Revealing the Correlations between Growth Recipe and Microscopic Structure of Multi-alkali Photocathodes

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Multi-alkali photocathodes are the workhorses and golden standards for industrially produced cathodes. They are grown in cost-effective thin-film technology permitting the use of a wide range of amorphous and polycrystalline substrates. The growth process parameters are chosen by heuristically optimized recipes which typically are proprietary. The resulting quantum efficiency (QE) of the detection devices is widely varying between 20% and 25% for typical detector systems and up to 42% for newly developed high QE detectors. Quantum efficiencies of up to 60% were even reported for one-of-a-kind cathode-systems. Our goal is to explain these variations by cross-correlating the microscopic and chemical compositions of the cathode film with the individual process steps and ultimately to develop a theory-inspired growth recipe which results in high quantum efficiency, wavelength tunability, and is compatible with conventional process technology in industry.

To achieve these objectives it is essential to visualize the microscopic structure, chemical composition, and speciation of the film during the execution of the growth recipe in real time. Using an in-situ X-ray diffraction (XRD) setup, we are able to analyze the crystal structure of the film, e.g. the identification of coexisting crystalline phases, their quantitative analysis, the determination of the crystallite sizes, and a preferential growth or texture if existent. By combining state-of-the-art detector technology and high flux x-ray beamlines at synchrotrons we are not only able to achieve a time resolution of 100ms or better but also perform grazing incidence techniques which allow a depth probe of the film. The achieved data quality in combination with the time resolution allow us to characterize all changes inside the cathode during the processing, including interdiffusion of the alkali metals into the antimony matrix, the solid state reactions of the alkalis with the antimony to the different inter-metallic compounds and to determine the individual time constants of these processes.

In our talk we will provide a short introduction to in-situ XRD techniques followed by an exemplary investigation of a standard growth recipe for a CsK_2Sb-cathode. The movie-like information on the temporal changes of the structural and chemical composition will be discussed in context of the cathode functionality and will demonstrate how the recipe should be modified to achieve enhanced quantum efficiency.