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Integration of Ferroelectrics, Ferromagnets, and Multiferroics with Silicon

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In this talk I will describe the epitaxial integration of ferroelectrics, ferromagnets, and materials that are both at the same time, with silicon. Until recently, "oxide" could only mean one thing to anyone working in the semiconductor industry—SiO_2. But oxides are an exciting class of electronic materials in their own right. Oxides exhibit the full spectrum of electronic, optical, and magnetic behavior including many functionalities not found in conventional semiconductors. Further, such oxides can be combined epitaxially not only with each other, but epitaxially with the workhorse of semiconductor technology, silicon, enabling the unparalleled variety of physical properties of oxides to be exploited in new ways for electronic applications. The specific oxides that my collaborators* and I have integrated epitaxially with silicon include EuO, ZnO, $CaTiO_3$, $SrTiO_3$, $BaTiO_3$, $BiFeO_3$, $Pb(Zr,Ti)O_3$, and $PbMg_{1/3}Nb_{2/3}O_3$-$PbTiO_3$. Highlights from these systems will be presented. * The work reported was performed in collaboration with the groups of Jochen Mannhart (U. Augsburg), Chang-Beom Eom (U. Wisconsin-Madison), Ramamoorthy Ramesh (Berkeley), Jeremy Levy (U. Pittsburgh), David Muller (Cornell), Xiaoqing Pan (U. Michigan), Jürgen Schubert (Jülich), Long-Qing Chen (Penn State), Susan Trolier-McKinstry (Penn State), Yves Idzerda (Montana State), Peter Böni (TU München), Joseph Woicik (NIST), Philip Ryan (Ames), Michael Bedzyk (Northwestern), Yuri Barash (Russian Acad. Sci.), Qing Ma (Intel), and Hao Li (Motorola).