Sensors & Devices @IIT Hyderabad

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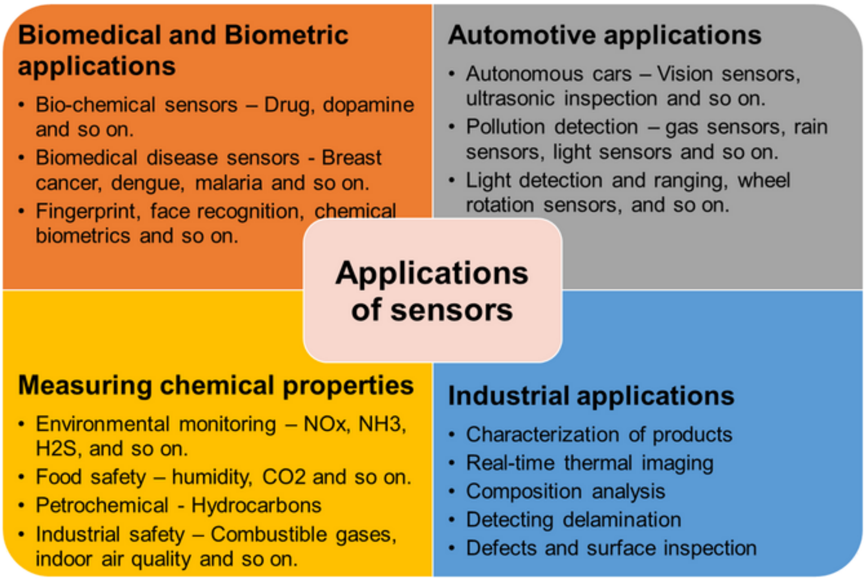
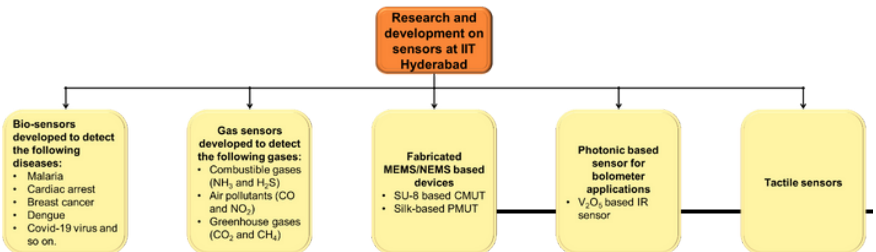
As we know, humans have five highly sophisticated natural senses (smell, taste, sight, touch, and hearing) and powerful mechanisms by which living systems interact with their surroundings. Also, each sense is highly sensitive and selective for target function to help living systems gather chemical or physical information from the surrounding environment. The remarkable properties of these natural sensors continue to inspire the development of new sensing technologies to detect various physical parameters in different applications that include biomedical and biometric applications, automotive applications, measuring chemical properties, and industrial applications [**Figure 1**].



On the other hand, the development of the Internet of Things (IoT) is expected to offer great potential to the sensor industry by connecting a large number of digitally augmented physical objects to the Internet. These objects, especially sensors, are connected everywhere and are of interest at all times.In this regard, a wireless sensor network (WSN)-based IoT platform is popular in modern monitoring systems, where a WSN is a collection of sensor and routing nodes that can be integrated in the environment to predict physical conditions for example wind, temperature, and many more. Here, WSN collects and processes data from routing nodes and then transfers it to operators. The emerging WSN-based IoT platform plays an important role in a variety of applications such as environmental monitoring, chemical and biological assault detection, home automation, aquaculture, oil industries, agriculture, health care, tactical surveillance and many more. Among all these applications, in today's world, WSN-based IoT platform can play a very crucial role in aquaculture, agriculture, environmental monitoring and health care applications because of continuous tracking and monitoring of the conditions of specific locations. To bring the WSN-based IoT technology to real life for the above important applications, the most critical component is the sensor, and it should be miniaturized, portable, highly sensitive and selective to its physical parameter, detection limit is in ambient concentration, high stability, and inexpensive.



Summary of research works on the development of sensors at IIT Hyderabad

However, existing sensor technologies have many limitations such as non-selective to target physical parameter, limited detection limit, non-portable, poor stability and expensive.

Therefore, we have started developing various types of sensors not only for the critical applications mentioned above but also for other applications. **Figure 2** provides a summary of the research work on sensors at IITH. Summary of research works on the development of sensors at IIT Hyderabad. All these research works have been published in international high-impact journals.

In recent years, due to rapid growth in population, increasing demands on quality of life, and increasing pressure on environmental protection have led to the initiation of social reform for a more intelligent lifestyle. The desire to create technologies that enhance awareness of the surrounding environment has led to further progress in the development of various types of sensors, and indeed, sensors work in almost all fields to make human lives more accessible and better.

Since the second half of the 20th century, chemical sensors and biosensors have become an indispensable part of modern society with wide applications in environmental monitoring, food products, industrial chemical production processes, pharmaceuticals, industrial safety, security, indoor monitoring, and healthcare applications.

