Fabrication and study of Manganese (Mn) doped Molybdenite (2H-MoS_2) sample by using spark plasma sintering (SPS) technique

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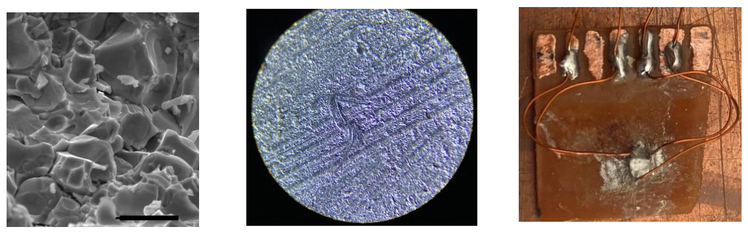
Background/Motivation

- Interests to Study and Probe physical Properties of Novel diluted magnetic semiconducting materials (DMS) for future practical applications within the filed of electronics technology as well as Spintronics.
- Molybdenite (MoS_2) Known to be an indirect gap semiconductor in bulk morphology with gap value of E_{gap}=1.3 eV & high dielectric constant ε~8 used as a base material for this research.
- Processing Mn salt (13%) mixed with MoS_2 ball milled homogenous Powder Into the Bulk wafer like Sample (to make new DMS) by implementing Spark Plasma Sintering (SPS) technique using both High Pressure (P ↑ 80 MPa) & Temperature (T ↑ 2200 K)
- Para-Ferromagnetic phase transition observed @ T_{Currie}=230 K, which might be useful in case of comprehensive characterization & study of the sintered sample for future practical applications

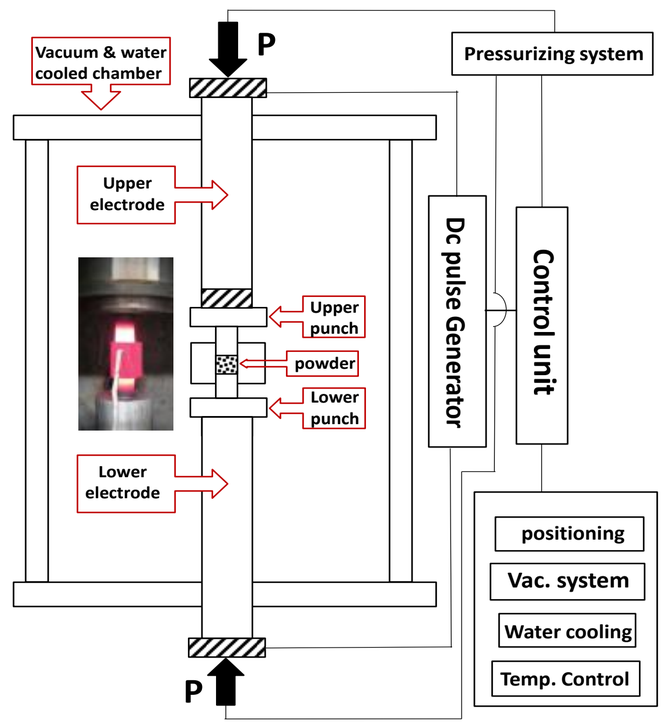
Present Sample

- From left: MoS_2: -Bulk Mineral Stone -Powder morphology -Bulk raw sintered Mn doped 2H-MoS_2 wafer (D=20mm, t=2 mm) -Scrubbed one



- From left: SEM image (Scale bar 10 μm), Optical Micrograph of sample (x100) & mounted bulk sample image

