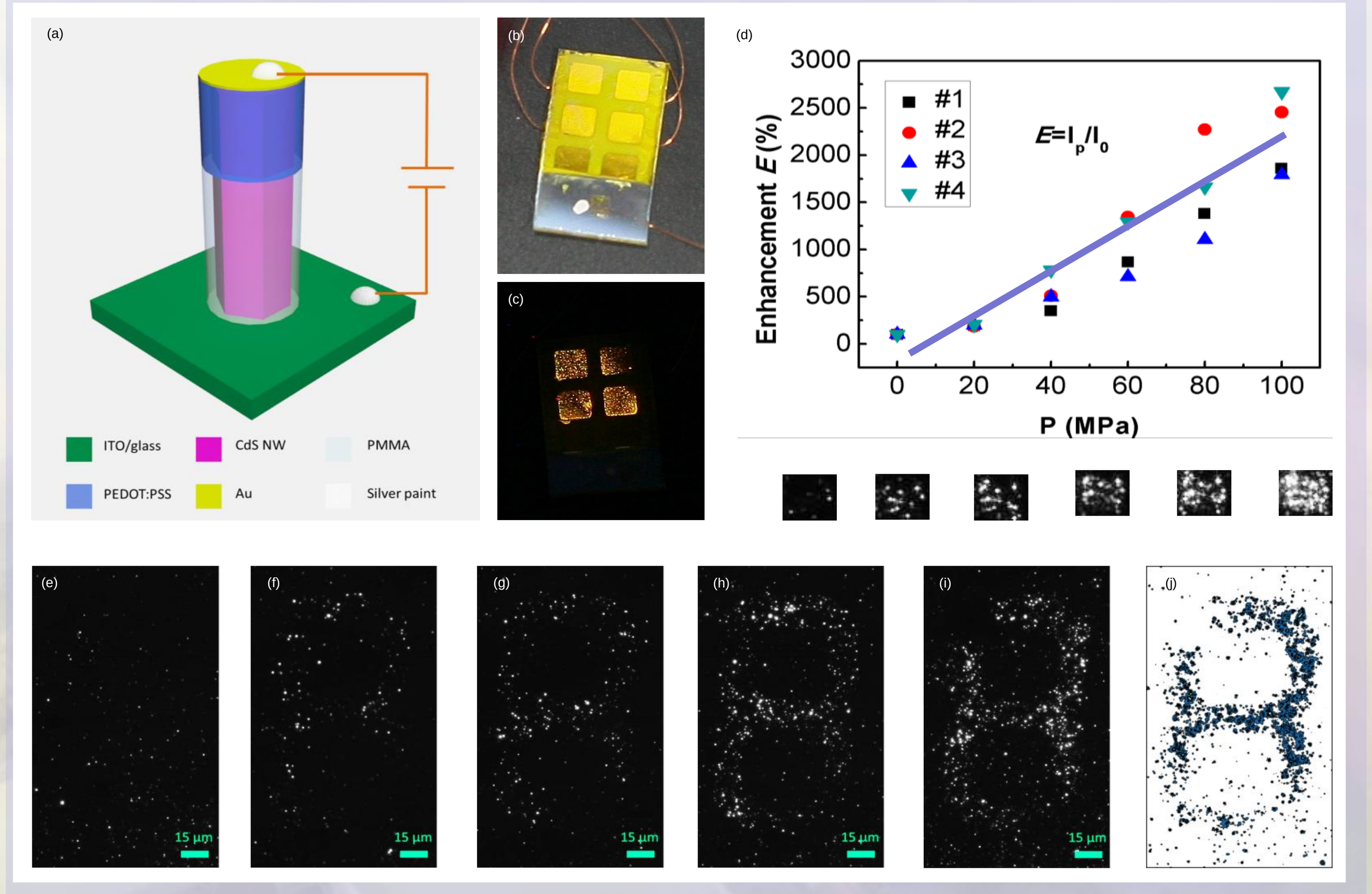

Figure 2. Mapping sensor matrix by CdS NW LEDs. (a) Schematic of the CdS NW LED. (b) (c) Optical image of the array LED device and the photograph when the device was lit up. The emission color of this array device is yellow-white. (b) Enhancement factor E of several nanorod-LEDs with applied compressive pressures of up to 100 MPa. (e–h) The light emission images of the array LED device at different pressures of 0 MPa, 20 MPa, 40 MPa, 60 MPa, 80 MPa and 100 MPa using a stamp with the pattern of '8'. These images show that the light intensity enhancement only occurs at the area with applied pressure and there is almost no change in the other areas.

