Transparent MESFET transistors on flexible substrates

Description

With the development of novel device applications, e.g. in the field of Internet of Things (IoT) or Poin-of-Care personalized diagnostic systems, came an increased demand for Schottky gate for amorphous In-Ga-Zn-O (a-IGZO) devices. They are needed for the development of Schottky diodes and metal–semiconductor field-effect transistors (MESFETs) for fast and low power consumption integrated circuits and active-matrix displays. The use of nanocrystalline Ru-Si-O transparent oxide conductor prevents interfacial reactions in the contact region and allows to avoid additional treatment of a-IGZO surface enabling utilization of such junction as gate electrode in MESFETs fabricated on flexible polymer substrates such as PET or paper. Fabricated devices exhibit field-effect mobility equals 8.1 cm^2/Vs, on-to-off current ratio above 10^4 A/A, and transparency as high as 70%. The subthreshold swing below 250 mV/dec results in a gate voltage sweep of 1.0 V necessary to switch the transistor from the on-state to the off-state, making a-IGZO MESFET favourable for low voltage applications.,

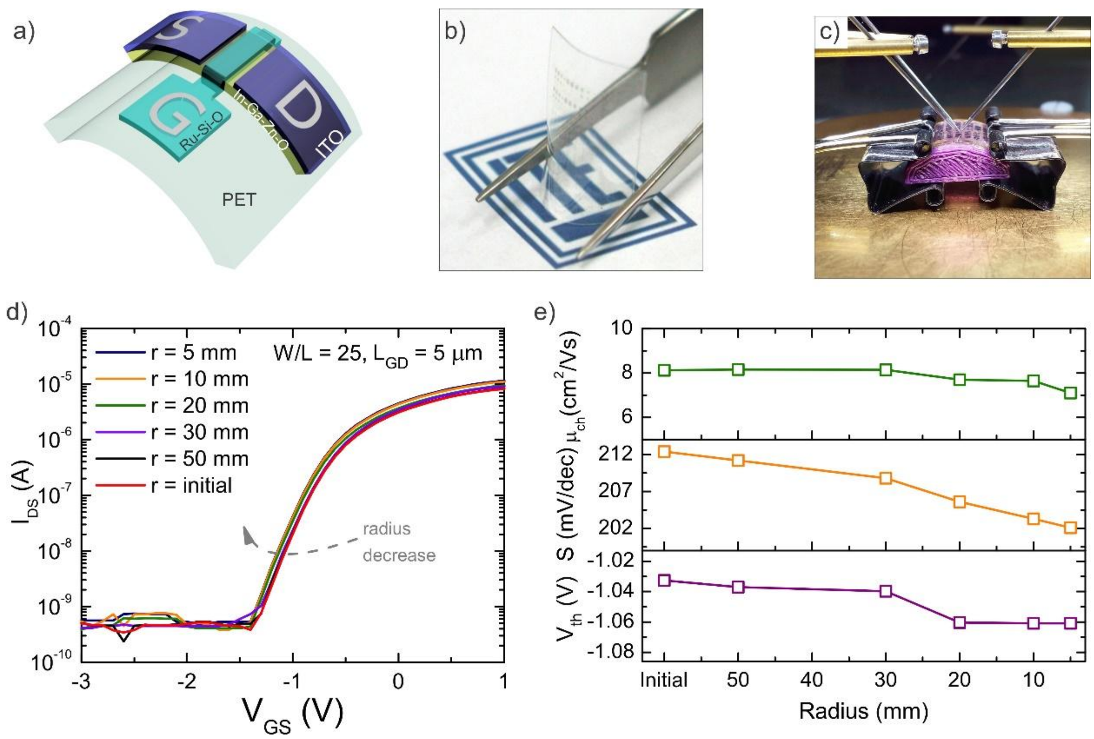

Fig. 1. (a) Schematic illustration of top-gate MESFET on flexible PET substrate. (b) Photograph of transparent MESFETs and Schottky junctions fabricated on flexible PET foil. (c) Photograph of flexible devices attached to 3D-printed elements and bent to a tensile radius of 10 mm parallel to MESFETs channel and prepared for DC characterization. (d) Transfer characteristics of MESFETs fabricated on PET foil measured while flat and bent to tensile radii from 50 to 5 mm.