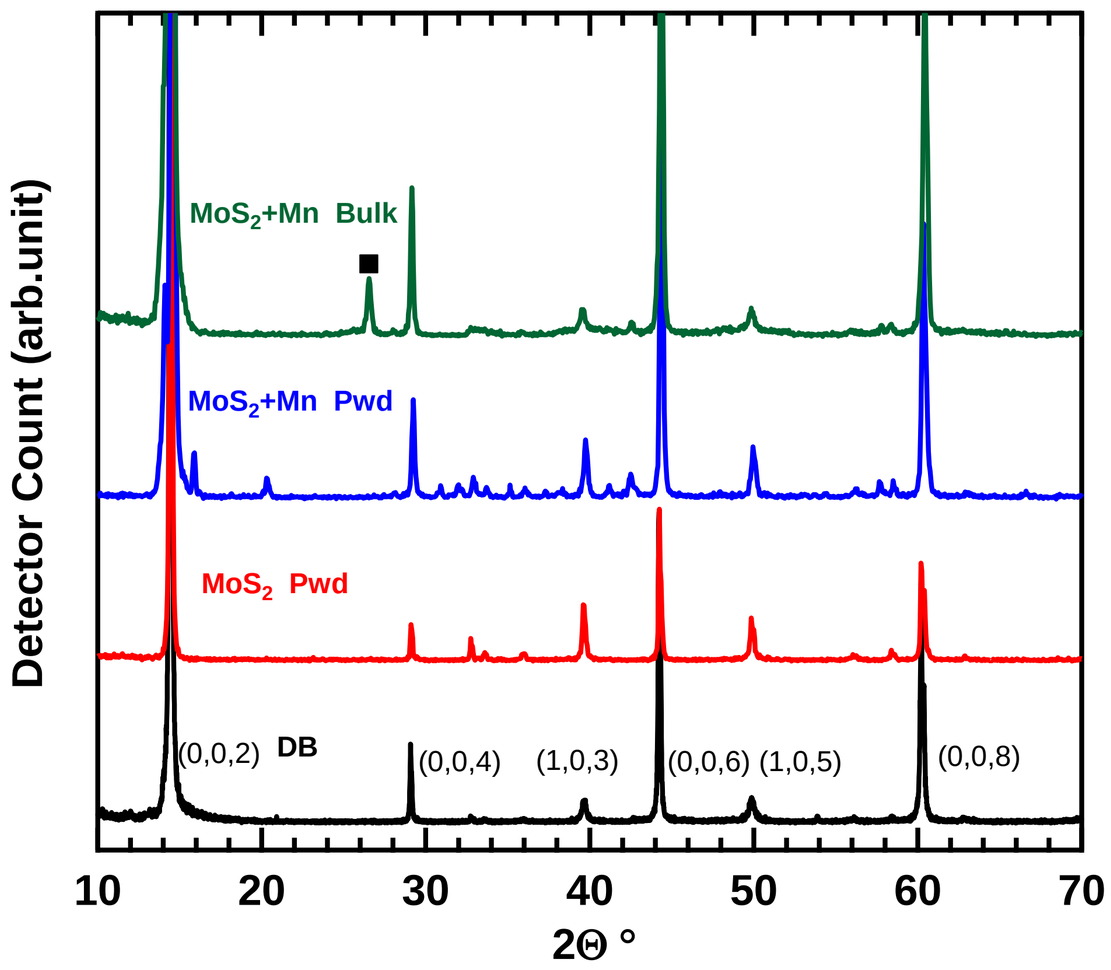
Sintering



- Combination of High Pressure (up to 80 MP) + High Temperature (up to 2200 K) being used for Solidification of the 2H-MoS_2+Mn mixture

