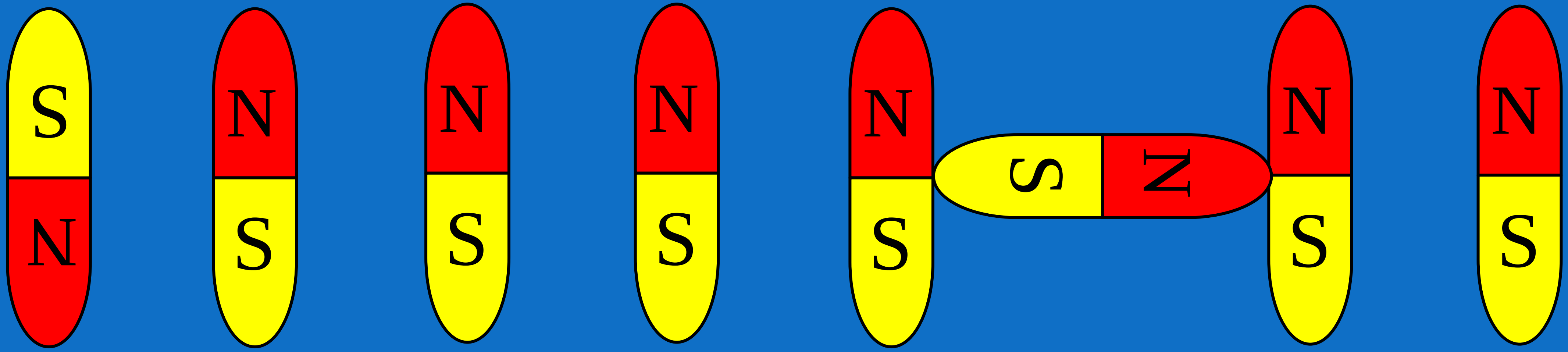


CONTROL your SPIN

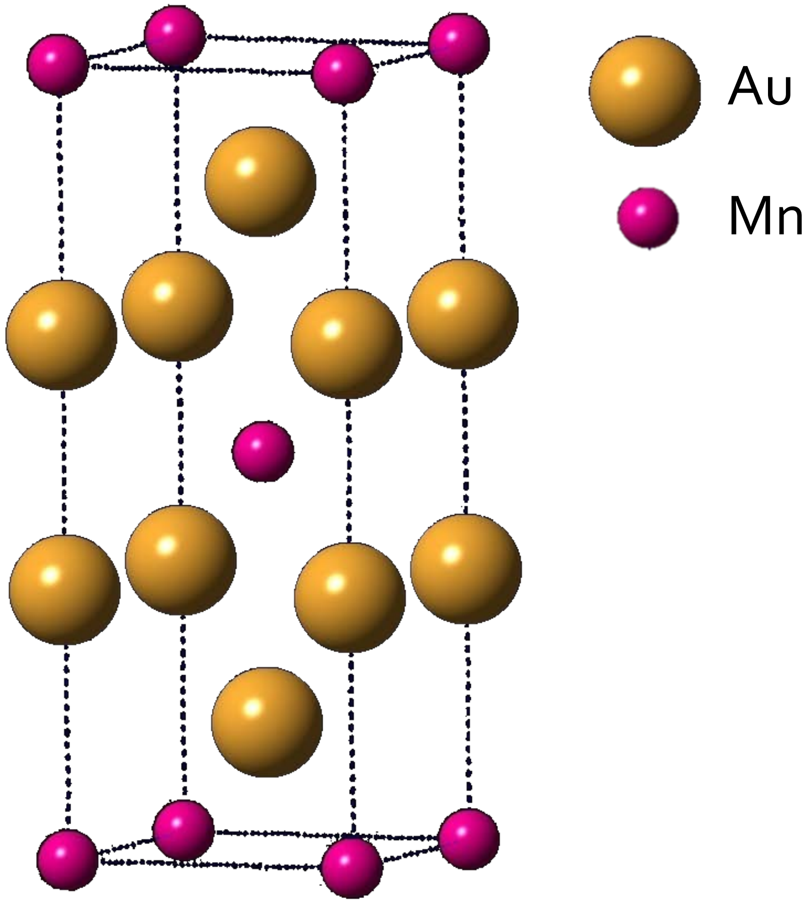
Au_2Mn

Maria Pascale

University of Maryland

NIST Center for Neutron Research

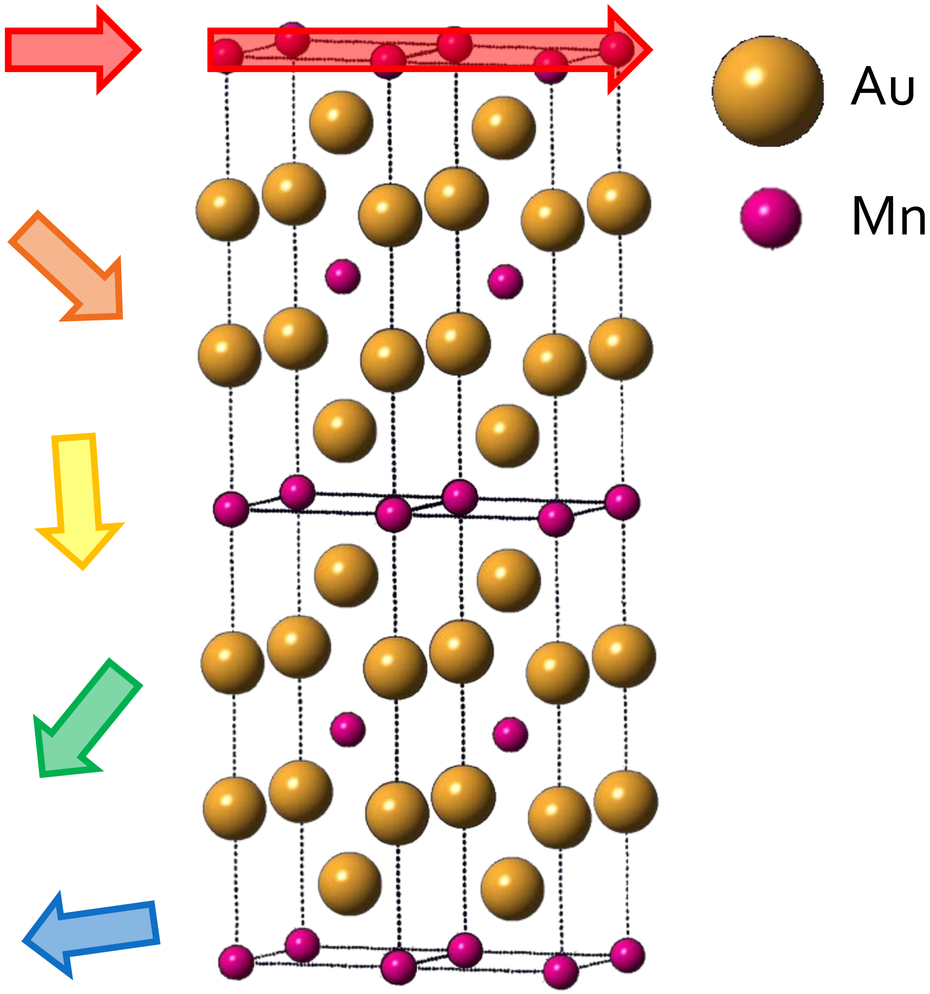
Background on Au_2Mn



Body Centered Tetragonal

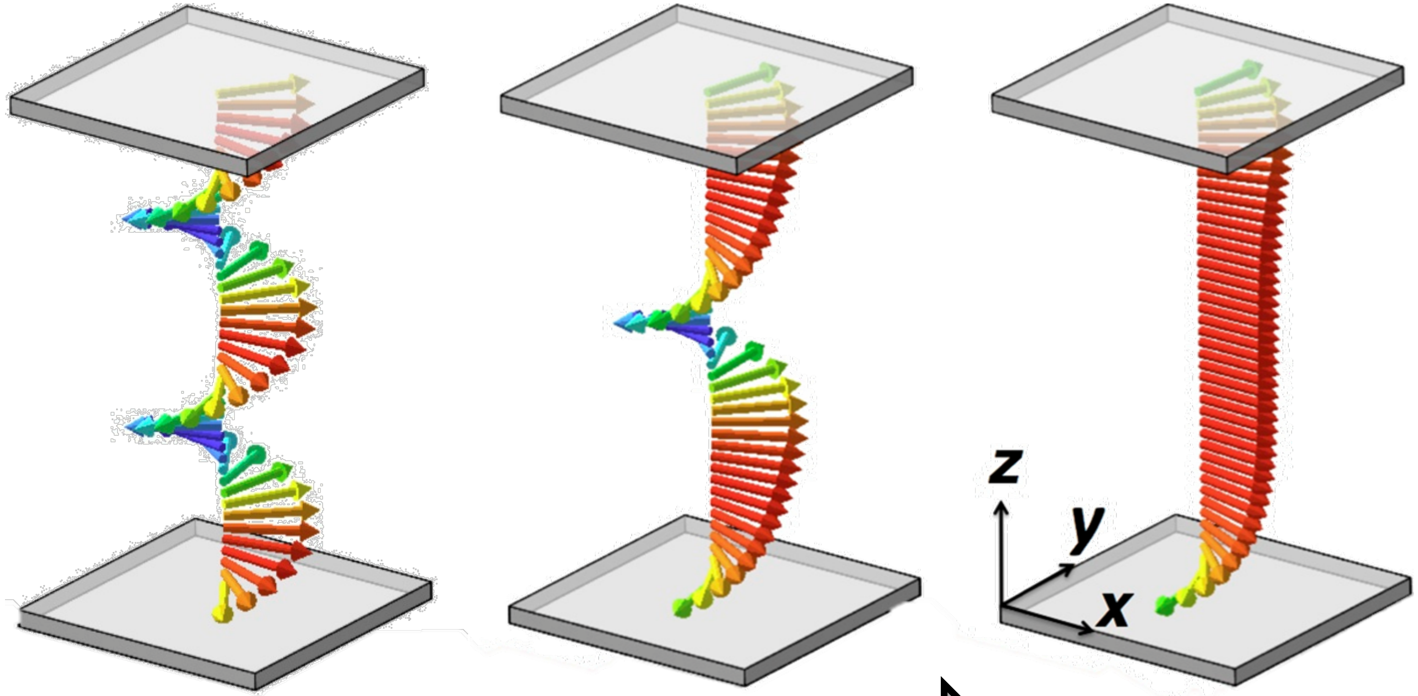
Background on Au_2Mn

Spin ∢



