Cryogenic Temperature MOSFET Device Performance Simulation and Optimization

Hari Shanker Gupta, A S Kiran Kumar, Dinesh K Shrama
Space Applications Centre, hari@sac.isro.gov.in

Infrared detectors need to operate at very low temperatures – often at liquid nitrogen temperature in the vicinity of 77K. Silicon Read-Out Integrated circuits (ROIC) are bonded with these detectors and therefore, these too need to operate at low temperatures. However, it is very difficult to predict MOSFET device operation at ultra-low temperature i.e. around 77K. Commonly available BSIM3V3 MOSFET models are adequate for simulation only in the 218K to 398K temperature range. The model library available from the foundry used by us (United Microelectronics Corporation – UMC) is valid down to −55°C or to 218K. The existing models do not adequately reproduce the cryogenic temperature characteristics of the MOSFET. This is because the foundry provided BSIM3V3 Level 49 models do not consider the low temperature effects. This paper discusses modeling and characterization of MOS transistors at low temperature in detail and proposed a method to simulate and test our designs for operation in the vicinity of liquid nitrogen temperature (≈ 77K). We have developed an engineering solution which can predict circuit performance down to cryogenic temperatures. A test chip consisting of different MOSFET geometries has been fabricated and characterized at cryogenic temperature. The variation in the measured performance at cryogenic temperature has been extracted. The method was used for simulation of Read out Integrated Circuit (ROIC) to estimate its performance at cryogenic temperatures. The method is capable of predicting the performance of ROIC at 77K which matches with experimentally measured results within 10% tolerance. The models further applied for the simulation of critical design parameter of Read out Integrated Circuit (ROIC) to estimate its simulation performance at cryogenic temperature. The model provides predictable integrated simulation performance of ROIC at 77K and matches with experimental results.