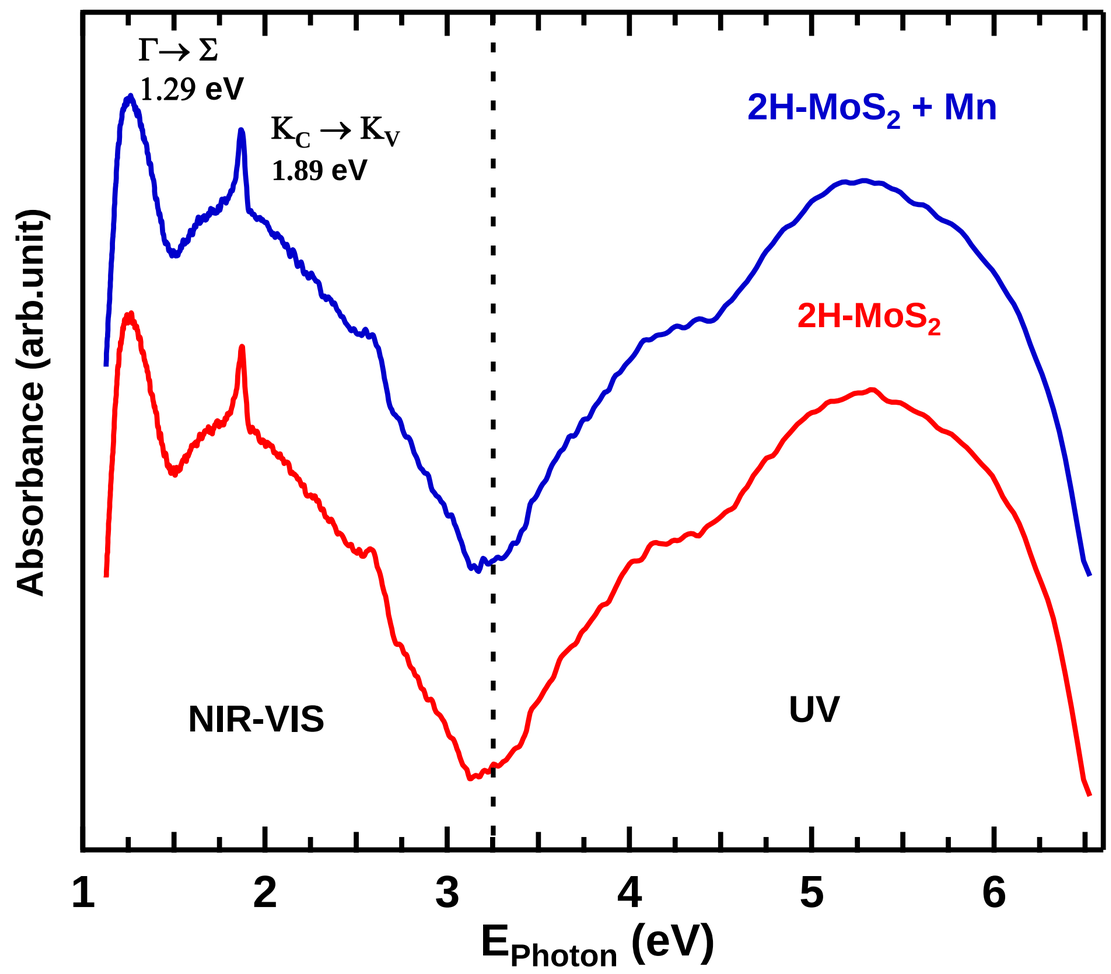
Sample characterization

Structural analysis (PXRD)



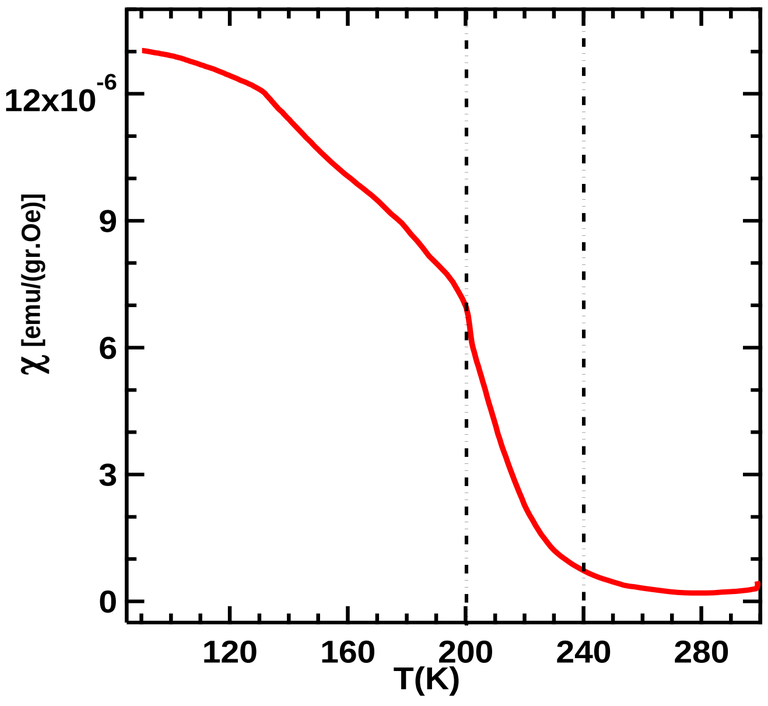
- PXRD pattern of the 2H-MoS_2 from Data Base (DB) with (0,0,2n) characteristic peaks, Good Matching between main peaks of MoS_2 Powder sample with DB one
- Mixing with Manganese salt (13 % Mn) adds new small peaks in 2H-MoS_2+Mn mixture PXRD pattern, Sintered sample is more or less like Mn mixed pwd sample with extra peaks@ 2θ=26.6° due to Carbon diffusion from Graphite mold into the surface layer of sintered sample

