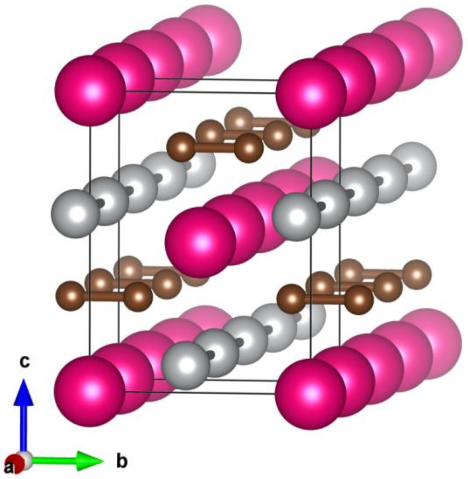
Description for the general public

Ternary nickel – rare-earth (R) carbides with a stoichiometry $RNiC_2$ were discovered more than three decades ago. Researchers did not expect how rich and fascinating this system would be. Depending on the rare earth metal, $RNiC_2$ can contain ferromagnetism ($SmNiC_2$), antiferromagnetism (eg. $NdNiC_2$), superconductivity ($LaNiC_2$ and $ThNiC_2$), and/or charge density waves (most of the family members including $SmNiC_2$).



$RNiC_2$ compounds form in a non-centrosymmetric orthogonal crystal structure *Amm2* (space group # 38) as shown in the figure. Important features of this crystal structure are Ni (grey atoms) and rare-earth (red atoms) chains along the crystallographic *a*-axis, and also carbon dimers along the *b*-axis.

It was shown that charge density waves (CDW) are centered on the Ni atoms and are easily detected by a sudden change of the resistivity observed during cooling. For $SmNiC_2$ a CDW state forms at 152K and further cooling reveals ferromagnetism at 17K. Remarkably, the CDW dissapers below the Curie temperature.

A main objective of the project is to investigate a relationship between charge density waves and antiferromagnetism in $NdNiC_2$ and $GdNiC_2$. The immediate motivation for the proposed research is the presence of a different type of magnetic ordering: ferromagnetism (FM) for $SmNiC_2$ and antiferromagnetism (AFM) for $NdNiC_2$ and $GdNiC_2$. Because Sm metal is located between Nd and Gd, its partial substitution in the $Sm_{1-x}R_xNiC_2$ system by larger Nd atom (or smaller Gd atom) will lead to an increase (or decrease) in the unit cell volume. Thus, it is possible to produce a solid solution of $Sm_{1-x}R_xNiC_2$ with a smooth change in lattice constants with doping. The Ni-Ni interatomic distance will change with doping and will subsequently influence the CDW temperature.

In the project, samples will be studied in both polycrystalline and single crystal form. Polycrystalline samples will be synthesized by the standard arc-melting method. This is a reliable and relatively simple method in which metals are melted under an ultra-pure argon atmosphere and the temperature can reach up to 3500^{o}C. Careful synthesis techniques with a slight excess of the metal R will be used to combat poorly reactive carbon and vaporization of the lanthanide metal. Due to a strong anisotropy of the physical properties of $RNiC_2$, part of the proposed research will be carried out on $RNiC_2$ single crystals. For this purpose, we propose purchasing an optical floating zone furnace.

As obtained samples will be annealed for at least two weeks at high temperature. This extra treatment is required in order to obtain high quality, homogenous material. Samples will then be analyzed by means of powder x-ray diffraction, magnetic susceptibility, and electrical resistivity. Temperature dependent magnetic susceptibility measurements will provide information about the character of magnetic ordering and the Curie or Néela temperature. High temperature resistivity will be used to detect anomalies, which are a manifestation of CDW formation. All measurements will be carried out by using a commercial Evercool II Physical Property Measurement System manufactured by Quantum Design.