Body Centered Tetragonal

- Ferromagnetic within each x y plane
- Helicoidal (Helical) Structure



Pressure ↑ Temperature

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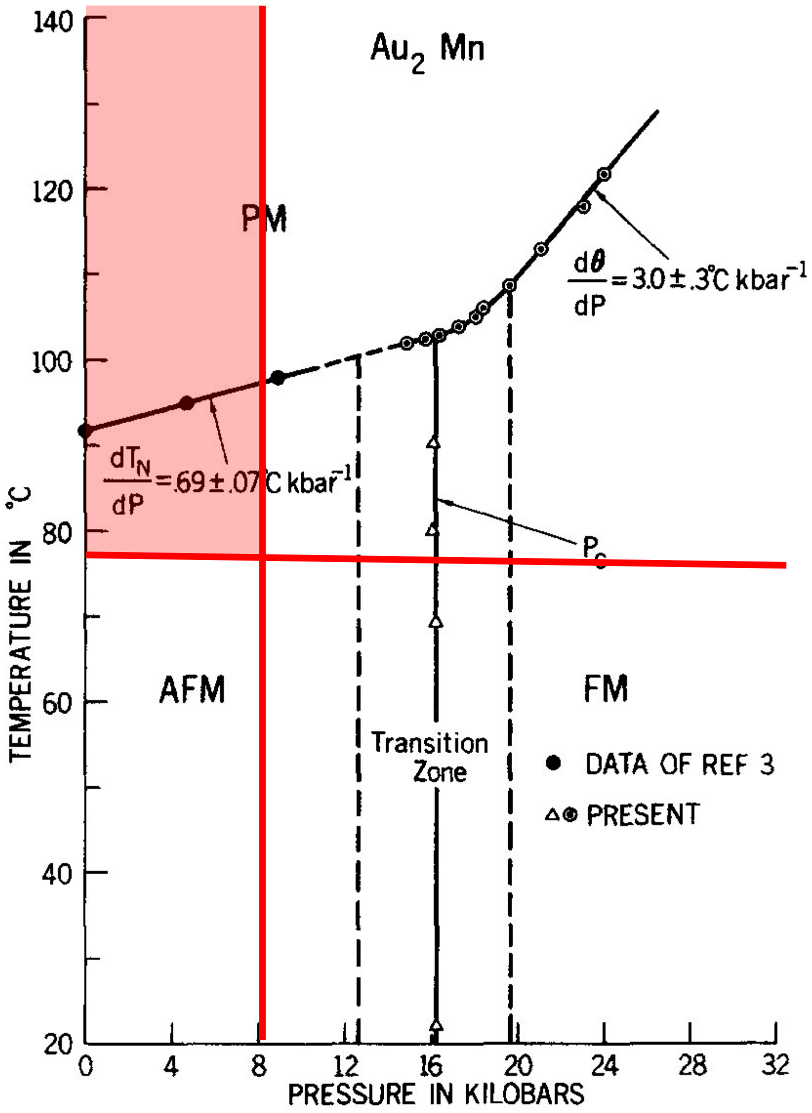
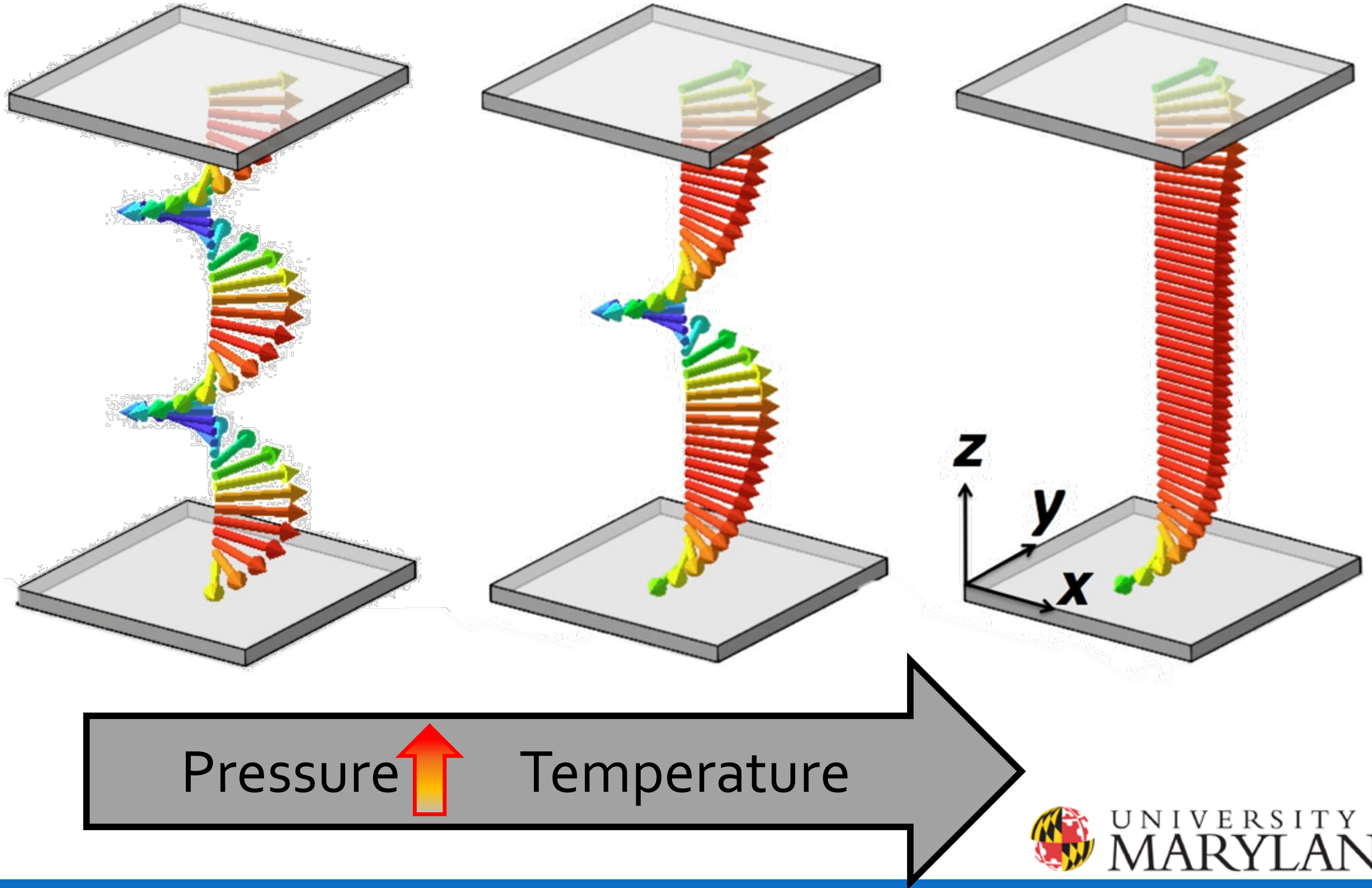
Wilson M. N., Karhu E. A., Lake D. P., Quigley A. S., Meynel S., Bogdanov A. N., Fritzche