Physics & Astrophysics Colloquium

Probing Electrical Properties of A Silicon Nanocrystal Thin Film Using X-ray Photoelectron Spectroscopy

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4:00 PM Friday, October 7, 2022, Room 211, Witmer Hall

Abstract:

X-ray photoelectron spectroscopy (XPS) is a powerful tool for extracting the chemical, physical, and electrical properties of surfaces and interfaces. Since XPS is a noncontact and mostly a non-destructive technique, it has been used to probe the electrical properties of materials while maintaining the inherent chemical specificity of XPS. Ideally, during an XPS measurement, the net sum of electrons coming into and leaving the sample should be zero, leaving the sample charge neutral. This is achieved by grounding the sample to the spectrometer ground. Therefore, any changes in binding energies are attributed to the chemical potential and polarizability of compounds. These chemical shifts are used to identify the state of the elements. When a DC or an AC external bias is applied to a conducting sample, the shifts in binding energies are equal to the applied external bias. However, for insulating samples, grounding the sample cannot prevent the accumulation of positive charges on the surface which causes differential charging. For a long time, differential charging has been considered a hindrance. Electron flood guns have been utilized to control and reduce the effect, but the complete elimination of differential charging is difficult, and if not done properly it can cause the accumulation of negative charges on the surface leading to erroneous interpretation. However, differential charging can also be employed to study the structural and electronic properties of dielectric films, where equivalent circuit models have been proposed to extract the capacitance and resistance from the observed shifts in binding energy with applied external AC or DC voltage. These previous attempts to determine capacitance rely on time-dependent protocols with external control of the applied bias and analyzer by using data acquisition cards. Therefore, they face with limitations when the time constant of the RC circuit is comparable to the dwell time. To overcome these issues, we propose an alternative method to extract the capacitance of the thin film. The advantage of this method is that closed-form mathematical equations are derived to model binding energy shifts as a function of applied bias. By using this method, a basic curve fitting algorithm can be used to extract the resistances and capacitances of thin films. Si nanocrystals (SiNCs) were chosen to test the proposed analysis method. Semiconductor nanocrystals have been at the epicenter of recent research for a wide range of potential applications ranging from photovoltaics and fluorescent contrast agents to color displays such as QLED TVs. The measurement consists of the application of $10\ V$ DC or square wave pulses of $10\ V$ amplitude to the sample at various frequencies ranging from $0.01\ Hz$ to $1\ MHz$ while recording X-ray photoemission data. To analyze the data, we propose three different models with varying degrees of accuracy. The calculated capacitance of SiNCs agrees with the experimental value in the literature.

Refreshments at 3:30 PM in Witmer Hall, Room 215

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