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#### Printed battery technology for Product Packaging

# Introduction:

Interactive food packaging is a broad category with many aspects available. The specific type of interactive packaging covered in this paper is the kind of packages with electrical elements integrated in the interactive features and would need a reliable power supply to function as designed. This paper will review paper battery technology available in current commercial packaging designs.

## **Commercial Application of Paper Battery for Product Packaging**

A paper battery is a flexible ultrathin energy storage device formed by combining carbon nanotubes with a conventional sheet of cellulose-based paper. A paper battery acts as both a high-energy battery and super capacitor, combining two components that are separate in traditional electronics [1].

## Paper Battery in Beverage Packaging

Oculto has used paper battery in a special packaging of their limited edition beer. The paper battery was used to power up printed electronic pathways, LEDs and a pressure-sensitive switch. The circuit setup was built on the label of the bottle and was activated when people hold the bottle and applied pressure on the label [2]. Upon activated, the LEDs would light up and shone through the eyes of the brand's signature skull symbol on the label. In an interview with Packaging Digest, senior brand director Monterio refused to disclose the cost per bottle of the design and said that such design is a significant opportunity to further the premium nature of the brand. He also said that they were looking into expanding the production and lowering the cost in 2016 [3].

#### Paper Battery in Food Package

Frito-Lay company also introduced a new Tostito package that would double as breath analyzer and would help the user request an Uber if the alcohol level is tested as unsafe to drive. A paper battery was used to drive LEDs and near-field-communication(NFC) devices [4]. The NFC would connect to the Uber application on users' phones and would help them locate a ride home nearby. These special packaged Tostito were available during 2017 Super Bowl season in selected venues to promote safedriving and were not on sale through regular retailers. The cost of the design is unknown but is likely to be high since the product is used as a marketing attraction by Frito-Lay and Uber.

### **Technology of Paper Battery**

Paper batteries are currently available in the market. According to one retailer Paper Battery Co., some key features of the batteries include ultrathin, high power and extended range of functionalities and flexible sizes [5]. For a 4.5V supply voltage the battery can be as thin as 5mm and it can be shaped by folding, bending and cutting out to fit the specific design requirements. The storage temperature of the battery ranges from -25 to 65 degree Celsius and the functioning temperature ranges from 0 to 65 degree Celsius, which are ideal for food or beverage that require low-temperature storage. The battery also has low leakage current and a cycle life of 25,000 cycles. The total energy stored ranges from 0.135 to 11 Whr [6]. This technology has been used to drive wireless sensors, IoT, handheld portable tools and toys on the commercial side.

Paper batteries are also non-toxic since the production process doesn't involve harmful chemical reactions which is ideal for food and beverage packages. Also, the batteries are disposable since they are made of cellulose which is biodegradable. Food and beverage packages are meant to be disposed after use, and this technology makes it easier for the garbage disposal process [7].

#### The Building Blocks for Paper Battery

Paper batteries are formed by combining the cellulose with carbon nanotubes. There are currently four ways to construct the battery. The first method is using zinc and manganese dioxide based cathode and anode. The second involves growing nanotubes on a silicon substrate and the third one is achieved by spreading specially formulated ink of carbon nanotubes on a sheet of paper with ionic coating. The third one is easier to achieve in the lab environment and is ideal for prototyping. The forth one involves coating stainless steel with carbon nanotubes [7]. However, for mass application in commercial products, ordering such batteries in bulk from suppliers like Paper Battery Co. would be the best way to ensure the quality consistency of the batteries.

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