H., Rößler U. K., Monchesky T. L. "Discrete Helicoidal States in Chiral Magentic Thin Films", *Physical Review B* 88(21) (2013):

Background on Au_2Mn



Wayne R. C., Smith F. A. *Journal of Physics and Chemistry of Solids*, 30(184) 1969

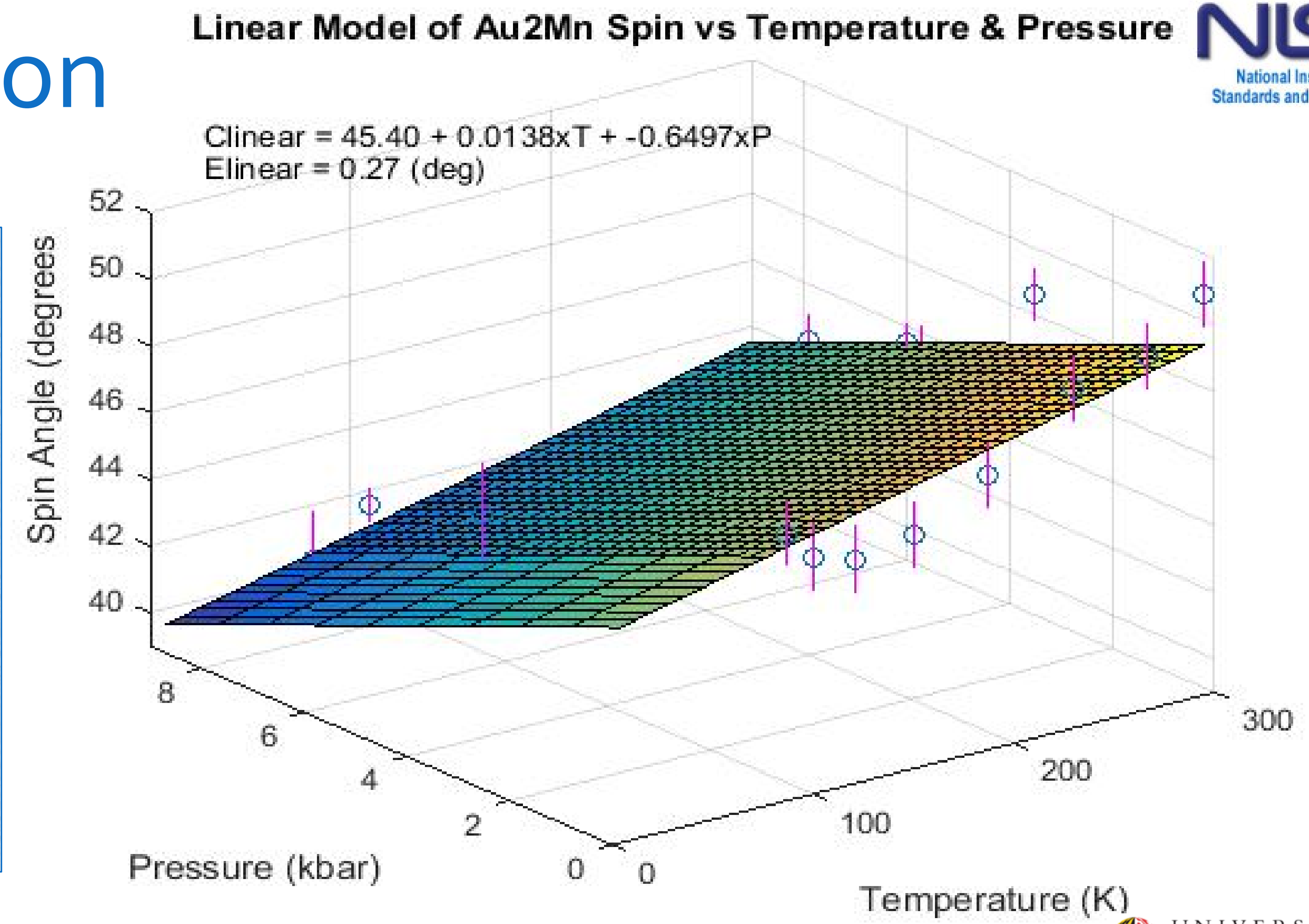
- Ferromagnetic within each x y plane
- Helicoidal (Helical) Structure



