

Sputtering of Organic Materials with a C_{60}^+ Ion Beam

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Depth profiling is one of the most important analytical capabilities of surface analysis techniques such as X-ray Photoelectron Spectroscopy (XPS) Auger Electron Spectroscopy (AES) and Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS). This involves repeatedly cycling between an ion beam sputtering phase and an analysis phase. Each successive cycle provides an analysis at incremental depths into the solid material. By choosing the appropriate sputtering conditions (e.g. beam voltage, beam current, raster size and sputter time) a depth profile can be acquired over depths ranging from only a few nm's to a few μm 's. The use of depth profiling for elemental analysis has been in widespread use for over 30 years. During this time, atomic ion beams have been used for nearly all depth profiling experiments. The use of atomic ion beams works well for sputtering inorganic materials. However, atomic ion beams do not work well for sputtering organic materials because they cause excessive sputter induced damage to the chemical structures, resulting in a highly reduced carbon-rich layer at the bottom of the sputter crater.

In recent years, C_{60}^+ ion beams have been used to sputter a wide variety of organic materials. Through the use of molecular dynamic simulations, a conceptual picture of cluster ion sputtering has emerged [1]. The mechanism of cluster ion sputtering is very different from atomic ion sputtering. When a C_{60}^+ ion strikes the surface of an organic material, the carbon atoms break apart and create 60 different collision cascades simultaneously in the same localized area. This simultaneous motion of so many atoms around the impact site causes an explosion of material and leaves behind very little damage to the underlying organic structure.

The ability to sputter organic materials without significant accumulated damage to organic molecular structures has been a major breakthrough. The use of C_{60}^+ sputtering has enabled molecular depth profiling by both XPS [1] and TOF-SIMS [2]. Figure 1 shows the XPS C1s and O1s spectrum of Teflon after sputtering to various depths with 500 eV Ar^+ and 10 keV C_{60}^+ . The chemical states of oxygen and carbon and the C/O stoichiometry are clearly degraded under Ar^+ sputtering while both the chemical states and stoichiometry are maintained under C_{60}^+ bombardment. Figure 2 shows a comparison of quantitative XPS depth profiles of Nafion 117. This comparison shows that under low energy Ar^+ sputtering the Nafion composition becomes increasingly carbon rich due to the loss of O, F, and S. On the other hand, under C_{60}^+ sputtering the chemical composition of Nafion remains intact. This ability to sputter organic materials while maintaining the chemical composition is unique to cluster ion sputtering.

References

- [1] Z. Postawa, B. Czerwinski, M. Szewczyk, E. Smiley, N. Winograd, and B. Garrison, *J. Phys. Chem. B*, 108 (2004) 7831.
- [2] N. Sanada, A. Yamamoto, R. Oiwa, and Y. Ohashi, *Surf. Interface Anal.* 36 (2004) 280.
- [3] C. M. Mahoney, *Mass Spectrometry Reviews* DOI 10.1002/mas.20233 (2009).

