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Oxygen Instabilities and the Electronic Properties of Oxide Tunnel Barrier Layers.

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Very thin AlO_x layers, usually formed by the controlled dose, RT oxidation of the surface of Al thin films, have long been the most successful and most reproducible approach for the fabrication of high-quality superconducting Josephson junctions, as well as for the formation of the gate-insulator for myriad non-conventional electronics studies. AlO_x has also been widely employed as the barrier in magnetic tunnel junctions (MTJs). In recent years, however, it has become clear that for demanding applications, most notably Josephson junction qubit devices, the performance of the AlO_x barrier layer is far below what is needed, particularly with respect to 1/f noise behavior; a determination that has given new urgency to the task of better understanding and significantly improving the properties of this barrier layer material, or of developing a better alternative. I will describe the results of a series of scanning tunneling spectroscopy, XPS and electronic transport studies on ultra-thin AlOx layers, in both half-formed and fully-formed junction configurations. These results demonstrate the inherently unstable nature of a significant portion of the oxygen component of the oxide. As the result of this instability, the process that forms a completed AlOx tunnel junction is much more complex than the reproducibility of the process might otherwise suggest. I will compare this character of amorphous AlOx barrier layers with the oxygen stability in crystalline MgO layers such as are currently being employed in MTJs, and on the basis of these findings discuss some approaches that might lead to more stable, lower noise Josephson junctions. Finally I will discuss some preliminary results that suggest that a low T tunnel-junction 1/f noise level that is much more than 10x less than the best that has been reported to date may indeed be achievable.