Wilson M. N., Karhu E. A., Lake D. P., Quigley A. S., Meynel S., Bogdanov A. N., Fritzche H., Rößler U. K., Monchesky T. L. "Discrete Helicoidal States in Chiral Magentic Thin Films", *Physical Review B* 88(21) (2013):

Motivation

- Spin Properties have only been tested down to 77 K and up to 8.83 kbar
- Single crystal has not been made



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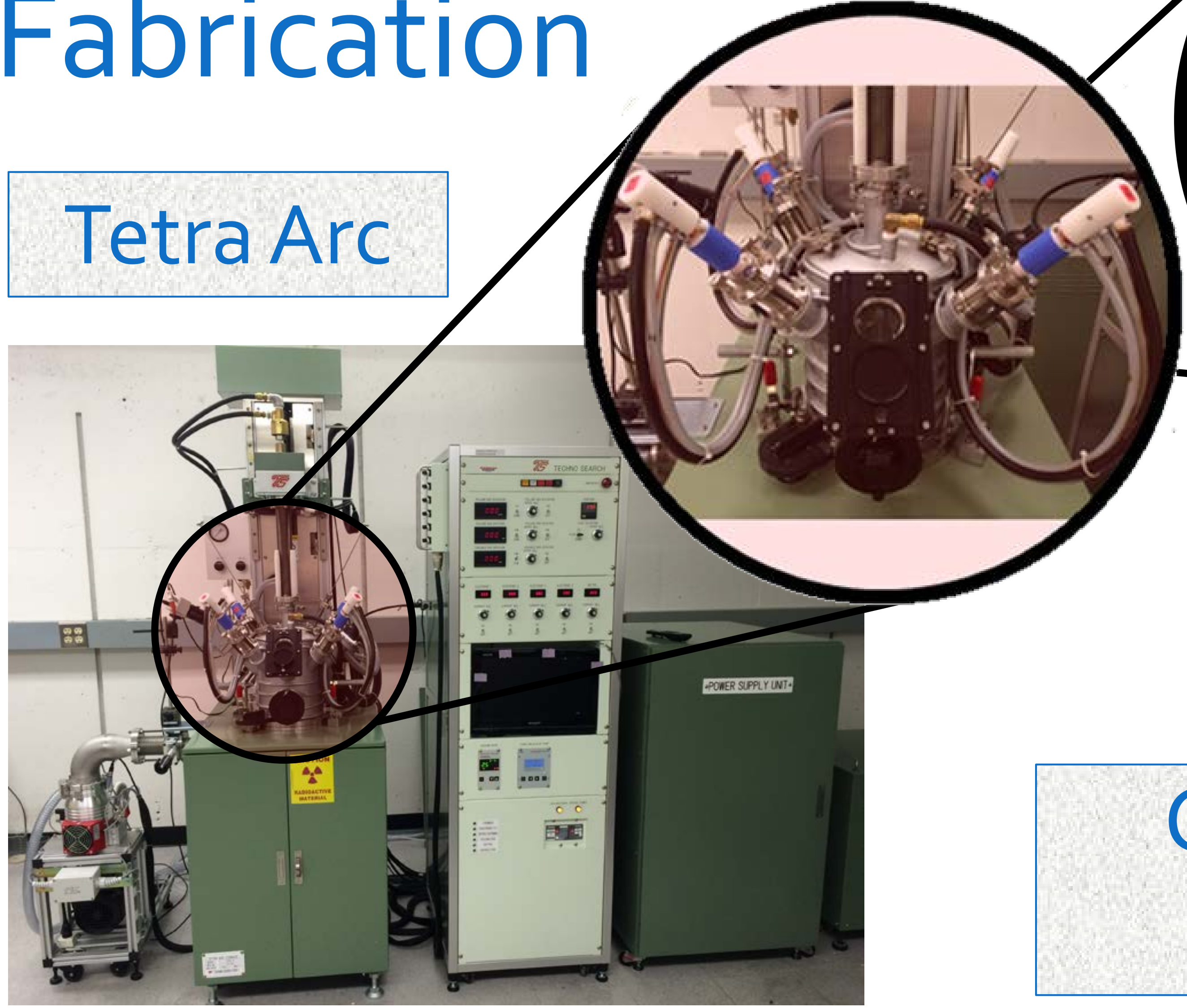
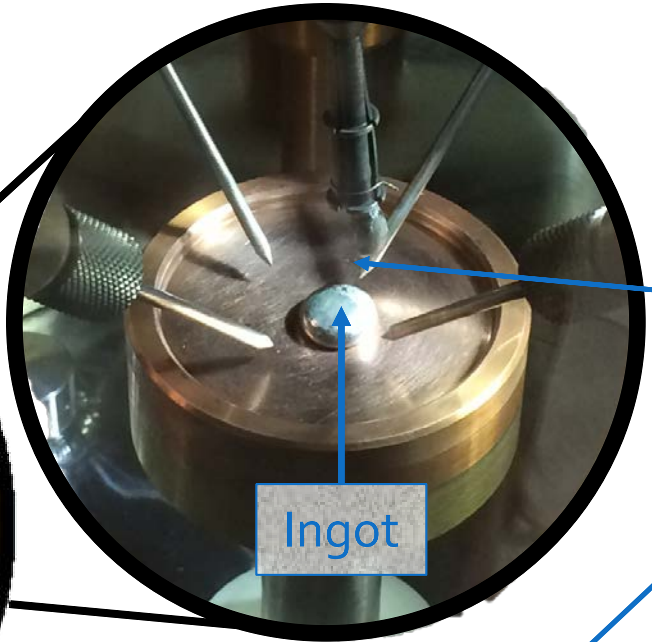
Au_2Mn Crystal Fabrication

