Ultimate limits in high-temperature operation of semiconductors (not just SiC)

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There are applications with such high operating temperatures that established silicon electronics does not survive long enough to handle the task. Fortunately, silicon carbide (SiC) and gallium nitride (GaN) could replace silicon in these applications. After twenty years of SiC research, both the material quality and device performance has improved. Now is the time to prove that SiC electronics can handle extreme environments (high temperature and radiation). We have already demonstrated digital [1] and analog [2] circuits in SiC operating at 500 °C at KTH. Some initial testing with irradiation of components and circuits has been done with good results [3]. This can lead to electronic applications in extreme environments such as space research, oil and gas drilling, jet and combustion engine monitoring and nuclear energy. However, already at 600 °C most metallization systems prove difficult to maintain without detrimental alloying reactions.

Testing high-temperature operation remains a challenge: the elevated fields and temperatures that are used to test silicon electronics are the same or lower than the operating conditions for SiC electronics in some cases. Moreover, this destructive testing consumes many components as errors occur with a statistical distribution in time. This means that we must develop new test methods based on semiconductor physics while at the same time improving the manufacturing process. This talk will discuss physical theory and methods for accelerated lifetime testing of electronics for temperatures > 225 °C and environments with ionizing radiation.

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2. R. Hedayati, L. Lanni, S. Rodriguez, B. G. Malm, A. Rusu, and C.-M. Zetterling, "A monolithic, 500 °C operational amplifier in 4H-SiC bipolar technology", *IEEE Electron Dev. Lett.* **35**, 693 (2014).
3. S. S. Suvanam, L. Lanni, B. G. Malm, C.-M. Zetterling, and A. Hallén, "Effects of 3 MeV protons on 4H-SiC bipolar devices and integrated OR-NOR gate", *IEEE Trans. on Nucl. Sci.* **61**, 1772 (2014).
4. See *www.hotsic.se*