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Direct media exposure of MEMS multi-sensor systems using a potted-tube packaging concept

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Abstract

A packaging concept for Data Storage Tags is presented. A potted-tube packaging concept, using a polystyrene tube and different epoxies as filling material that allows for direct sensor exposure is investigated. The curing temperature, water uptake and the diffusion coefficient for water in the filling material is measured. The packaging concept is used to encapsulate a microfabricated multi-sensor (measuring temperature, water conductivity, pressure and light intensity). The direct exposure of the sensors results in high sensitivity and fast response time. The design of an elongated multi-sensor is described and effectiveness of the packaging is demonstrated with the precise measurement of water conductivity using the packaged multi-sensor. The packaging concept is very promising for high accuracy measurements in harsh environments.

Keywords: Packaging; Multi-sensor; Direct exposure; Potting; Harsh environment

1. Introduction

Reliable monitoring of individual fish behavior and migration in their natural environment is crucial in order to make accurate population estimations and plans for preservation of the different species. A Data Storage Tag (DST), Fig. 1 is an autonomous system that when sutured onto the back of a fish can measure parameters in the surroundings of the fish and store the data until the fish is re-caught [1].

The Data Storage Tag consists of a microcontroller, which activates sensors and stores measured data in a non-volatile memory. Batteries power the system. When the fish is re-caught, the system can be powered through a wireless interface while data is read out.

In our case, the sensor can measure temperature, pressure, light intensity and electrical conductivity allowing the salinity of the water to be determined. Based on these parameters, the fish migration route can be reconstructed [1].

A very compact and reliable system capable of measuring the parameters very accurately with a high sensitivity and short response time is needed. This calls for a packaging scheme that allows for direct exposure of a silicon sensor to the surrounding environment. Isolating the sensing area from the packaging material also imply that the sensors are stress de-coupled from the packaging. This in turn allows for pre-packaging wafer scale calibration.

We use microtechnology and a potting packaging to make such a system. DST manufacturer CEFAS Technology Ltd. [2] uses a potting packaging system in their G5 tag. This system does not expose the sensors directly but relies on internal sensors coupled to the surrounding environment through the packaging. The G5 tag shows that potting using a two-component fill can be used in yearlong exposure to seawater.

Our system has to be partly sealed off from the surrounding water. This is obtained by placing the sensors, PCB and batteries in a polystyrene tube which is subsequently filled with epoxy leaving one end of the sensor exposed to the surroundings (Figs. 2, 3 and 4). This process is known as potting. Potting with epoxy in a polystyrene tube was chosen because the complete filling leaves no room for water to condense as opposed to an “o”-ring packaging concept that relies on ventilation of the dry side of the packaging to remove water vapor [3]. The silicon–epoxy interface is also very strong which is not always the case for injection-molded thermoplasts, that tends to shrink

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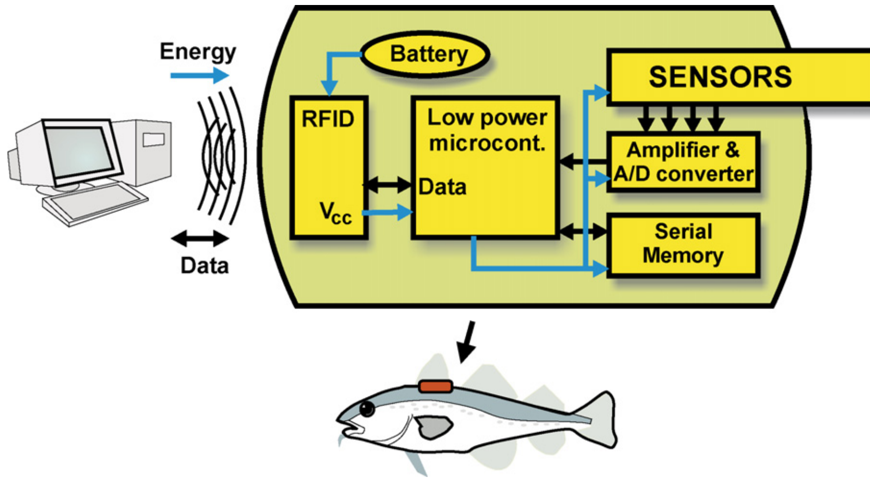

Fig. 1. Data Storage Tag (DST) system overview. A microcontroller manages the power to and data from the sensors and stores the data in the memory. Batteries power the system. When retrieved the system can be powered via the wireless interface while data is read out.

slightly when cooled. The water uptake and diffusion in polymers and epoxies has been investigated in Refs. [4–7] but an investigation of the specific epoxy in this system is needed in order to ensure that it meets all the requirements set by the harsh system environments.

