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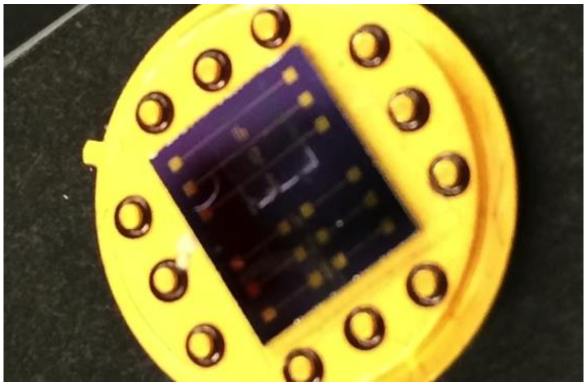
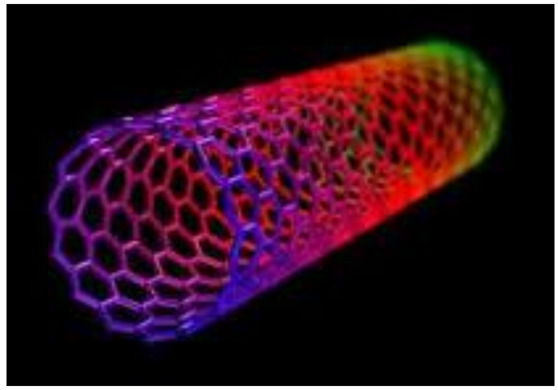
Case Study: Downhole flow sensor





The Problem

The BP oil spill of 2010 prompted companies in the oil & gas industry to explore technologies that would help increase the safety of drilling operations. Early detection of hazardous conditions in the downhole could help the driller take prompt corrective actions to protect the environment and save lives.

During oilwell drilling, the drill bit and drill string encounter a mixture (called gumbo) of rock cuttings, coarse and fine particles, gases, synthetic fluid, and liquids of varying densities. The composition of this mixture is an excellent indicator of the drilling conditions. It is essential to understand the composition, flow rate and pressure of the material encountered by the drill bit at downhole to indicate the presence of oil or to warn the drilling team of an impending harmful gas discharge. The oil industry, therefore, felt that there was a strong need for a flow sensor that can measure the pressure, flow rate, and phase of the mixture at downhole, and transmit this information to the driller in real time, so that any corrective actions can be performed. The information in conjunction with other downhole parameters, can also be used to increase the drilling efficiency.

However, developing and installing a downhole flow sensor was not an easy task. An efficient downhole sensor had to be capable of sustaining temperature variations from -50 to 300 degrees C, and pressure of up to 10,000 psi. The only available option for the companies was the Coriolis meter, the most widely used flow measurement sensor in the oil & gas industry. However, the Coriolis sensor is not suitable for downhole flow measurement because of its size,rig modifications required to install in downhole, loss of accuracy in downhole environment, and its high cost. Therefore, companies expressed the need for a smaller, more robust, and highly accurate alternative to the Coriolis sensor, prompting Quarkonics to investigate potential solutions.

The Solution

Quarkonics scientists researched the properties of a number of flow measurement devices in operation in different industries. After extensive analysis of the materials based on the three main criteria of robustness, size, and sensitivity, the carbon nanotube (CNT) material was identified to be the best fit among the possible candidates. Our scientists fabricated a 1 cm x 1 cm prototype chip containing a thin layer of carbon nanotube material connected to electrodes. When the CNT layer is exposed to a fluid or gas flow, a small current is generated in the chip. Changes in flow rates generate a corresponding change in the current produced. The chip can therefore be calibrated to accurately provide the flow rate of the material it came in contact with.

Carbon nanotubes are intrinsically resistant to changes in temperature and pressure due to the chemical composition of their molecules. To protect the electrodes, the chip is surrounded by a protective steel casing, only exposing the carbon nanotube layer to the downhole conditions. Laboratory testing results for the prototype indicate that the sensor can withstand the required temperature and pressure ranges. The sensor is also highly accurate, measuring the flow rate with only a + 1 / -1 Gallon per minute margin or error. The entire sensor assembly is small enough to fit inside the drill shaft. Therefore, no major design changes to the drill pipe are needed to install the sensor assembly, and the sensor can be installed at multiple points along the drill string for additional analysis.

Thus, the carbon nanotube based flow sensor can be a viable alternative to bulky Coriolis sensors in downhole conditions, help drillers identify hazardous conditions faster and make drilling operations safer and more efficient.

Key aspects of the downhole flow sensor:

- Sensor operates at a large temperature range and high pressure conditions.

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- Small size of chip and enclosures help with easy installation at multiple points in the drill shaft
- Sensor is impervious to mud and grease encountered in downhole drilling conditions.
- Accurate flow rate measurement of about +/1 Gallon per minute