Automated Continuously-Manufacturing Line of All-Printed Organic TFT Array Flexible Film

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Abstract

In the printed electronics field, it has been needed to realize the manufacturing technologies for inventing mass production phase. We JAPERA, which was organized 2011 as a NEDO project to develop the manufacturing technologies of large area flexible printed electronics, established the automated and continuously operated manufacturing line for which produced the all-printed TFT array flexible film. We operated the offset printer, inkjet printer, screen printer, and slit-die coater. Specialized ink materials, for example Ag nano particle ink for gate electrode and source/drain electrode, highly purified polymer ink for gate insulator, and organic semiconductor ink for TFT active layer have been developed. We have been acquiring successful results of TFT array flexible film by high yield. The applications of our THT array flexible film for making a display device or a sensor device are presented.

Introduction

Printed electronics is believed to contribute the low-power consumption society, and is supported by energy saving production method for realizing electrical devices rather than photo-lithography technologies. Printing processes have been used common printing technologies, such as screen printing, flexography, gravure, offset printing, slit-die coating and inkjet. Electrically functional inks are deposited on the flexible substrate, creating active or passive devices, such as thin film transistors. Printed electronics is expected to facilitate widespread, input devices; sensor, and output devices; display, e-paper, and digital signage.

In 2011 Japan Advanced Printed Electronics Technology Research Association (JAPERA) was founded by 27 Japanese companies from various industries, such as electronics manufacturers, printing companies, equipment supplies, and material manufacturers, together with the National Institute of Advanced Industrial Science and Technology (AIST).

We focused on the development of the printed electronics technology which can fabricate large-area electronic devices with low power, low resource, and high productivity. The aims and research subjects of JAPERA is shown in Figure 1.

Recently, it has been needed to realize the manufacturing technology for inventing mass production phase in the printed electronics field.

Figure 1   Aims and Research Subjects of JAPERA

Results and Discussion

We have constructed a sheet-to-sheet (S2S) manufacturing line in order to prove the possibility and reality of production technologies and integrated processes of all-printed electronics devices. We choose an organic TFT array on a flexible film as all-printed electronic devices, which is the fundamental key component applying wide variety of printed electronics.

It is important to make a practical trial production run of TFT back plane in reasonably sufficient yield. To achieve the purpose we established the automated and continuously operated manufacturing line for which produced the all-printed TFT array flexible film.

Manufacturing Line

The automated and continuously operated manufacturing line in which main clean robot carried film substrates in class 10 clean tunnel connected various printers and heat process funnels. We operated the offset printer for electrode pattern, inkjet printer for organic semiconductor layer, slit-die coater for insulator layer, and screen printer for electrode and insulator layer.

The applied production technologies on manufacturing line are described below;

1) CIM production line system technology

2) automated substrate transporting system by robotics
3) localized clean zone control technology on minimum area
4) continuously printing process technology alignment - printing - drying - cure
5) high resolution technology for offset printing process of Ag nano ink
6) high accuracy digital inkjet printing process technology of organic semiconductor ink

By combination of these technologies, we have constructed the automated consistently operating printing line for organic flexible TFT array film.

Organic TFT

We selected the bottom-gate/bottom-contact structure TFT as shown Figure 2. This structure is suitable for smooth interface between the printed under layer and the over-printed layer on it.

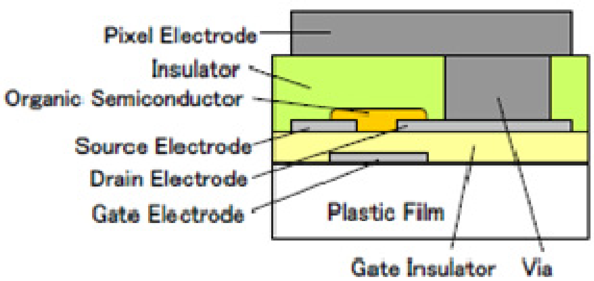

Figure 2 Cross Sectional View of TFT Element

Specialized ink materials, for example Ag nano particle ink for gate electrode and source/drain electrode, highly purified polymer ink for gate insulator, and organic polymer or low-molecular weight semiconductor ink for TFT active layer have been used after fine tuning of developed and formulated inks. We have developed the process technologies which were suitable to continuous manufacturing of printing and curing fine pattern without vacuum process and photolithography process. The maximum process temperature was less than 180 degree C. The film size of TFT array was 300mm x 400mm x 50um. We used PEN, PC, and PI film as needed. The density of TFT element was 85ppi as a first trial sample as shown in Figure 3.

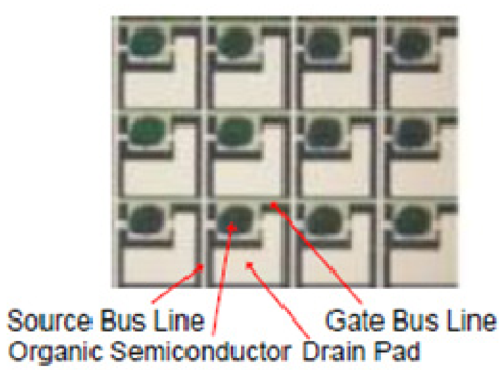

Figure 3 Plane View of TFT Array

The electrical properties of TFT array is shown in Figure 4 and described below; average mobility is 0.3 cm2/Vs, average ON current is 5 uA with less than 10% sigma in A4 size area, and ON/OFF current ratio is 5 multiplied by ten of order 6.