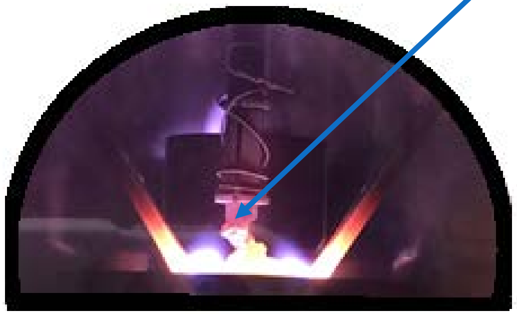
National Institute of Standards and Technology

Tetra Arc





Seed / Pulling rod



Czochralski Process

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http://www.miracrys.com/CCinit.php?id=technologyam_4

Au_2Mn Single Crystal Fabrication

National Institute of Standards and Technology

Au-Mn Phase Diagram (1990 Massalski T.B.)

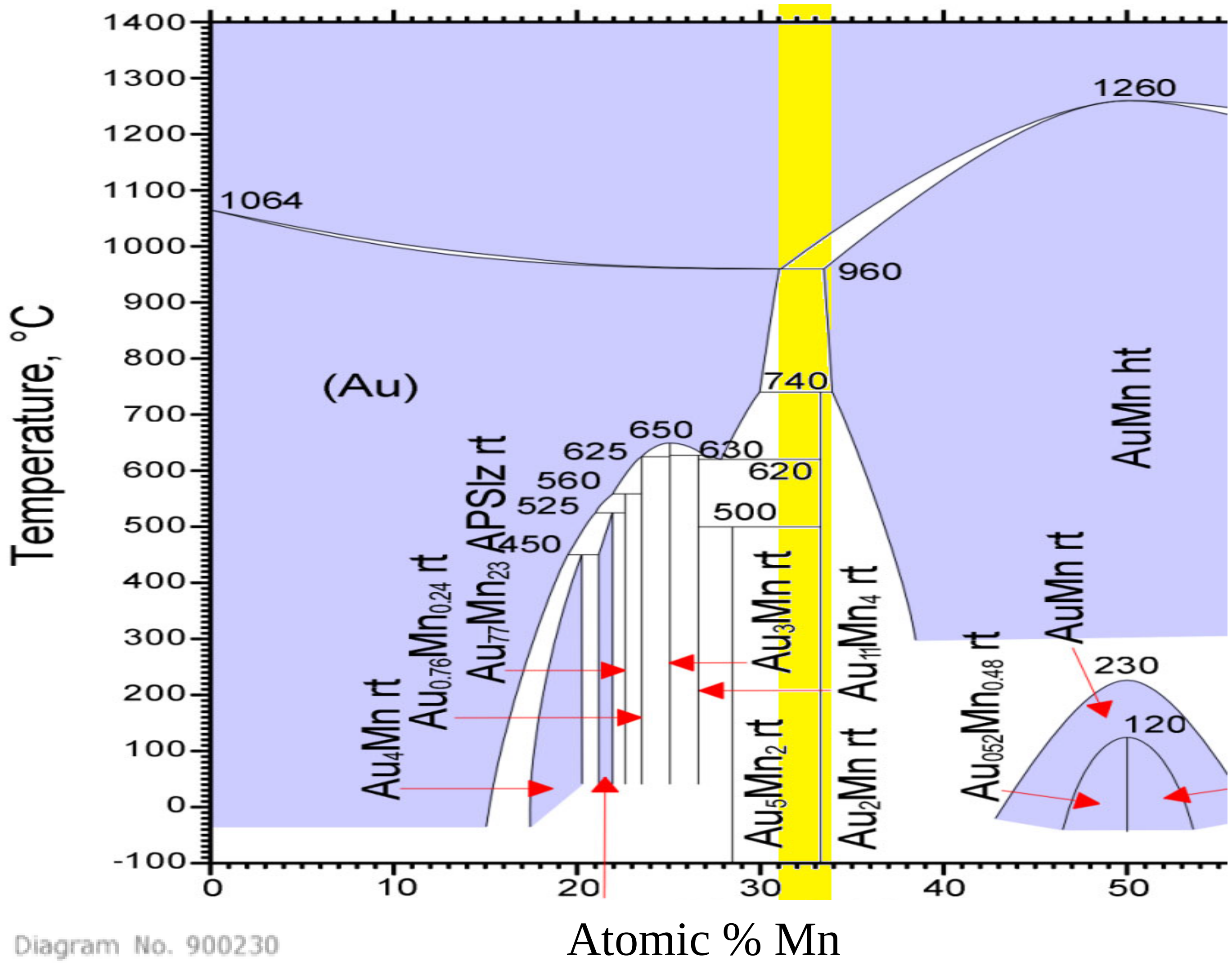
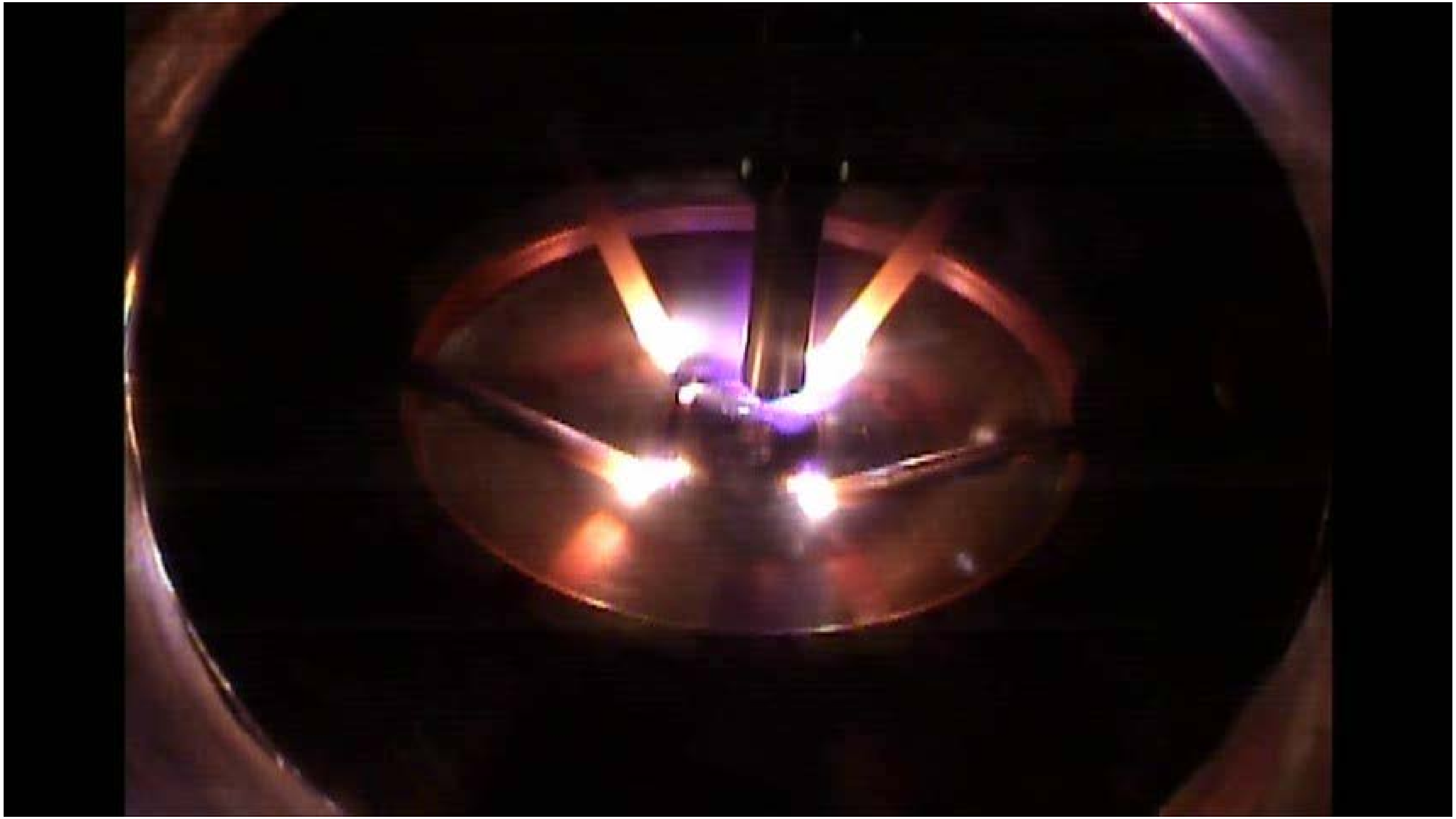


