General Research Statement (2/2): Engineering for the Natural Sciences

Materials and Measurements in 'Quantum Engineering': Mathematics, Physics, Chemistry, Biology

Dear Esteemed Colleagues,

This letter of research statements is intended to summarize my current goals and interests in engineering and natural sciences. I also hope that this will also serve as a supplemental document to further explain my past experiences in scientific research.

1) Interests in Materials Science, Chemistry and Physics

A short, yet useful definition can be made for 'Quantum Engineering': Engineering within 'uncertainties' to make 'exact' scientific findings.

In my opinion, materials science serves a fundamental role in 'Quantum Engineering,' in ways that we can find new solid-state materials with different physical properties, which are open to many new applications.

My research experience of 15+ years has focused on synthesizing new materials for sensors and precision measurements, starting from basic chemistry (from raw materials) and growing crystals to be used in microelectronics fabrication of these sensors.

In the search of materials for new electronics, we can find different classes of materials: superconductors, semi-metals, semiconductors, insulators, which we can investigate in different applications in sensors and signal sources for measurement systems. To process these materials into working (micro)electronics we will be using various chemical methods and cleanroom techniques.

Therefore, I firmly believe that optimizing materials fabrication and experimental materials characterization techniques can be a purposeful direction for initiating new areas of Quantum Engineering and natural science research.

The 'Front-End' of an engineering application is where the 'user' is situated to have a meaningful outcome: I wish to collaborate with my colleagues in investigating and testing new electronic materials in different 'Front-End' engineering applications.

2) Electronics Fabrication, Application Specific Integrated Circuits and Systems

In the making of sensors and measurement systems, we should focus on the specific measurement type (such measurements could be: temperature, pressure, optical, RF, etc.) to match with a sensor and specific electronics directly tailored for the application.

We can use different electronic architectures depending on the specific application of the measurement system. For example, a regular camera system may require different features; a pixel array sensor, analog and digital electronics, and software. In this example, depending on the wavelength (energy) of the photons that we are interested in measuring, and depending on the imaging requirements, we may use different optical and electronic filters to acquire image data.

The efficiency of such imaging systems can be simulated and then fabricated in integrated circuits. Then, these systems can be tested in carefully controlled environments and optimized separately in the context of fabrication and for software specified for the use of the system. Finally, the measurement system may be tested in the Front-End application for an experiment (such as in an imaging system) in which the system will be re-optimized for its specific use.

3) Front-End Applications in Computing and Communications Systems

By engineering new electronics for precise measurements we can create such communications systems (and related computer technologies for accelerated information processing or physical control systems) that are only limited by quantum efficiencies of the physical transceivers and media of transmission. Following the above example of optical detection, we can encode (and also compress) information within light (such as spatial, spectral modulation) on which we can transmit communications or pioneer new computation schemes.

4) Front-End Applications in Biology and Medical Sciences

There are a lot of interesting applications in biology and medical sciences, such as in radiology or imaging, and in biosensor medical diagnostic systems. In bio-medical imaging systems, we may use a metrology system to take very-high resolution x-ray, optical or magnetic resonance images that can be combined with computer-vision analysis for medical diagnosis or prognosis of patients or for cell microscopy. We can engineer such systems with new materials and electronics to reduce cost and improve the applicability of these technologies. With new biosensor systems specifically made for molecular detection, we can improve ‘time to diagnosis’ in maladies such as cancer or communicable diseases. We can also improve auxiliary techniques in bioreactor controls or in genetic engineering, which play a vital role in food science and in drug development.

5) Front-End Applications in Energy Technologies and Sciences

In energy technologies, we can use similar detection systems for nuclear particle detection and diagnostics (in nuclear power plants, astronomy, research & development). By focusing on materials science, we can also engineer materials for solar cells, thermal and vibrational energy-harvesting, and other renewable energy technologies that can withstand harsh environmental conditions. We can also use such optical / electromagnetic detection systems for more traditional gas combustion technologies or liquid flow particle detection systems. Finally and importantly, materials can be engineered for battery technologies or power semiconductor relays that will work with vehicle or residential power systems.

6) Front-End Applications in Geographical Mapping and Transportation Technologies

In addition to vehicle power systems, we can use new materials technologies in measurement systems for vehicle ranging (radar, lidar) and accelerometers/gyroscopes in combination with computer-vision technologies for (semi or fully) autonomous vehicle navigation – adjusted within electronic control units. These technologies can be used in geographical mapping in combination with other sensing technologies.

In conclusion, I intend to set up a network of collaboration of people that are interested in working on the above subjects. In my new workplace, I will create a research laboratory to investigate experimental and related theoretical aspects of new applications of materials science and electronics to solve long-term problems in science and engineering. Scientific findings will be published in journals to share information with the scientific community, and engineering results will be patented and partly commercialized in industrial products.

Sincerely,
Rahmi Orhon Pak, PhD