3. Mapping Sensor Matrix based on Organic or QD/ZnO NW LEDs

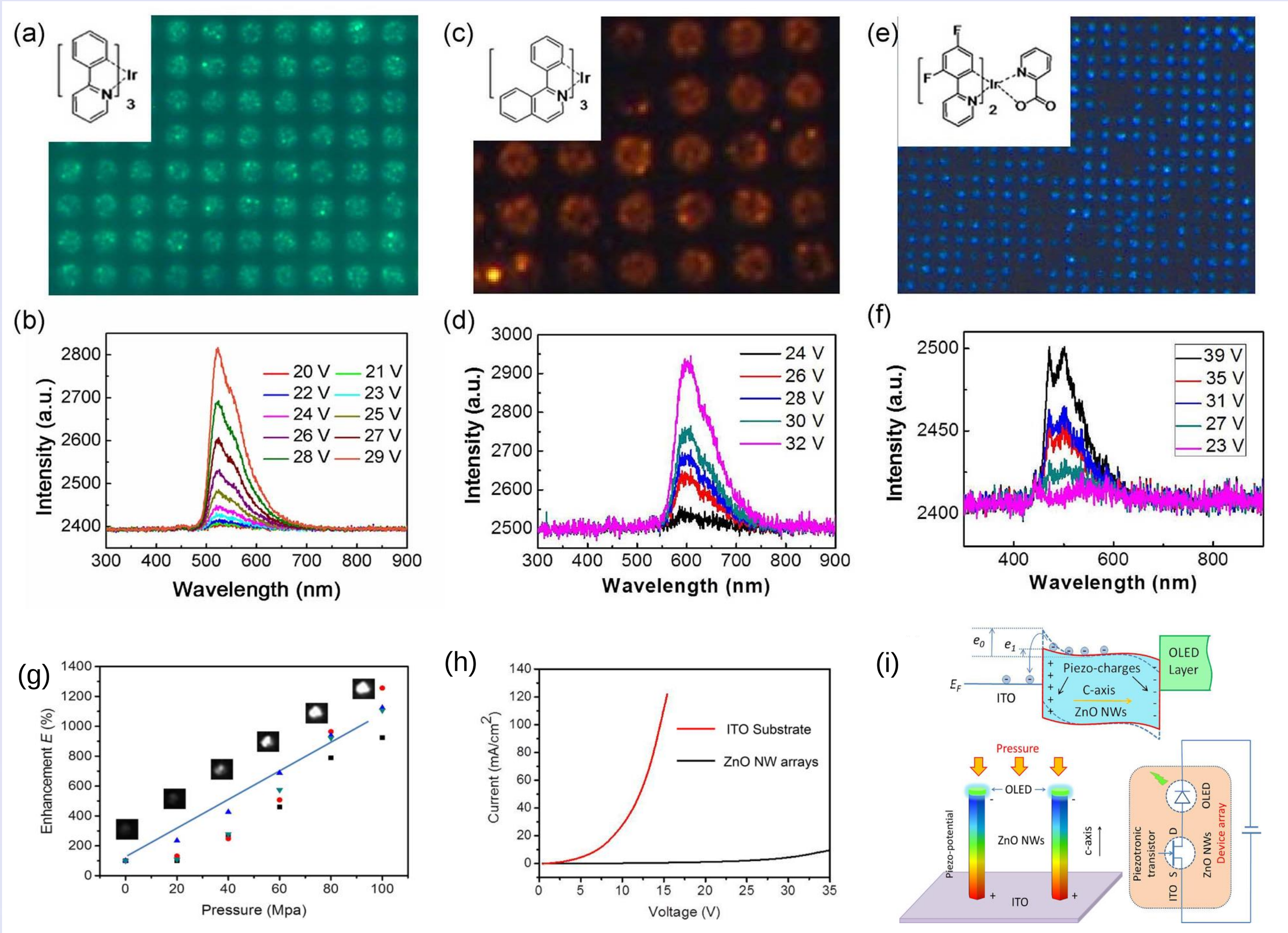

Figure 3. Mapping sensor matrix based on organic or QD/ZnO NW LEDs. (a-f) . Micrographs and EL spectra of array devices with different colors. The inset pictures show the molecular structure of the fluorescent molecules. (g) Enhancement factor E of the light-emission performance of NW LEDs under different applied pressures of up to 100 MPa. (h) Current density−voltage characteristics of the devices with ZnO NWs and without NWs. (i) Schematic band diagram of a ZnO under (solid line) applying a compressive strain. Upon applying pressure, a positive piezopotential is induced at the Schottky contact, which reduces the barrier height at that contact and hence increases the transport conductance of the ZnO NWs. The inset is a schematic of the device equivalent circuit. The ZnO NW plays a role of piezotronic transistor. Piezopotential distributions occur in a ZnO nanowire under applied pressure and thus enhance the current and light emission intensity of the device.

Conclusion: We designed and fabricated a flexible LED array composed of PEDOT:PSS and patterned ZnO NWs with a spatial resolution of 7 μm for mapping of spatial pressure distributions by using the piezo-phototronic effect. A LED array composed of PEDOT:PSS and CdS nanorods had been demonstrated for mapping spatial pressure distributions. The emission intensity of which depends on the local strain owing to the piezo-phototronic effect. Therefore, pressure distribution is obtained by parallel-reading the illumination intensities of LED arrays based on electroluminescence working mechanism. The spatial resolution is achieved as high as 1.5 μm. Flexible LED device array has been prepared by CdS nanorod array on Au/Cr/Kapton substrate. Furthermore, we combined the advantages of organic light-emitting diodes (OLEDs) and piezophototronic effect of ZnO NW array to fabricate a color-controllable high-efficiency flexible pressure-distribution sensor. When the ZnO NW array is under pressure, the piezophototronic effect modulates the current of OLED, thus changing the luminous intensity. The ZnO NW/OLED array will be used as a color-adjustable ultrahigh resolution visual pressure-distribution sensor. The outstanding flexibility, high resolution and controllability of these pressure mapping sensors provide promising technologies for future applications in biological sciences, human-machine interfacing, smart sensor and processor systems, and even defense technology.

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