 Diagram No. 900230

UNIVERSITY OF MARYLAND

Au_2Mn Crystal Growth



MEASUREMENTS

X Ray Diffraction

Energy Dispersive Spectroscopy

Magnetic Susceptibility

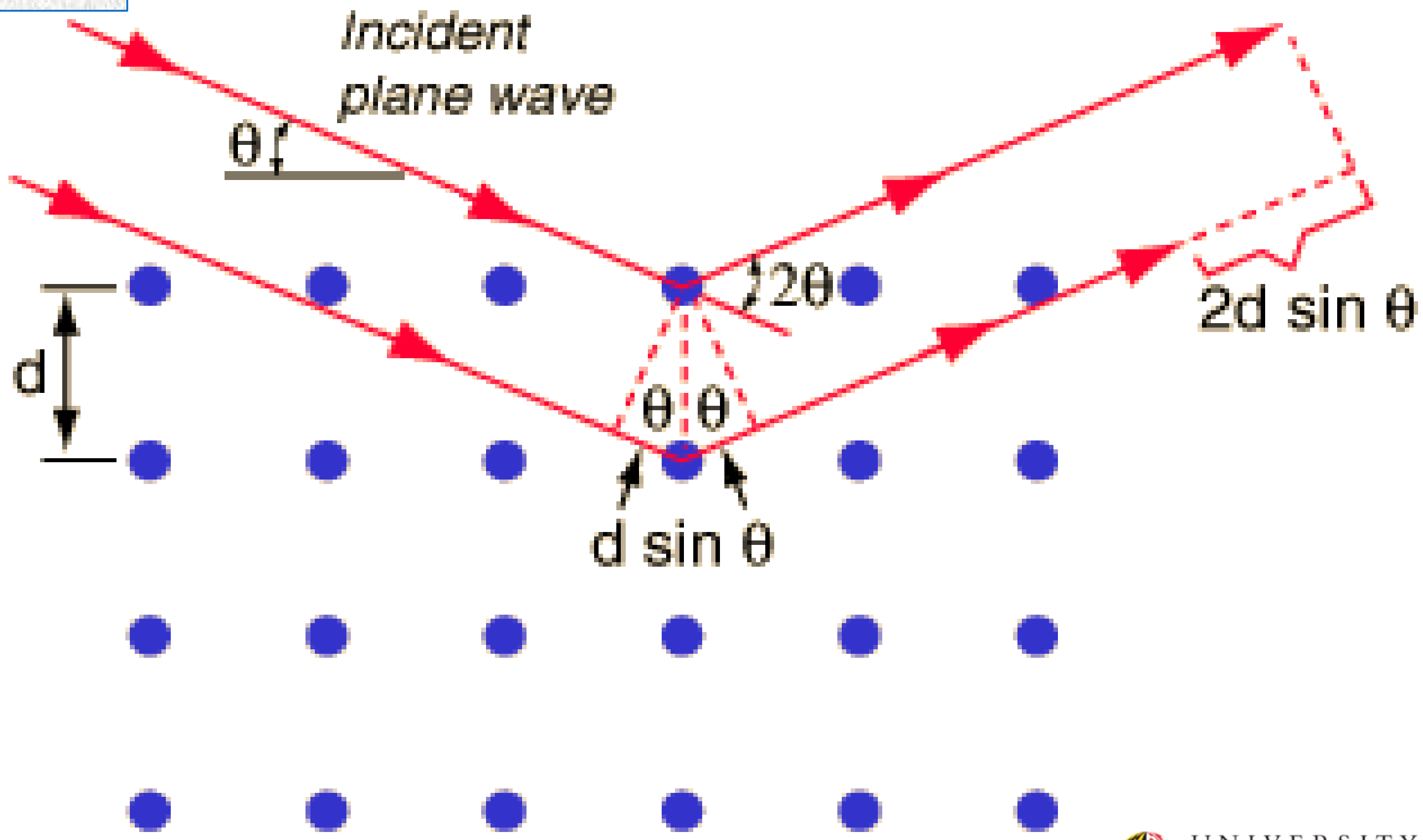
Electrical Resistivity

Neutron Scattering

X-Ray Diffraction

Operates using Bragg's Law

$$n\lambda = 2d\sin\theta$$



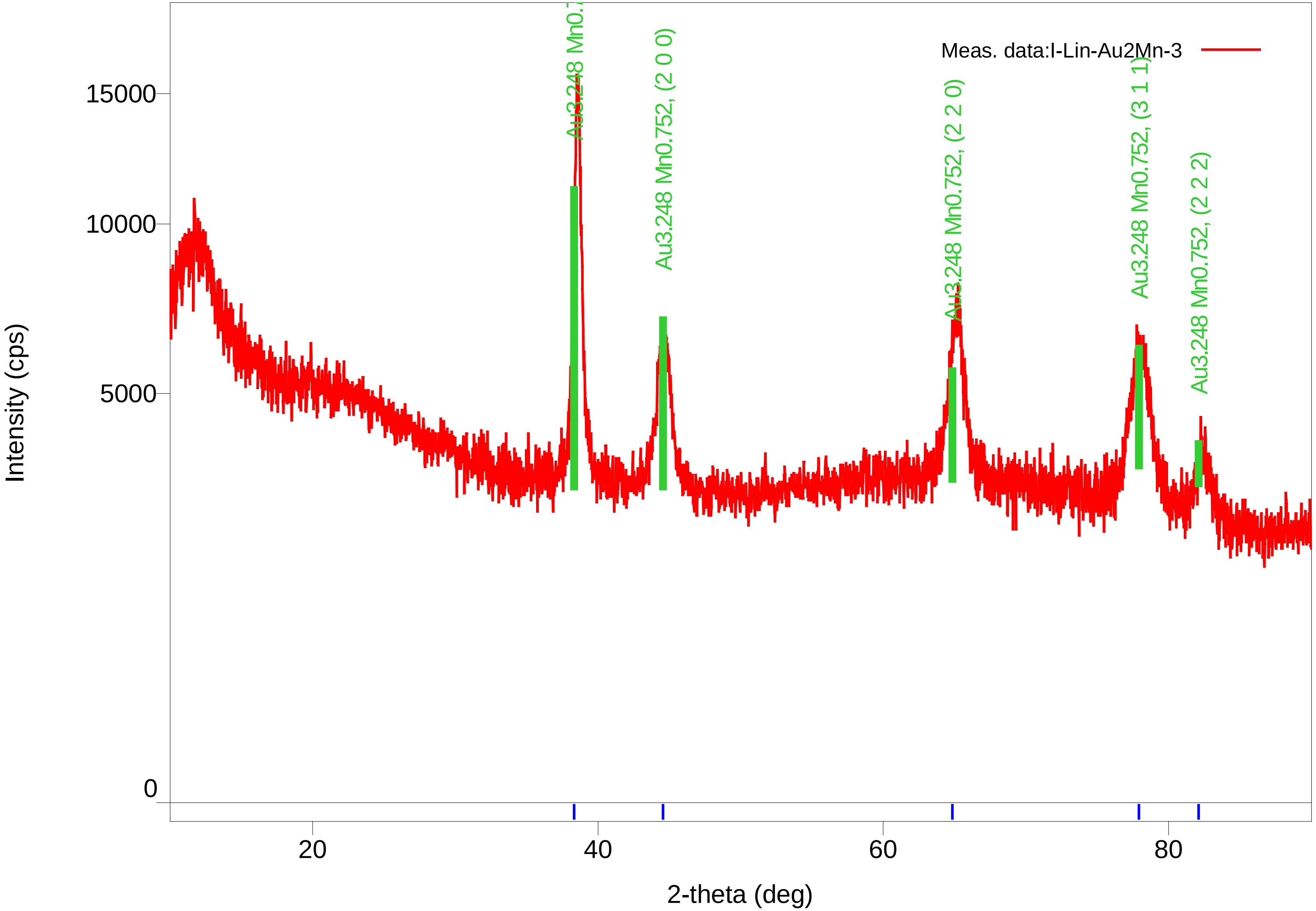
Gives interatomic distances, which can be used to confirm or to deduce crystal structures

National Institute of Standards and Technology

University of Maryland

Nave, R. HyperPhysics: Quantum Physics. "Bragg's Law". http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/bragg.html

