Giant Conductivity Modulation of Aluminum Oxide using Focused Ion Beam

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Aluminum oxide (Al_2O_3) is an enabling material in many technologies, thanks to its exceptional mechanical strength and dielectric properties. Unlike semiconductors, giant increase in the conductivity of wide bandgap dielectrics, such as Al_2O_3, has not been reported. Here we present a versatile method for increasing the conductivity of Al_2O_3, with nanoscale resolution, by ~14 orders of magnitude. This method uses focused ion beam to pattern zones in Al_2O_3, with a controllable conductivity. We investigated the source of conductivity modulation, and identified trap-assisted conduction as the main charge transport mechanism. Temperature-dependency of the conductivity and optical characterization of the patterned areas offer further insight into the nature of the conduction mechanism. We also show that the process is extremely reproducible and robust against moderate annealing temperatures and chemical environment.
We believe that the record conductivity modulation, combined with the nanoscale precision in patterning conductive zones within the highly insulating, mechanically hard, chemically inert, and bio-compatible Al_2O_3 matrix could find broad applications in electronics, optoelectronics, and medical implants.