Optical absorbance



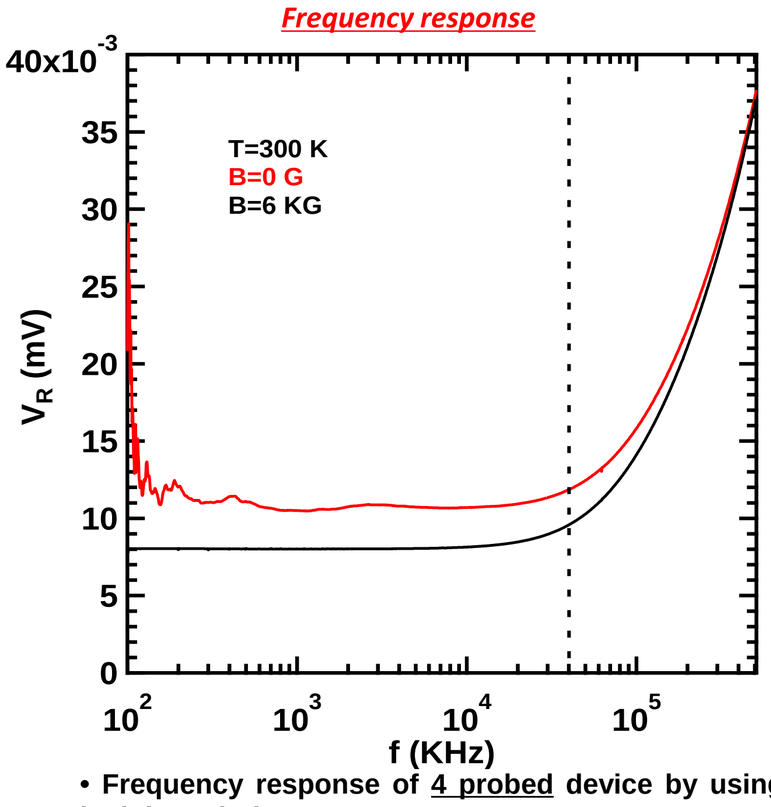
- Optical absorbance profile in the range of NIR-UV (190<λ<1100 nm) confirms semiconducting nature of the sintered samples with Interband transitions observed @ 1.29 & 1.89 eV as predicted for 2H-MoS_2 bulk sample
- Same profile for 2H-MoS_2+Mn case, like the one for 2H-MoS_2 @ T=300 K, This behavior is expected due to the fact that Mn doped sample is in Paramagnetic phase (T>Tc)

Magnetic Susceptibility Functionality



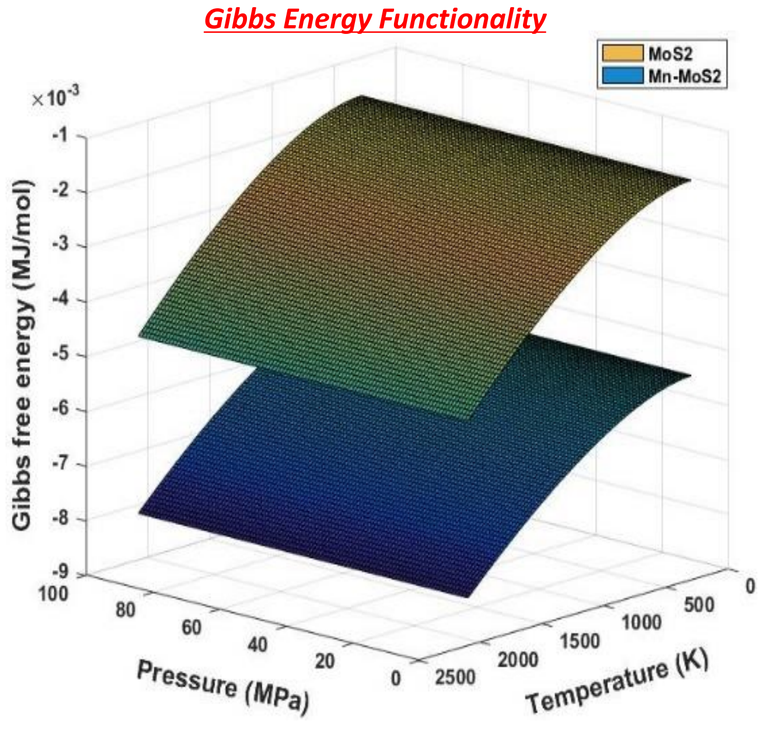
- Magnetic Susceptibility X(T) behavior of the sintered sample by decreasing temperatures
- Several breaks observed with Para-Ferromagnetic phase transition seen @ T_C=230 K (expected for DMS')

Frequency response



- Frequency response of 4 probed device by using lock-in technique
- Linear response @ range of 100 < f < 40 KHz within the low frequency region, B field removes 1/f noise

Gibbs Energy Functionality



- Study of 2H-MoS_2 & 2H-MoS_2+Mn samples' Gibbs energy functionality E_{Gibbs}(T,P) on Temperature & Pressure (as the related thermodynamical potential of the SPS process, with No Phase transition)

Summary/Conclusions:

- Synthesis of Manganese(Mn) doped Polycrystalline Bulk wafer shape Molybdenite sample (2H-MoS_2+Mn) by using Spark Plasma Sintering (SPS) technique
- Initial characterization of the sample through PXRD structural analysis confirms its Hexagonal crystal structure (2H-MoS_2) with further study improves semiconducting nature of the sintered sample & its Para to Ferromagnetic phase transtion @ Tc=230 K, further studies need to be done!!!