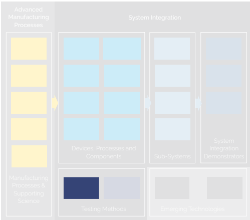


FLAGSHIP

SYSTEM INTEGRATION

Platform for high speed testing of large-area electronic systems (PHISTLES)

ANDREW FLEWITT
ABHAY SAGADE

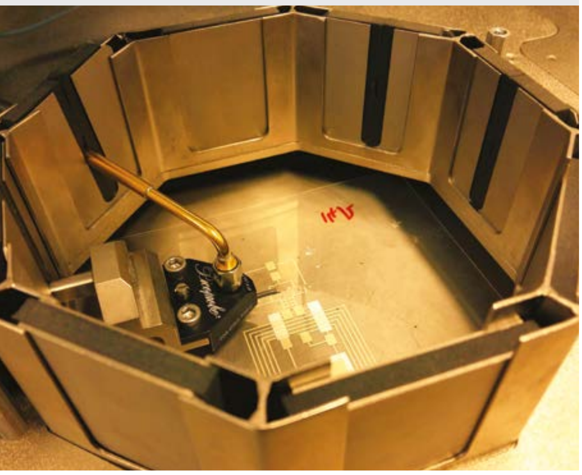
In the first year of the PHISTLES project, we successfully developed 'Simultaneous Multiple Device Tests' (SMUDTs) to address the need for high-speed testing of large-area electronics produced by reel-to-reel (R2R) manufacturing. In the current phase of the project, we are considering the design and testing of fully printed high speed diodes. The diode is widely used in a variety of circuits such as rectifiers, voltage multipliers, and charge pump circuits, with particular for energy harvesting circuits to extract energy from radio frequency (RF) waves. These diodes have a critical role in the Flexipower project, whose aim is to produce all of the components for a printed RF energy harvesting system. Therefore a diode capable of operating at high frequencies should be part of the printed circuit. High performance printed rectifiers capable of operation in the UHF (300 MHz to 3 GHz) band is the cornerstone in interfacing printed electronics with mobile technology and hence in 'internet of things' (IoT) applications.

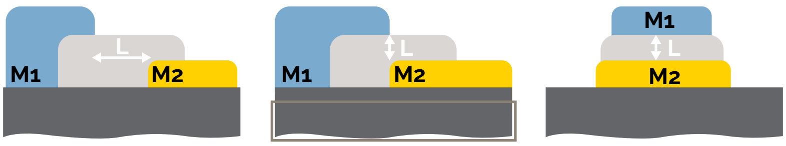
There are several challenges in realizing such a printed UHF diode. Printing diodes requires semiconductor materials with high mobility and carrier concentration which can also be processed from solution and at low temperatures. Device geometry considerations are equally important, and we have come up with a device simulation strategy to optimise this. Schottky barrier diodes (SBD) are more suitable for high speed operation than p-n junction diodes: Firstly, the low barrier height in SBDs assists charge carriers to move more quickly into the circuit. Secondly, device fabrication is simplified with a semiconductor sandwiched between two different metals of appropriate work function. Thirdly, this simple processing reduces the cost of fabrication many fold.

The different potential diode geometries are summarized schematically in Figure 1. Each of these three structures have their advantages: Device 1 shows minimal parasitic capacitance, which is highly desirable for UHF operation, but it is most suitable for materials with high mobility or conductivity. Device 3, in contrast, is more suitable for low conductivity materials but shows high parasitic capacitance. Device where the two metal electrodes are perfectly aligned 2, may be the best choice with low parasitic capacitance and a sufficiently low resistance path for conduction.

Objectives

- To develop strategy for fabrication of diodes compatible with reel-to-reel manufacturing.
- To create library of materials suitable for Schottky barrier diodes.
- To establish device simulations for various geometry parameters to produce high performance and test diodes in UHF range.
- To understand the device physics of different diode geometries.





Device 1
- Suitable for material with good conductivity
- Minimal stray capacitance

Device 2
- Suitable for any material conductivity
- Low stray capacitance

Device 3
- Suitable for material with low conductivity
- Large stray capacitance

Figure 1: Various geometries of Schottky diode considering overlap between two metals (blue and yellow) of distinct work functions and semiconductor (light grey).

We carried out simulations of the diode structures using a software suite from Silvaco®. This industrial interaction has strengthened our understanding of the SBDs. The simulations have been performed with amorphous Indium Gallium Zinc Oxide (a-IGZO) as a model material, which is well known for its high performance in thin film transistors (TFTs). The device performance for geometries Device-2 and Device-3 are shown in Figure 2. The Device-3 shows a uniform distribution of electric field in the whole semiconductor from anode to cathode with very high electric current. For Device-2, the electric field is intense only at the facing ends of electrodes; shown by the dotted area. With the reduction in thickness of semiconductor, increased currents are seen for both structures. Although the current in Device-2 is two orders lower than Device-3, the ON/OFF ratio is very similar, ~10^8. Also, the turn on voltages for both devices are comparable. The important difference is found in capacitance values, for Device-2 it is two orders lower than Device-3 for a 0.1 µm semiconductor thickness; which is highly desirable for high frequency operation. These device simulations and analysis will provide guidelines for printing diodes for various applications.

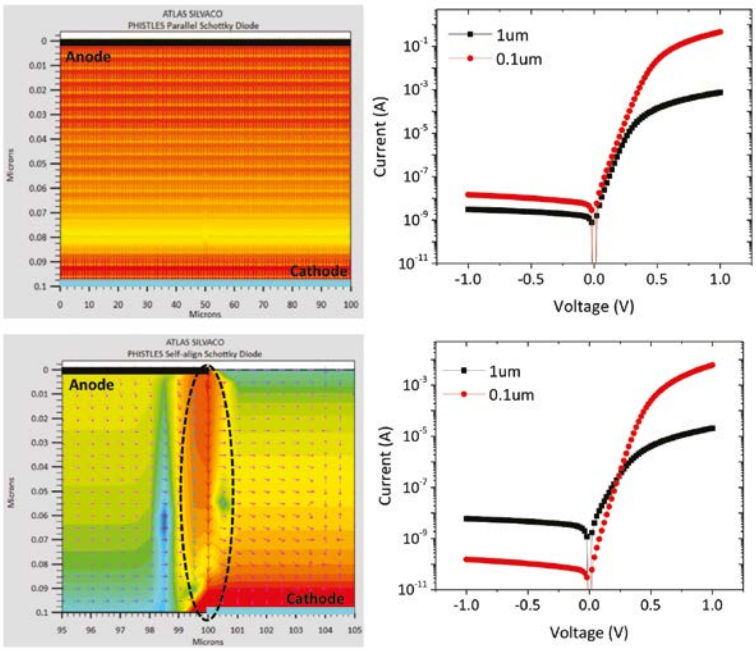


Figure 2: Device simulation of Schottky barrier diodes for geometries of Device 3 (top) and Device 2 (bottom). The colour contours and arrows indicate electric field and electron current direction, respectively.