Improving Chemisensor Reliability using Machine Learning

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Ion-sensitive field-effect transistors (ISFETs) have emerged as indispensable tools in chemisensing applications due to their remarkable precision and accuracy that comes in conjunction with a highly scalable design. ISFETs operate by converting changes in the concentration/composition of chemical solutions into electrical signals, making them ideal for environmental monitoring, healthcare diagnostics, and industrial process control. However, the reliability of ISFETs is impeded by various non-ideal factors including cycle-to-cycle, sensor-to-sensor, and chip-to-chip variations arising from manufacturing processes, material properties, and environmental conditions. These challenges hinder the widespread adoption of ISFETs in commercial applications. In this study, we leverage the capabilities of machine learning (ML) algorithms to address the challenges mentioned above, using nonfunctionalized graphene-based ISFETs as a testbed. We utilize pH-sensing as a benchmark to illustrate the advantages of integrating ML algorithms with ISFET sensors before demonstrating the ability of the sensing platform to discern instances of food fraud, food spoilage, and food safety concerns. Furthermore, we assess various human-derived figures of merit (FOMs) that are directly linked to the transport properties of graphene-based ISFETs and correlate these human-derived FOMs with regions of interest obtained from maximally activated nodes in artificial neural network (ANN) models trained on the same datasets. We anticipate that the fusion of compact, energy-efficient, and reusable graphene-based ISFET technology with robust ML algorithms holds the potential to revolutionize the detection of subtle chemical and environmental changes, offering swift, data-driven insights across a wide spectrum of applications.