To fully demonstrate the possibilities of using the presented Ru-Si-O/IGZO MESFETs in flexible electronics devices were also fabricated on regular sticky-note paper, without any substrate preparation schemes (Fig. 2.).

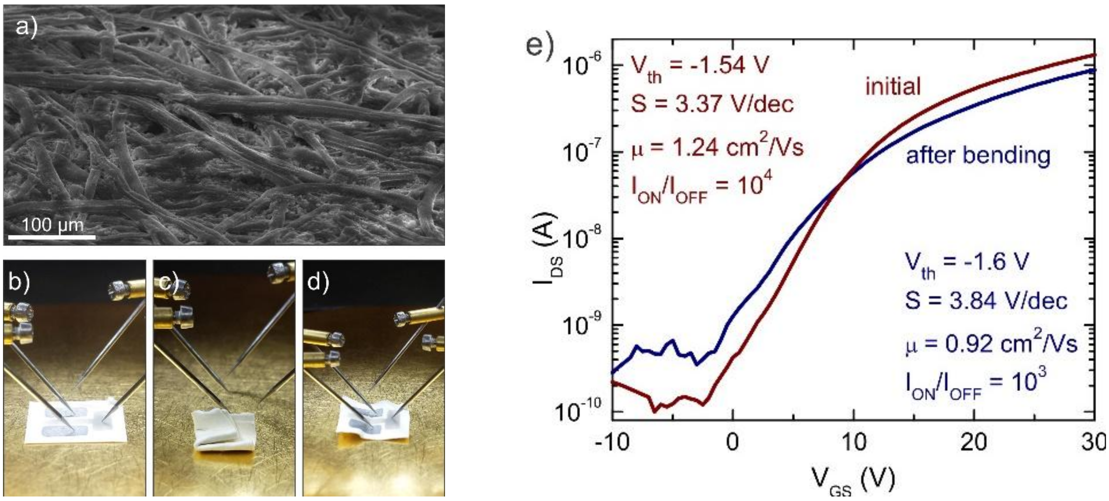

Fig. 2. (a) SEM image of the surface of sticky-note paper used as a substrate for MESFETs fabrication. (b) Photograph of MESFET structure on paper prepared for DC characterization before, (c) during, and (d) after introducing random mechanical stress. (e) Transfer characteristics and main electrical parameters of MESFETs on paper before and after introducing mechanical stress.

Possible applications

Recently, a-IGZO TFTs have gained much attention as possible candidates for Internet of Things (IoT) applications. On the one hand, it relates to applications that exploit both large area and ruggedness, like touch screens, e-ink, or OLED displays. On the other hand, it is linked to areas that exploit the functionality of a-IGZO TFTs, e.g. their flexibility and high throughput, aiming at achieving cost competitiveness with silicon for low computational complexity intensity devices. The latter for instance include Radio-Frequency Identification (RFID) tags augmented with sensors, able to monitor the storage and supply chain of products in new generation of packaging solutions, as well as wearable Point-of-Care personal diagnostic systems. The key challenge is the ability to fabricate low power transistors at low process temperatures enabling manufacturing the circuits on flexible plastic or paper substrates.

Scientific, economical and social impact

Conventional transistors are made from electronics-grade silicon, the production of which is a wasteful process with significant environmental impact. The process is wasteful because up to 80% of the naturally occurring metallurgical silicon is lost during purification. And the impact is high because of the use of greenhouse gases like sulphur hexafluoride - the most potent greenhouse gas per molecule, a single tonne being equivalent to 25 000 tonnes of CO^2.

A switch to paper-based transistors would alleviate the environmental burden of silicon and boost the European cellulose market, which accounts for 30% of the world's total production. In the near future, the most promising area for cellulose-based transistors is in the electronic smart packaging market. According to an IDTechEx report the global demand in this field will grow rapidly from EUR 26 million (USD 30 million) in 2012 to EUR 1.51 (USD 1.7 billion) by 2022.

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