2. Sensor chip design and fabrication

The high demands on the packaging scheme with regards to long-time stability and direct exposure calls for a system design approach. Special care has to be taken in the chip design to ensure that the design facilitates a direct exposure in the pre-decided packaging scheme. This includes protecting all sensor parts while making good electrical contact to the interface electronics and to distance sensors from bond pads.

The silicon multi-sensor is fabricated using conventional bulk micromachining [8,9] including ion-implantation to functionalize the silicon. Thermally grown SiO_2 and deposited Si_3N_4

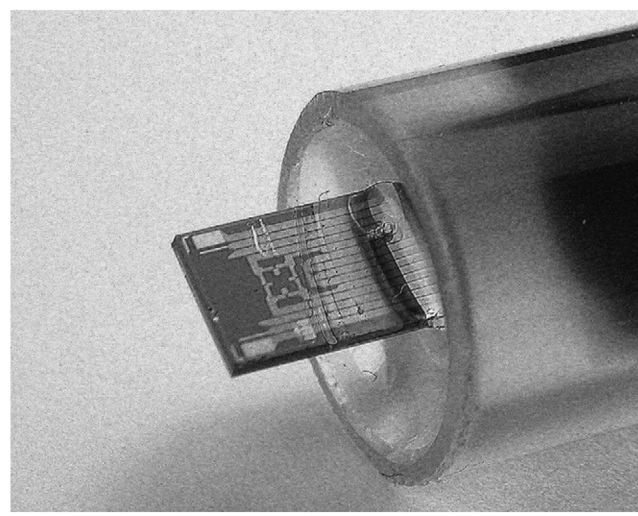

Fig. 3. The exposed sensor chip. The sensors include a piezoresistive pressure sensor, a thermistor temperature sensor, a pn-junction light sensor and a four-electrode conductivity sensor. The sensors are contacted via $TiSi_2$ wires and are protected by a Si_3N_4 film.

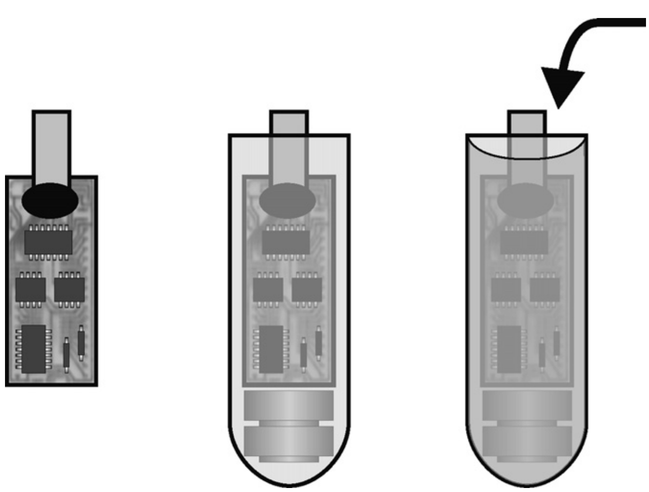

Fig. 2. Packaging scheme. The sensor chip is mounted on the PCB and the wire-bonds are glob-topped. The PCB and batteries are connected and put in a polystyrene tube. The tube is filled with glue (potted) covering the system while leaving one end of the sensor chip exposed.

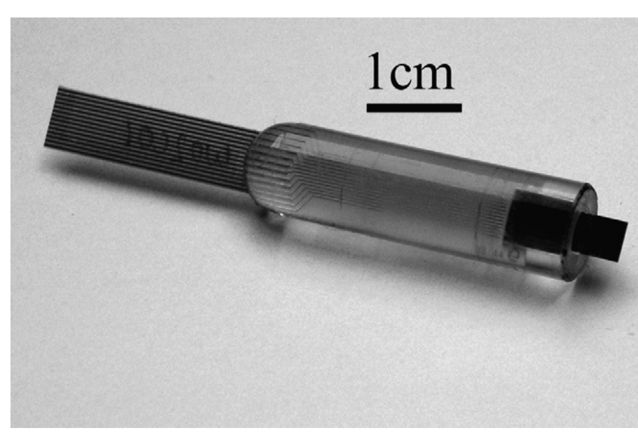

Fig. 4. A packaged multi-sensor. The packaging is made in two versions. One (shown here), where the connector print is exposed on the rear end to allow for online monitoring. And one, where electronics and batteries are potted inside to allow for autonomous measurements in the field.