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Surface Structure Modelling for Laser-Assisted Reduction of SEY

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Systems operating under vacuum conditions in the presence of alternating magnetic fields such as particle accelerators are susceptible to electron clouds thus limiting their performance. In the Large Hadron Collider (LHC), electron clouds are a consequence of a material with an undesired inherent secondary electron yield (SEY) in proximity to the beam path. In order to mitigate electron clouds, Laser Engineered Surface Structuring (LESS) can be used [1]. Although, the theoretical background regarding these structures is not fully understood and there isn't a complete model which can predict the energy-dependent SEY corresponding to these structures [2].

Here, Furman's model [3] is implemented and developed via commercial software CST Particle Studio because it segregates electrons based on their energy which allows for better representing phenomena involved in LESS. The objective is to reproduce SEY-Energy curves of experimental data published on copper beam screens found in the LHC [1]. Complex structures with different aspect ratios, nanoparticle densities and unique surface chemistry were investigated in order to offer insight and determine the relationship between LESS and SEY. When reducing the SEY, current models available capture the reduction, however lack the ability to predict the shape of the curve. Generally, the curve will resemble the shape of copper (Fig 1 (a), black) but reduced. This is not the case according to experimental data, where the curve plateaus and the maximum SEY (δ_{max}) is shifted to a higher energy.

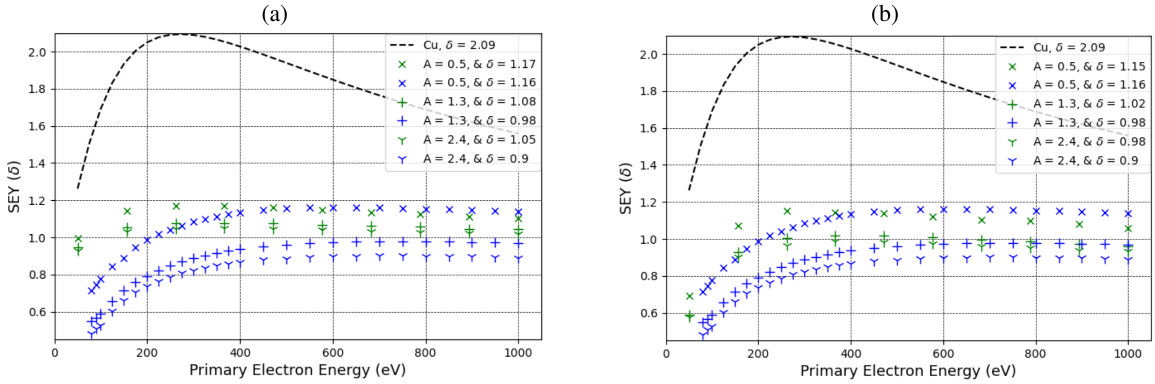

Fig. 1 (a) SEY-Energy curve of LESS modelled, (b) LESS model parameters optimised, blue points depict experimental data and green refers to simulated data, δ is the SEY and A is the trench aspect ratio (i.e., height/width), see [1].

Consider Fig. 1 (a), the curve shape is captured with a maximum error of up to 15% for δ_{max} values. Insights from modelling suggest this margin could be attributed to the surface chemistry of the nanoparticles as the numerical data is a result of only "as received" copper surface chemistry which is not the case after laser processing [4], as well as nanoparticles in general. If attention is focused on the higher energy section, one notices that the plateauing behaviour of the curve is modelled effectively. Modelling suggests this behaviour is mostly mechanical, i.e., due to the slanted lateral walls of LESS and nanoparticle hemispherical geometry favouring higher energy electrons due to the SEY angular dependency phenomena as well as a "trapping" effect which induces successive collisions, limiting survival of lower energy electrons. Because SEY is a measure of the ratio of a sample's emitted current (I_e) to the collision current (I_c), when δ_{max} energy electrons interact with such features they generate many electrons (resulting in a high I_e), these secondary electrons have low energy and may often be reflected causing an increase in I_c relative to I_e. This behaviour reduces the effectiveness of δ_{max} energy electrons and causes higher energy electrons to have similar SEY. The shift in energy of δ_{max} is attributed to both surface chemistry effects due to the unique SEY-energy dependency of different compositions of materials and the nanoparticles which have the ability to increase backscattering yield [5], thus increasing escape probability of energetic electrons. By adjusting the model to reduce the yield of low energy electrons due to surface chemistry and a slight increase in backscattering yield due to nanoparticles, one captures a better representation of the SEY curve (Fig. 1 (b)).

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