18.3 Bidirectional Communication in an HF Hybrid Organic/Solution-Processed Metal-Oxide RFID Tag

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7 4K tags and come at the cost of a slow reading time. In this paper, we for the first time realize a reader-talks-first low-temperature thin-film transistor (TFT) RFID circuit. We use a complementary hybrid organic/oxide technology. As organic transistors with reasonable channel lengths (≥2µm) have a cut-off frequency below 13.56MHz, the base carrier frequency of HF communication, present technologies on foil do not yet allow to extract the circuit clock as a fraction of the base carrier. We solve this by introducing an original uplink (reader-to-tag) scheme, in which a slow clock (compatible with our transistors’ speed) is transmitted as amplitude-modulation on the base carrier while data is encoded on this clock by pulse width modulation (PWM).

In TFT technology, the p-type and n-type transistors require different semiconductors. Stable p-type organic semiconductors with charge carrier mobility up to 3cm2/Vs now exist, but their n-type counterparts are still quite immature. Meanwhile, solution-processable n-type oxide semiconductors are emerging. The hybrid organic/oxide technology used in this work combines a 250°C solution-processed n-type metal-oxide TFT with typical charge carrier mobility of 2cm2/Vs with an evaporated pentacene p-type TFT with mobility of up to 1cm2/Vs. We use a high-k Al2O3 dielectric, which increases the transistors’ current drive. Output characteristics of both devices are shown in Fig. 18.3.1a. Fig. 18.3.1b shows the typical inverter characteristics for different supply voltages and the process cross-section is shown in Fig. 18.3.1c. Further process details on the hybrid integration of both devices can be found in [7].

Low-cost tags will need to be passive, i.e., draw the power for the circuit from the RF field by means of a rectifier operating at HF (13.56MHz). We designed double half-wave transistor rectifiers [8] using solution-processed metal-oxide TFTs. These rectifiers operated up to frequencies beyond 100MHz, owing to both double half-wave transistor rectifiers [8] using solution-processed metal-oxide TFTs and that both the high mobility (µ > 2cm2/Vs) and the low zero-VGS current of the oxide TFTs. These rectifiers operated up to frequencies beyond 100MHz, owing to both transistors closely integrated on the same substrate.

In conclusion, we have demonstrated a viable route towards bi-directional communication at 13.56MHz by low-cost RFID tags in a complementary, hybrid solution-processed metal-oxide/organic thin-film transistor technology. As these transistors do not allow a clock to be decoded directly from the HF base carrier, the up-link clock is transmitted as amplitude modulation of the carrier, and uplink data by pulse width modulation of this clock. Our solution will enable true anti-collision protocols for low-cost HF RFID tags.

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References:
Figure 18.3.1: (a) output characteristics of typical solution-processed oxide and evaporated pentacene transistors, (b) inverter characteristics of the hybrid technology at different power voltages. The inset shows a photograph of an inverter, (c) Cross-section of the hybrid technology process.

Figure 18.3.2: Rectified voltage of double half-wave rectifiers as a function of frequency at a 5V AC amplitude. The rectifiers comprise 2 capacitors and 2 solution-processed oxide transistors. The inset shows the current voltage characteristics of the oxide transistor-diode.

Figure 18.3.3: (a) schematic overview of the different building blocks of the hybrid RFID tag, (b) detailed schematics of the uplink data extractor and shift register.

Figure 18.3.4: (top) toggling of the hit signals from both decoders (A and B) as a consequence of an input stream comprising multiple codes; (bottom) output of code sequencer 1 operated at 5V as a consequence of a hit signal at the input.

Figure 18.3.5: (left) Uplink shmoo plot of the reader data rate range versus the tag internal supply voltage for the input decoders A and B. (right) The corresponding code sequencer data rate (downlink) for different supply voltages.

Figure 18.3.6: (a) Measurements of the internal voltages of the bi-directional hybrid RFID tag when powered by the 13.56 MHz signal of the reader. (b-c) show a zoom of the hit and the kill transients.
Figure 18.3.7: (top) Die photographs of the input decoders A (left) and B (right); (bottom) Die photographs of the code sequencers 1 (left) and 2 (right).