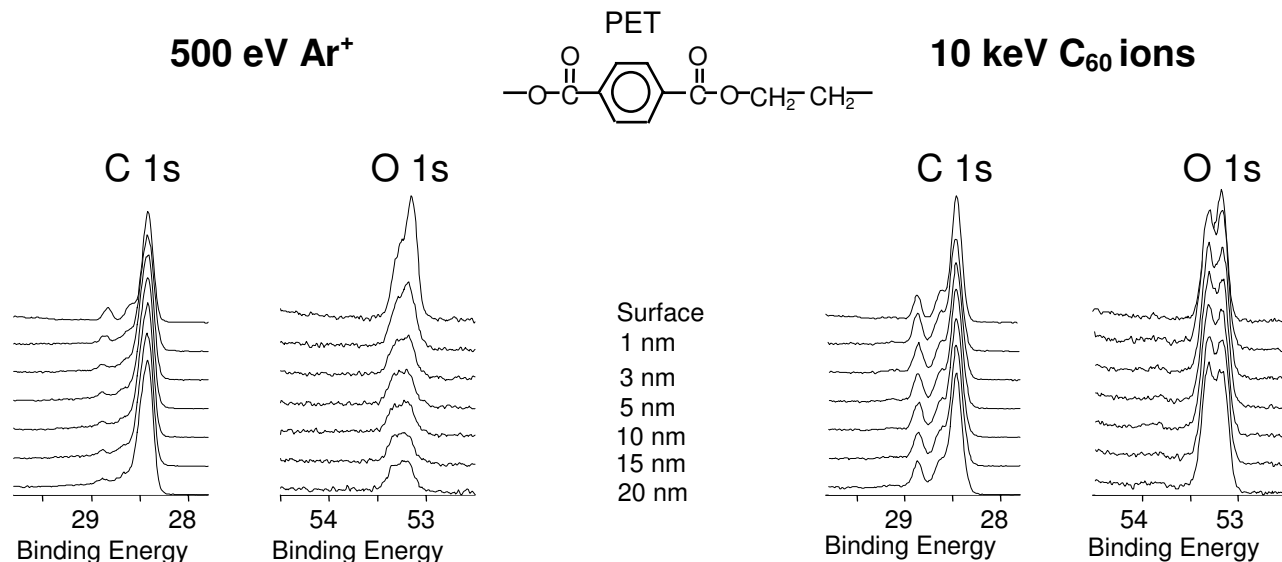


FIG. 1. XPS analysis of the C1s and O1s peaks of PET as a function of depth using 500eV Ar⁺ and 10 keV C₆₀⁺ sputtering.

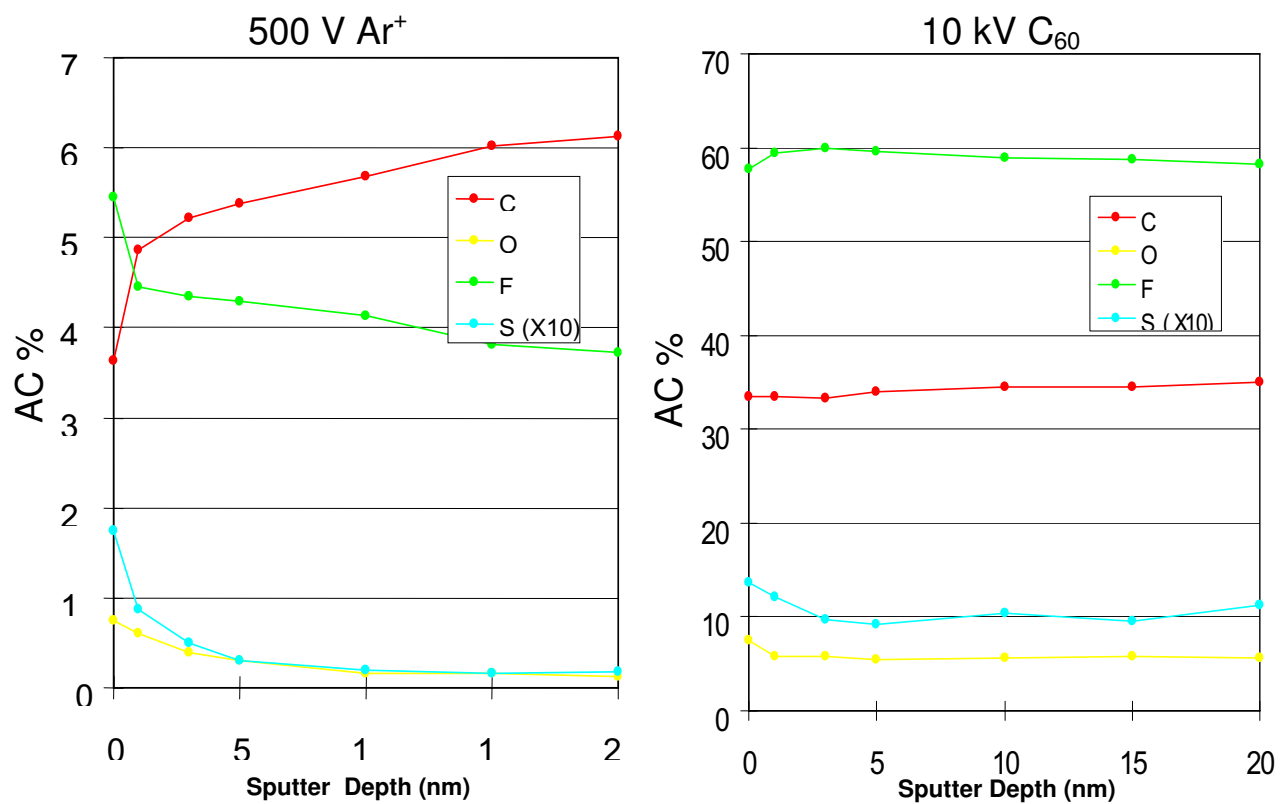


FIG. 2. Quantitative depth profiles of C, O, F, and S from a Nafion film under Ar⁺ and C₆₀⁺ sputtering.