A Short History of Topological Properties of Nanoscale Materials that Lead to the Idea of a Topological Periodic Table for Crystalline Materials

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Abstract:
Mendeleev's famous 1869 version of a periodic table of the chemical properties of elements is so fundamentally important that it is taught in high school. As the principles of quantum mechanics evolved, it became clear that the chemical properties described by the Periodic Table are a result of the periodic nature of electronic structure of the atoms. This periodic electronic structure also governs the compounds that are formed by the elements many of which are crystalline. Another classification of crystalline materials is metal, semiconductor, and insulator. To a large extent, electronic properties especially transport properties followed expected trends until early on the morning of April 2^{nd} 1980 (notice he avoided April 1^{st}) von Klitzing observed quantized steps in the Hall resistivity of a transistor with a very thin conducting channel known as a 2D electron gas (2DEG) at 4.2 K in a high magnetic field. Topological physics was used to explain the quantized conductance. Key to the discussion about the quantized conductance of a 2DEG is concept of the Berry phase of the carriers. A brief introduction to the Berry phase will be provided. Along comes graphene with low energy electrons that behave like nearly massless Dirac fermions instead of Schrodinger fermions. The low temperature, topological Hall transport properties of graphene and the unusual low energy (IR) optical properties of graphene with the constant 2.3% absorbance can be explained using the Dirac fermion picture for the low energy carriers. The search for other materials that exhibit resulted in the observation of Dirac fermion surface states with topological transport properties in topological insulators such as Bi_2Se_3. Topological properties have been observed in a wide variety of materials. Recently, an effort to develop a Topological Periodic Table bring the hope that the potential for a material to exhibit Topological Properties can be based on both non-spatial and spatial symmetry. This effort will be introduced.