X-Ray Diffraction



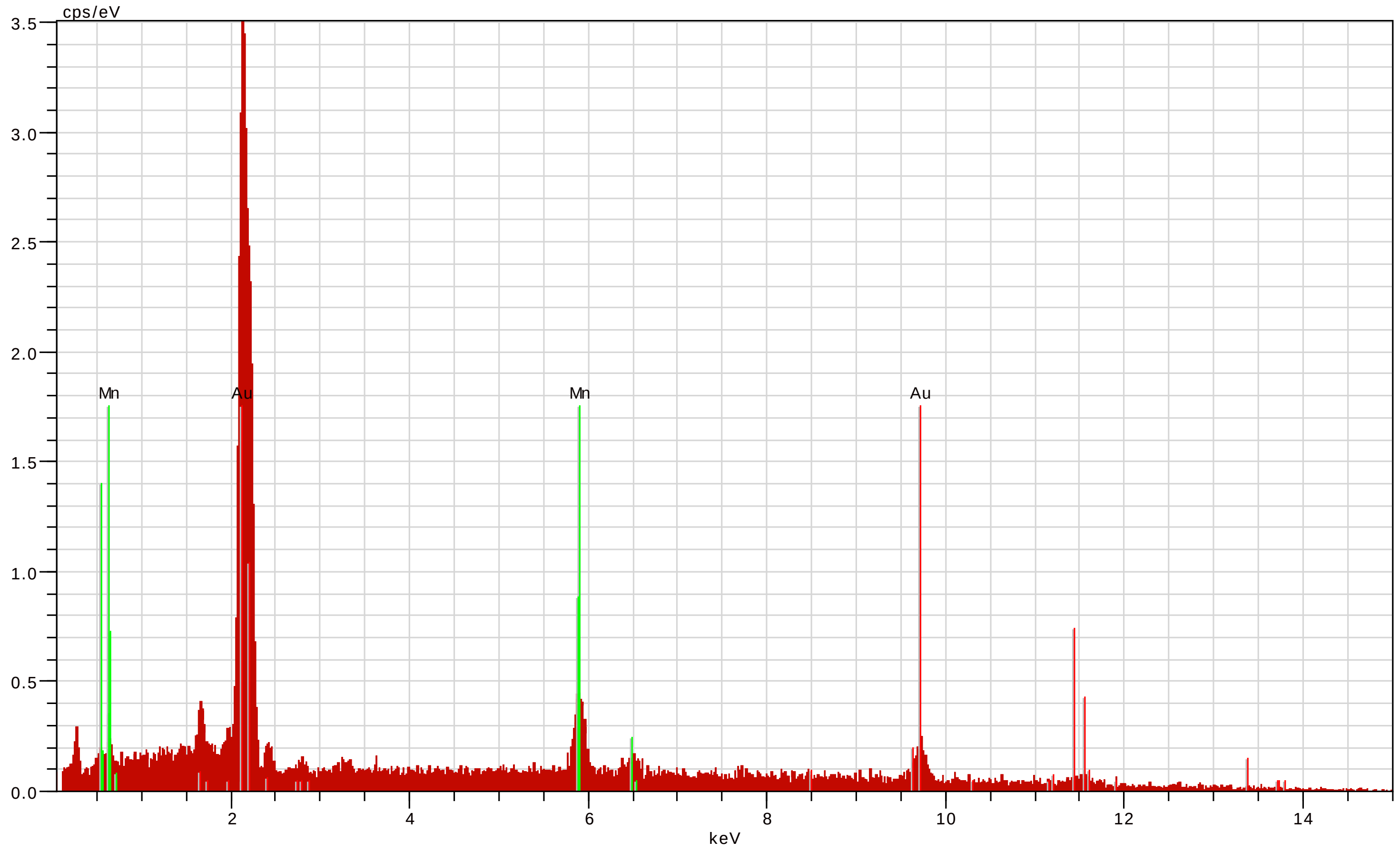
Pulled Sample: Primarily Au_3Mn

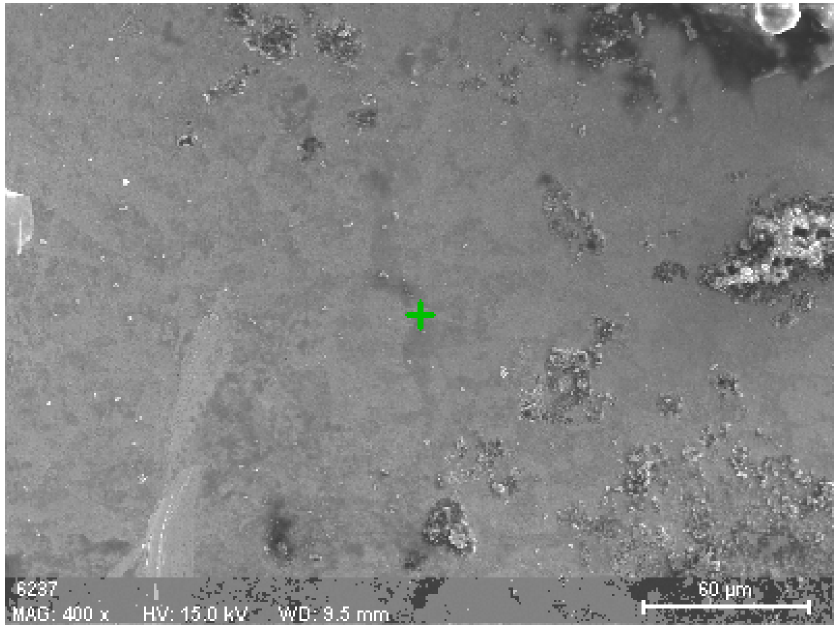
CAUTION! XRD Data may be unreliable due to sample preparation

Energy Dispersive Spectroscopy

Pulled Au-Mn Crystal

