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Machine Learning Classification of Silica Glass Jewellery Beads for Thermoluminescence Dosimetry

For personal radiological health monitoring, thermoluminescence dosimetry (TLD) provides a method to estimate the absorbed dose for an individual over a specified time interval. A dosimeter captures and traps ionised electrons, which, when heated, release the trapped electrons via electron-hole recombination, through an emission of light called a glow curve. For TLD, the material's composition, features and the readout heating parameters affect the glow curves'characteristics, which should be proportional to absorbed dose. While trapped, the electrons can be released early due to tunnelling, material defects, and early thermal excitation, thereby compromising an accurate measurement of absorbed dose. With an ever-growing nuclear industry, new dosimetry materials and efficient analysis techniques remain an active research field.

The research presented explores the application of machine learning (ML) for advanced glow curve classification, specifically advancing past work into the use of micro silica glass jewellery beads as retrospective body and extremity TL dosimeters. A seed training dataset containing 1016 glow curves is formed of 348 LiF:Mg,Ti TLD-100 chips, 333 LiF:Mg,Cu,P TLD-100H chips and 335 silica beads with varying colours and sizes, alongside varying isotopes, doses and various heating parameters. This is injected into two ML frameworks: a random forest classifier (RFC) and a convolutional neural network (CNN). To further enhance this analysis, four sub-datasets were created, amplified using data augmentation techniques to 10,160 and 101,600 on raw and Gaussian-filter smoothed glow curves. All model variants were tested to classify the sample names and colour, with all the RFC-variants producing accuracy, precision, recall and F1 scores > 0.9 and the 1D CNN-variants outputting accuracies of > 0.86 with precision, recall and F1 scores > 0.8 for sample names and mixed scores for colour. The adoption of image classification is supported for accurate sample colour classification, enhanced further within a multi-modal framework in ensuing development.

Future work aims to elucidate the relationship between the underlying material physics, physical kinematics and glow curve mathematical modelling using deconvolution. An ML model is envisaged to inform these complex kinematic parameters faster, more accurately and efficiently than current processes, exposing the hidden luminescence elements of a material under irradiation for the use of TLD. Providing an enhanced analysis of the glow curve structure and a precise calculation of absorbed dose for individual health monitoring within the nuclear sector.

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