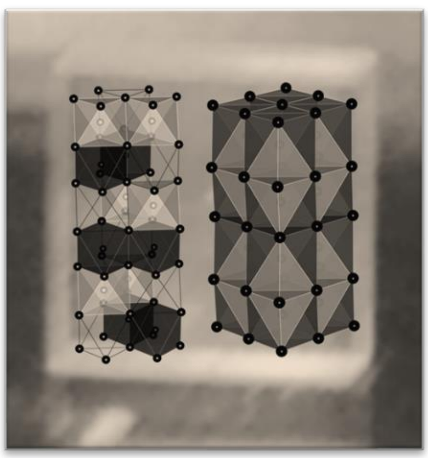
Rare-Earth-Free Magnetic Thin Films from Common and Affordable Elements for Semiconductor Industry by Advanced Manufacturing

Helsinki, Finland, September 6th, 2019 - Recent study conducted by Reciprocal Engineering – RE Ltd. and the Center for Nanophase Materials Sciences researchers at Oak Ridge National Laboratory shows that thin layers of high-temperature ferromagnetic insulators can be manufactured from Mg, Ti and O. Oxygen arrangement is the same as in the common, non-magnetic $MgTiO_3$ yet the films exhibit distinct magnetic behavior, due to the different Mg and Ti arrangement and quantity. Combination of ferromagnetism and electrical insulation facilitates information processing with minimal losses – a key requirement in electronics.

Same Stoichiometry - Different Atomic Arrangement - Different Magnetic Properties



The magnetic and electric properties of Mg-Ti-O films can be controlled by adjusting the filling of oxygen octahedra by Ti and Mg.

Magnesium titanate - a well-known paramagnetic insulator - has a formula $MgTiO_3$. $MgTiO_3$ exhibits no remnant magnetization: after the external magnetic field is removed, the material is not magnetized. In contrast, magnets holding notes on a refrigerator door are permanently magnetized. Though $MgTiO_3$ finds applications, for instance in microwave devices, there is much more one can do with contemporary *manufacturing* techniques operating *at nanoscale*. The study demonstrates how structural degrees of freedom - the fraction of filled octahedra and the cation arrangement in the octahedra - can be applied to tailor the properties of Mg-Ti-O thin films. By adjusting the Mg/Ti atomic percentage ratio to differ from one introduces electrically insulating thin films with reversible magnetization. For a given elemental ratios there are infinite number of ways to arrange the Mg and Ti cations within the octahedra, resulting in different magnetic characteristics. Fortunately, it is possible to find many - if not all - technologically valuable ferro-, ferri- and paramagnetic arrangements.

Technical applications

Applications include magnetic field sensors, spin filters for spintronic devices and memory devices consisted of multilayer (stack) structures. *Example* device - one layer possesses a rigid magnetization (not aligned with external field), while the other layer possesses easily reoriented magnetization. The magnetic layers may need to be separated by a non-conductive, paramagnetic layer. Functioning *principle* - electrons transmission through the stack depends on the external magnetic field.

All layers can be grown from affordable non-toxic Mg, Ti and O: the flow of elements can be adjusted during the growth cycle so that several processing steps can be merged during multilayer device manufacturing. A further benefit comes from the fact that the octahedra network remains intact – enabling a fabrication of high-quality interfaces critical for *reliable* device performance. Materials are functional at and above room-temperature, eliminating cooling necessary in many pioneering devices applied, for instance, in quantum computers.

About Reciprocal Engineering – RE

Reciprocal Engineering – RE Oy is a Helsinki based company founded in 2017, which develops new sustainable magnetic thin film materials for semiconductor industry. Device manufacturers are urged to consider the origin of raw materials and their environmental impact – development of these materials is our specialty. The focus is on the crystal structure – property relationship. Advanced materials provide a route to more efficient and significantly smaller electronics without compromising the environmental aspects. Patents are pending for several new thin film materials.

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