"Smart" Near-Surface Nanocomposites Formed Using Ion-Beam Techniques: New Physics and New Materials

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Recent investigations at ORNL have shown that "smart" or "active" nanocomposite surfaces can be formed on otherwise inactive ceramic hosts through the use of ion implantation and thermal processing to form embedded nanophase precipitates whose properties change either at a phase transition or in response to an external perturbation. The applicability of this approach to forming active near-surface nanocomposites was initially established by implanting vanadium and oxygen ions, followed by a thermal treatment, in order to create nanophase VO_2 precipitates that were embedded in single-crystal Al_2O_3. At a characteristic temperature, the embedded VO_2 precipitates undergo a semiconducting-to-metal phase transition that provides the physical mechanism for the creation of an active surface layer. This ion-implantation and thermal-processing concept is also applicable to the creation of near-surface nanocomposites consisting of magnetic precipitates embedded in oxides, and the approach has been used to produce embedded nanophase particles of Fe, Fe_3O_4, Co, and Ni in various oxide hosts. The resulting nanocomposite surface exhibits a unique combination of characteristics including a new type of magneto-optical effect via magnetic circular dichroism. In addition to the interesting physical phenomena exhibited by complex surfaces consisting of active nanophase precipitates embedded in a host, there are numerous opportunities to extend this approach to the formation of a variety of devices (e.g. optical switches, modulators, sensors, etc.) in thin-film, fiber-optic, and integrated-device configurations.