PhD Annual Report

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During my PhD, I am dealing with **transport properties of Van der Waals topological materials** belonging to the series $(Bi_2Te_3)_n MnBi_2Te_4$, *n = 0-4* or to the family $(W_{1-x}Mo_x)Te_2$. These phases are respectively classified as magnetic topological insulators and topological Weyl semimetals. Topological materials are one of the hottest topics in condensed matter physics: they are interesting from a fundamental point of view, but the applicational counterpart is also intriguing. I'm performing the study on samples in form of single crystals provided through an international collaboration with the **IFW institute of Dresden**. The aim of my research activity is to **probe the emergence of phenomena related to topological protection in electric and thermoelectric transport measurements** and to **achieve their control by varying external knobs like thickness, carrier density, external magnetic field and applied strain**.

On one hand I'm searching topological phenomena looking through the transport properties of the samples under study.

1) Concerning this, I have observed the Anomalous Nernst effect (**ANE**) in a **bulk single crystal of** $MnBi_4Te_7$: this phenomenon is topological, because it is linked to the creation of two pairs of **Weyl nodes** in the band structure applying a sufficient high external magnetic field at cryogenic temperature.

On the other hand, I'm also designing a series of experimental set-up to achieve the control of previous phenomena, changing the external knobs mentioned before:

2) Firstly, I am investigating the effect of the application of a moderate **uniaxial strain using a piezolectric device** to stretch or compress bulk samples in fully controlled way. The transferred strain ranges from $5\ 10^{-5}$ at helium bath to 10^{-3} at room temperature.
   During the first year, I have characterized the elastoresistance (**ER**) (strain-derivative of the electric resistivity variation) of bulk samples of semimetallic transition metal dichalcogenides $(W_{1-x}Mo_x)Te_2$ **for x = {0%, 6%, 15%, 35%, 90%, 100%}** as a function of temperature and applied magnetic field. Electric resistance of these semimetallic samples is strongly affected by uniaxial strain: the two pure compounds ($WTe_2, MoTe_2$) behave very differently and, changing the doping ratio, I have probed a

very heterogeneous response. The ER at low temperature is very sensitive to an external magnetic field and this phenomenon could be the key to unbundling the various contributions in the ER. The band structure is affected by strain and both the mobility and the density of the carriers are strongly modified.

3) Secondly, I am studying how bands are modified by a **thickness control**, so I am developing the techniques needed to characterize exfoliated flakes. Starting from bulk single crystals of a Van der Waals compound, I have obtained flakes performing **mechanical exfoliation** using scotch-tape and PDMS (a viscoelastic material). Following a reproducible procedure, I have obtained samples with thickness that ranges from 15nm to 200nm and with a surface area of about 100 μm^2.Using a micromanipulator and a PDMS sheet, it is possible to perform a **deterministic transfer** of the obtained flakes on a substrate and the final position could be tuned with a micrometric precision. To **measure transport properties** of a flake, I have designed suitable Au patterns on STO substrates (insulating high-k dielectric material) using Optical Lithography (**OL**) thanks to an internal collaboration with **Dott. N. Manca at the CNR-SPIN of Genoa**. Finally, I have created suitable electric and thermal contacts using a Focused Ion Beam (**FIB**), depositing stripes of a metallic element (such as W) thanks to an internal collaboration with the **Postdoc. M. Schott and Prof. L. Repetto at UNIGE**.
   At the end of the first year, I have characterized **electric transport properties of a flake of $MnBi_4Te_7$** made up of **30 layers** (thickness of 70nm). The carrier density is two orders of magnitude lower than a bulk sample and magnetic transitions are shifted at lower temperatures.
   Furthermore, I have successfully tested the thermoelectric assembly, measuring the Seebeck coefficient as a function of temperature and magnetic field of a flake of the semiconducting transition metal dichalcogenide $SnSe_2$, thanks to its huge thermopower of 100 $\mu V/K$ at room temperature (the measured sample has a thickness of 60nm).

4) Lastly, I am manipulating **the carrier concentration of exfoliated flakes by field effect devices**. Up to now, I have seen only small effects probably because FIB's action damages the STO substrate reducing its dielectric constant. However, lowering the thickness of the samples can certainly amplify the phenomenon.

Attended courses	Classes	Exam given
Fasi topologiche della materia condensata	6	V
Topological Quantum Matter: Theory and Applications (International school in S. Margherita Ligure, Italy)	3	
Introduzione alle tecnologie quantistiche	6	V