In light of this, we have focused on the research and development of electrically transduced biosensors and gas sensors. Regarding the development of biosensors, we have developed easy-to-use, next-generation, ultrasensitive nano-biosensor and point-of-care diagnostic devices for detection of target-specific antibodies (malaria, cardiac arrest) and DNA hybridization (Breast cancer, Dengue etc.). Furthermore, we have developed an affordable artificial intelligence-based Covid-19 Home (COVIHOME) test kit to detect and produce results within 30 minutes for symptomatic and asymptomatic patients [**Figure 3**]. In contrast to bio-sensors, we are also developing gas sensors to detect different types of gases such as flammable gases (NH3 and H2S), air pollutants (CO and NO2) and greenhouse gases (CO2 and CH4). These sensors are highly sensitive with superior selectivity and detecting ambient concentrations. The developed sensors can be suitable for many applications including environmental monitoring, food safety, and fuel-based household appliances. In fact, we are not limited to the development of sensors at laboratory level but are working in the direction of bringing these sensors to production level for monitoring in real-time applications.

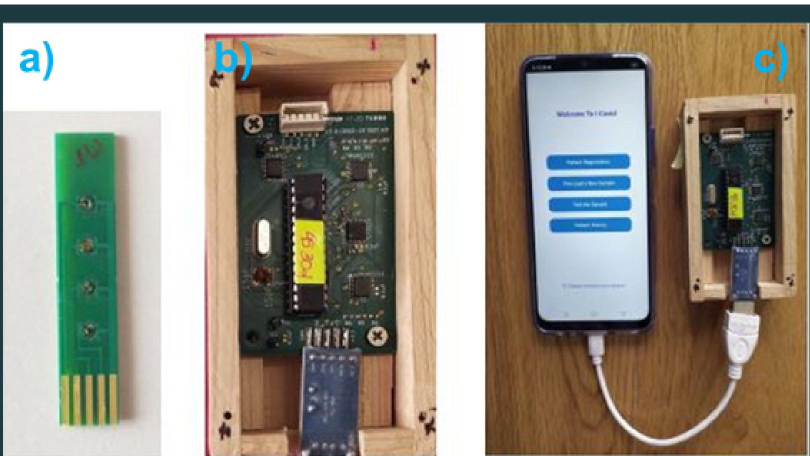


Figure 3 a) Sensor used for analysis. b) Readout circuit. c) Readout circuit connected to sensor and its interfacing with smart phone.

Moreover, we are working on the development of microelectromechanical systems (MEMS)/nanoelectromechanical systems (NEMS) and photonic based sensors. MEMS/NEMS based sensors have been instrumental in developing a robust and stiction free bulk micro machined process to achieve indigenous micro-bolometers, which are essential for developing thermal image camera, a long-standing dream of Indian defence and research embellishment. A reliable and robust MEMS hanging structure is a matter of significant concern, which often becomes the show-stoppers for micro-bolometer fabrication.

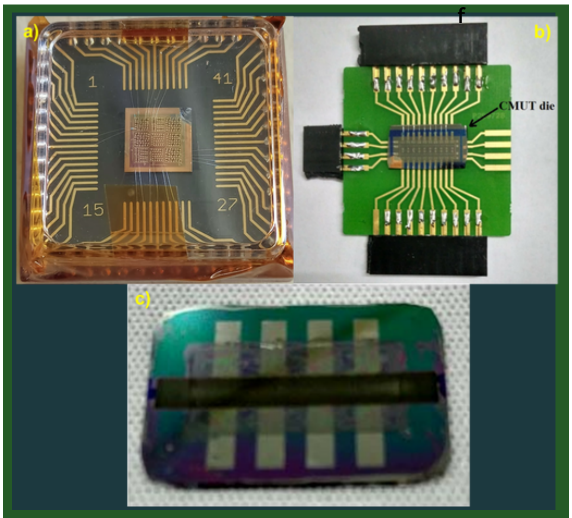
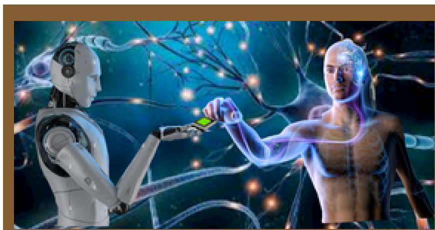


Figure 4. a) Fabricated device of Uncooled IR detector. b) Fabricated SU-8 based CMUT die with wire bonded on to the PCB. c) Fabricated device of Silk-based PMUT.

Towards this goal, an uncooled infrared (IR) detector based on vanadium pentoxide (V2O5) was fabricated and characterized thermally and electrically to determine their bolometric performance [**Figure 4a**].

In addition to that, we have successfully fabricated and characterized a SU-8 based capacitive micromachined ultrasonic transducer (CMUT) [**Figure 4b**] and silk-based piezoelectric micromachined ultrasonic transducer (PMUT) [**Figure 4c**]. Recently, we have started working on the development of tactile sensors for detecting external mechanical stimuli (e.g., strain, pressure, humidity, sound, and temperature), and measures the electrical signal corresponding to the mechanical stimuli [**Figure 4**]. Here, the electrical signal of tactile sensors depends not only on the relationship between the stimulus and the device properties but also on the stimulus properties. In detail, it provides data on the magnitude, shape, position, and distribution of forces derived from the tactile sense (stimulus properties). Currently, our goal is to develop a system that mimics human capabilities with the help of appropriate materials and signal-converting systems.

To this end, we are working on the development of a biocompatible silk thin-film based piezoelectric tactile sensor that can also be used for implantable applications.



Tactile sensor with human mimicking capabilities.

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