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30 keV Ga^+ FIB Induced X-Rays (FIBIX) of Conductive Materials

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Particle induced X-ray emission (PIXE) is a well known characterization technique which typically uses a beam of light energetic ions (i.e., protons between 2- 5 MeV) to create inner shell electron vacancies, ultimately resulting in the emission of characteristic X-rays [1]. It is also well known that characteristic X-rays can be created with high probability even at collision energies from slow, heavy ions, where the incident ion velocities are small compared to the velocities of the inner-shell electrons [2-11]. Since heavy ion bombardment in this energy range is dominated by nuclear collisions, momentum transfer of an incident heavy energetic ion to lighter target atoms can result in recoils with higher velocities than the incident ion. Thus, a significant percentage of the X-ray generation due to heavy ion bombardment can be attributed to the recoils in the collision cascade, especially when the incident ion is heavier than the target atoms. A molecular-orbital level crossing model was proposed to explain this phenomenon [10]. For some ion-target combinations, energetic recoils may account for the majority of all emitted X-rays.

Giannuzzi [12] recently reported on the emission of characteristic X-rays from (i) NIST glass standards 1872 and (ii) an Al sample induced from 30 keV Ga^+ focused ion beams and coined the phrase FIBIX to differentiate X-rays induced from MeV ions. It has since been recognized that the spectra obtained from the insulating glass standards included spurious X-rays due to tertiary electrons as a result of charging artifacts [13]. However, the Al Kα signal from the well grounded metal conductive sample (i.e., figure 7 in the ref. 12) was indeed consistent with the production of characteristic X-rays from heavy ion bombardment. In particular, the Bremstrahhlung was quite small and had a value of zero in some energy channels. The observation of the extremely low background was consistent with the theory of heavy ion X-ray generation.

Recently, we have shown that X-rays can be generated from a well grounded stainless steel using standard DualBeam instrumentation and EDS detectors, illustrating that velocity matching for ion induced X-rays to be generated is not required [14]. Below is another example of a FIBIX spectra obtained from a well-grounded $YBa_2Cu_3O_7$ sample bombarded with 30 keV, 20 nA, Ga^+ ions. FIG. 1 shows a full scale and enhanced scale FIBIX spectrum from the $YBa_2Cu_3O_7$ sample. The characteristic X-rays are easily observed above the very small background. Note that the spurious Al X-ray signal is from the sample stub and the Fe X-ray can be attributed to the pole piece. The probability cross-section increases for soft X-rays. Thus, the oxygen K edges are not resolved and the broad low energy peak < ~ 1 keV is likely due to the superposition of several low energy L,M,N, and O transitions. As per previous observations of heavy ion induced X-rays the likely mechanism of X-ray formation is due to energetic recoils [15].

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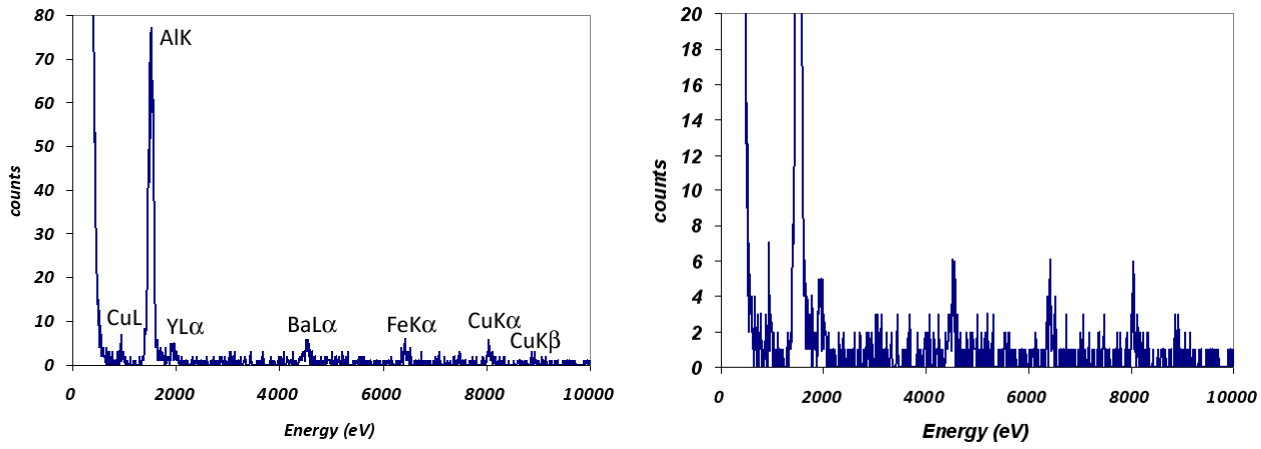

FIG. 1. (Left) Full scale and (right) enhanced scale FIBIX spectra from YBCO sample showing all characteristic X-rays above a very small background.

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