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Stress in Three-Dimensionally Integrated Sensor Systems

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The ability to incorporate gas sensing devices into always-on wearable technology such as smart phones, tablets, and wrist watches will revolutionize the environmental health and safety industry by providing individuals with a convenient way to detect harmful chemicals in the environment. Although thin metal oxide films have shown their gas-sensing ability, several challenges must still be overcome in order to enable full CMOS integration with bearable production costs. The drive for CMOS integration has led to the implementation of novel techniques for the deposition of the sensing layer and the three-dimensional integration using Through-Silicon-Via (TSV) technology. The fabrication of these complex structures leads to the generation of stress in the metal and metal-oxide layers. This stress is a result of two components: the intrinsic stress, which arises during film deposition, and the thermo-mechanical stress, which develops when cooling down from the deposition temperature to room temperature. Sputtering has shown to be a potential deposition technique for metal oxides; however, the resulting layers experience an intrinsic compressive stress in the GPa range. When a cost effective alternative of spray pyrolysis is used for deposition, the experienced intrinsic stress can be significantly reduced. The thermo-mechanical stress is caused by differences in the coefficients of thermal expansion between the deposited material and the underlying silicon or oxide. This source of stress can significantly degrade the performance of TSVs, especially when Deep Reactive Ion Etching (DRIE) is used to etch through the wafer prior to metal deposition. This etching technique results in scallops along the TSV sidewalls, modifying the stress behavior of the deposited conducting metal. Through simulations, invaluable information is obtained about the stress development in the essential metal and metal oxide layers required for the fabrication of CMOS-integrated gas sensors.