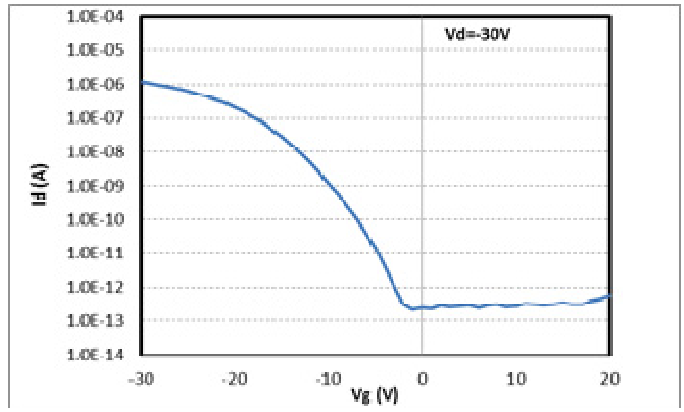

Figure 4 Electrical Properties of TFT Elements

We have been acquiring successful results of TFT array flexible film by a reasonable high yield. The printed sample of TFT array film is shown in Figure 5.

Figure 5 Printed Sample of TFT Array Film

Applications

We have constructed the new automated S2S manufacturing line of all-printed flexible TFT array film, which is the first challenging line in the world.

By using the line we are able to supply the requested back plane for combining with any kinds of front plan, for example electrophoresis film, liquid crystal layer, OLED plan to make flexible and light-weight displays and sensors.

One example of application is a pressure sensitive sensor, which cross sectional view of one pixel area is represented in Figure 6. The electrical resistance of layer of pressure sensitive rubber is changed by pressed force shown in Figure 7 and a signal corresponding pressure is detected by selected TFT. In Figure 8 the equivalent circuit is represented.

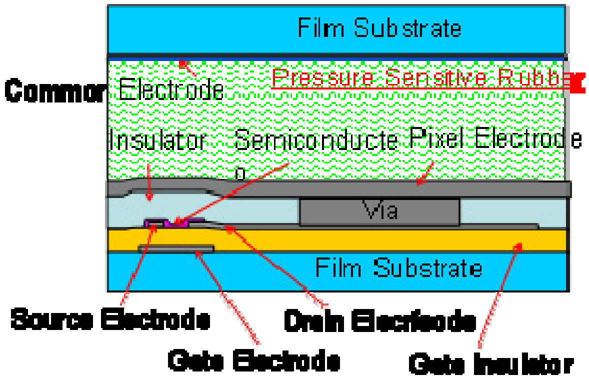

Figure 6 Cross Sectional View of Pressure Sensitive Sensor

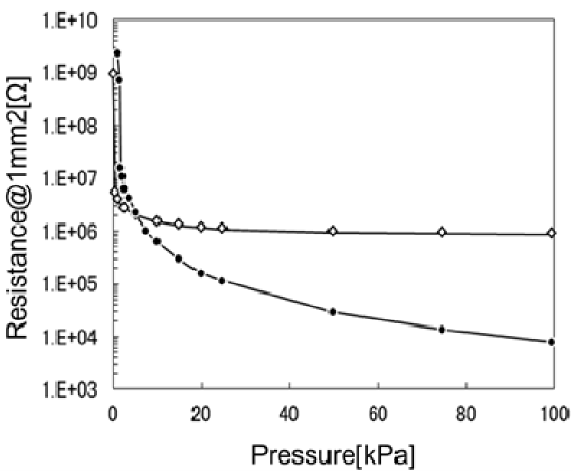

Figure 7 Correlation between Resistance of Pressure Sensitive Rubber and Added Pressure

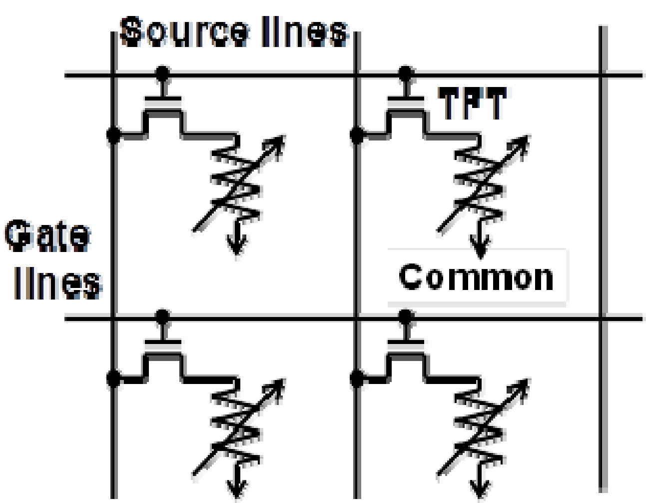

Figure 8 Equivalent Circuit of Pressure Sensitive Sensor

The sample of pressure sensitive sensor A4 size was demonstrated at Nano Technology Show 2014 in Tokyo, as shown in Figure 9.

Figure 9 Pressure Sensitive Sensor A4 Size Demonstrated at Nano Technology Show 2014 in Tokyo

Conclusion

We have constructed the new automated S2S manufacturing line of all-printed flexible TFT array film. Electrics property of 480,000 TFT elements on one plane was sufficient uniformity. By using the line we are able to supply the requested back plane for combining with any kinds of front plan, for example electrophoretic film, liquid crystal layer, OLED plane to make flexible and light-weight displays and sensors.

Acknowledgment

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Author Biography

Dr. Shinichi Nishi received his doctor degree in applied chemistry from Tohoku University in Sendai Japan in 1980. He joined Konica and worked in the field of LCD and developed the jisso of electric devices, and inkjet head technology. In 2011 he joined JAPERA and has been developing production technologies of printed electronics in organic TFT array film. He is a fellow of ISJ (The Imaging Society of Japan).