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Review

# Review of the potential of a wireless MEMS and TFT microsystems for the measurement of pressure in the GI tract

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**Abstract**

Telemetry capsules have existed since the 1950s and were used to measure temperature, pH or pressure inside the gastrointestinal (GI) tract. It was hoped that these capsules would replace invasive techniques in the diagnosis of function disorders in the GI tract. However, problems such as signal loss and uncertainty of the pills position limited their use in a clinical setting. In this paper, a review of the capabilities of MicroElectroMechanical Systems (MEMS) and thick film technology (TFT) for the fabrication of a wireless pressure sensing microsystem is presented. The circuit requirements and methods of data transfer are examined. The available fabrication methods for MEMS sensors are also discussed and examples of wireless sensors are given. Finally the limitations of each technology are examined.


*Keywords:* Transducers; Telemetry capsules; Microsystems; MEMS sensors; TFT sensors

**Contents**



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## 1. Introduction

Radio telemetry pills, for use in the gastrointestinal (GI) tract, have existed since the 1950s and were called endoradiosondes, radio pills or sometimes, "gutnick", as they first appeared in 1957, the year sputnik was launched [1]. Radio pills usually contain a sensor, the associated electronics and a radio transmitter. It is small enough to be swallowed and capable of operating inside the gastrointestinal tract. The pills primarily transmit information on temperature, pressure and pH [2–4].

It was hoped that these capsules would provide information to aid in the diagnosis of disorders in the GI tract. At present, manometry is the preferred technique for investigating pressure changes within the GI tract. However, manometry systems are considered cumbersome and suffer from inaccuracies in the dynamic signals [5]. The mobility of the patients is restricted and periods of observation are limited to a few hours [6].

Examples of early radio telemetry pills can be seen in Table 1. These capsules were based on the use of discrete components and failed to make use of the advances made possible through the development of silicon chips [6,7]. The uses of discrete components lead to a high cost of fabrication. Furthermore, the capsule had to be recovered for repeated use when single use capsule was preferable [8]. Other complications were also encountered. For example, the pill was allowed to move freely through the digestive tract and as a result, the exact location of the pill was uncertain and the signal was often lost [6,9]. As a result of these drawbacks, early radio telemetry capsules failed to become a viable alternative to invasive techniques, such as manometry, as very little useful information could be gathered.

Invasive techniques such as manometry are time consuming, uncomfortable and embarrassing for patients. However, the exam is often an essential tool for the diagnosis of functional disorders in the GI tract, where no abnormality is visible but differences in bowel activity are measured. The implementation of micro-fabrication technologies has allowed the development of devices with decreased size and power consumption. Given Imaging Ltd., have taken advantage of these advances to produce their M2A capsule for the visualization of the GI tract and the diagnosis of structural disorders such as Crohn's disease or obscure gastrointestinal bleeding. The product is commercially available and uses a complementary metal oxide semiconductor (CMOS) imager to allow visualization of the oesophagus, stomach and small bowel. The capsule has shown itself to be capable of a higher diagnostic yield than invasive techniques and full visualization of the small bowel (not possible with invasive methods) can be achieved. The success of this capsule has lead to commencement of research and development of other capsules aimed at monitoring processes in the GI tract. A summary of the most recent projects involving the development of telemetry capsules and their purpose can be seen in Table 2.

This paper discusses the use of MEMS and thick film sensors for the measurement of pressure in wireless biomedical applications. There are some issues associated with MEMS devices, such as reliability, which need to be addressed. Despite this, MEMS technology has the potential to be utilized in a telemetry capsule.

## 2. MicroElectroMechanical Systems (MEMS)

The term MEMS refers to microsensors and actuators that can sense their environment and have the ability to react to changes in that environment with the use of microcircuit control [10]. MEMS pressure sensors are particularly useful for biomedical applications because of the capability for mass cost effective manufacturing, with on-chip circuitry, which improves their effectiveness [11,12]. Miniaturization is also an advantage as most MEMS devices are less than the size of a 50 μm human hair and can be used singly or in groups of millions [13].

MEMS sensors are employed in a variety of medical equipment, including intrauterine pressure sensors, angioplasty pressors, and catheter tip pressure sensors [14]. A new category of sensors termed BioMEMS has also become popular in recent years. BioMEMS includes two main types of sensors for use in medicine and surgery [14]. The first is biomedical sensors, which are used to detect biological substances. The second category is biosensors, which include any measuring device that contains a biological element. Potential applications include the monitoring of pH or glucose levels in blood.

To monitor pressure changes, capacitive sensors are preferred. They are suited to biomedical applications because

Table 1
Some early radiotelemetry pills, for monitoring pressure, pH and temperature in the GI tract

| Name | Power source | Capsule dimensions | Measurement type and range | Reference |
|---|---|---|---|---|
| Hans Noller | Battery | | Type: pH | [52] |
| Heidelberg pH capsules | Saline activate battery | 20 mm × 8 mm | Type: pH; range: pH 1–pH 7 | [52,53] |
| Rigel Research Ltd. | Mercury battery | 8.8 mm × 6 mm | Type: pressure; range: 0–40 kPa | [6,7,9] |
| Weyrad Electronics Ltd. | Mercury cell battery, lifetime of up to 9 days | 10 mm × 15 mm | Type: pressure; range: 0–24.13 kPa | [54] |
| Gaeltec Ltd. | | | Type: pressure | |
| CorTemp® | Silver oxide battery | | Type: temperature | [8] |
| Bravo pH system | | 6 mm × 5.5 mm × 25 mm | Type: pH; range: pH 1.68–pH 7 | [19,55] |