

Dear Editor,

Please find our uploaded manuscript “Quantum theory of electronic excitation and sputtering by transmission electron microscopy” that we are hereby submitting for consideration as an Paper in *Nanoscale*.

Electron beam irradiation by transmission electron microscopy (TEM) is an effective tool for defect engineering in 2-dimensional (2D) materials, potentially with atomic-scale precision. This degree of spatial control can provide powerful solutions to many of today’s most pressing challenges in nanotechnology, including quantum device fabrication, hydrogen evolution catalysis, and electronic device miniaturization. However, despite the broad application of TEM-driven defect engineering in materials science, current theoretical models fail to quantitatively describe defect formation rates, as the non-equilibrium physics taking place during irradiation remains poorly understood. Specifically, existing models drastically underestimate sputtering rates in insulators, in which beam-induced electronic excitations may weaken the bonding between the irradiated atoms. To address this anomalous behavior, this work develops the first quantum electrodynamics (QED)-based method to accurately describe electron beam-induced sputtering cross sections in 2D crystals by explicitly calculating the probabilities of beam-induced electronic excitations and their effects on sputtering kinetics. The consideration of excitations yields cross sections that quantitatively match experiment and correctly predict appreciable sputtering rates at beam energies previously predicted to leave the crystal intact.

We feel that this work is appropriate for *Nanoscale*, as it significantly advances the state of the art in modeling the response of nanomaterials to TEM irradiation. The QED-based prediction of excitation rates could also push efforts to simulate both TEM images and electron energy loss spectra towards a more analytical, quantum field theory-based direction. Lastly, we believe this new quantitative theory can help arm materials scientists and engineers with precise nanoscale control of any 2D material.

Finally, a preprint for this work is available on arXiv under identifier 2112.10002.

Thank you for your consideration.

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