Proportions vary slightly depending on the location in the material





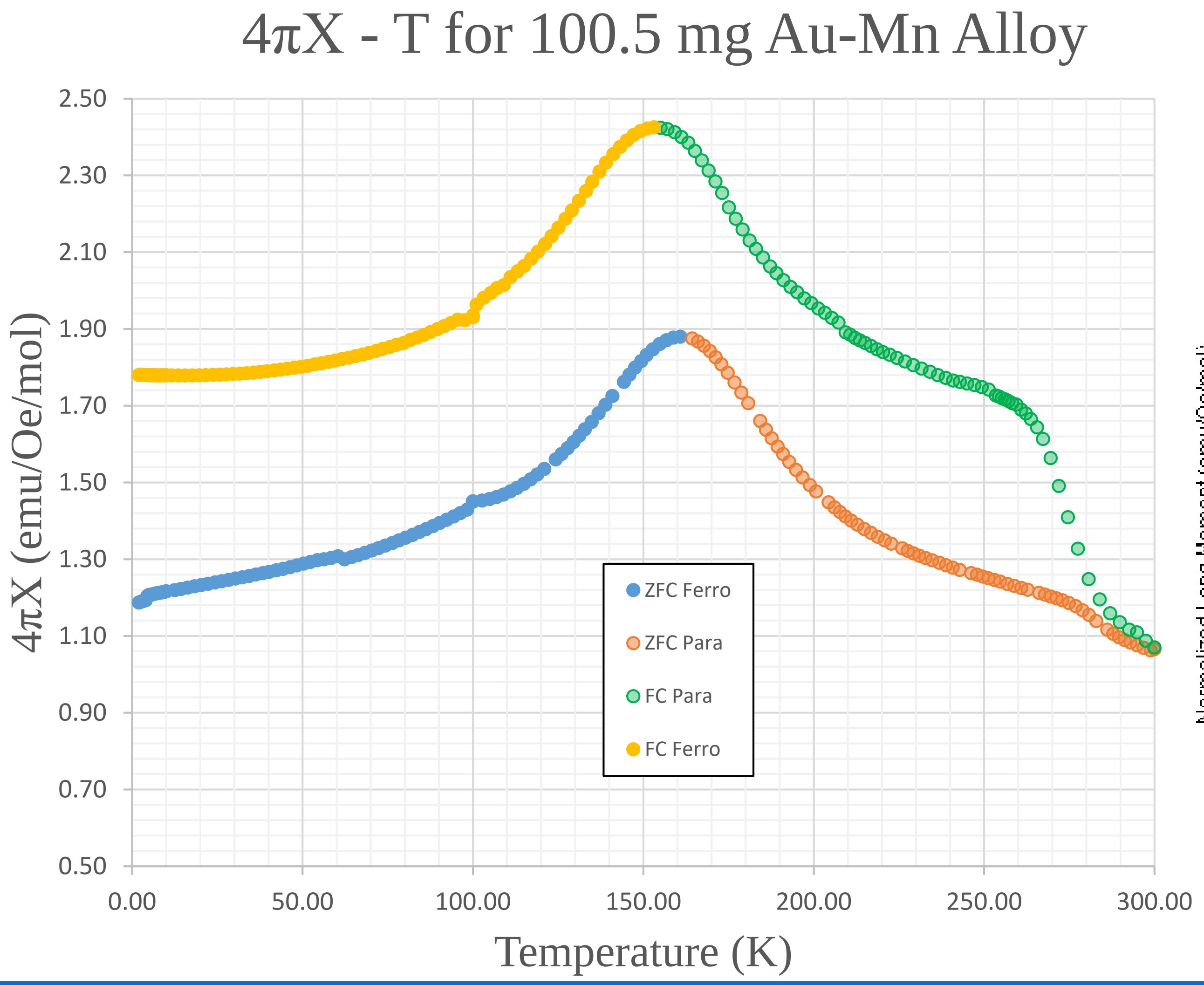
El	AN	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Au	79	M-series	94.04	87.09	65.29	3.7
Mn	25	K-series	13.95	12.91	34.71	0.6
		Total:	107.99	100.00	100.00	

Possibly mix of different structural phases

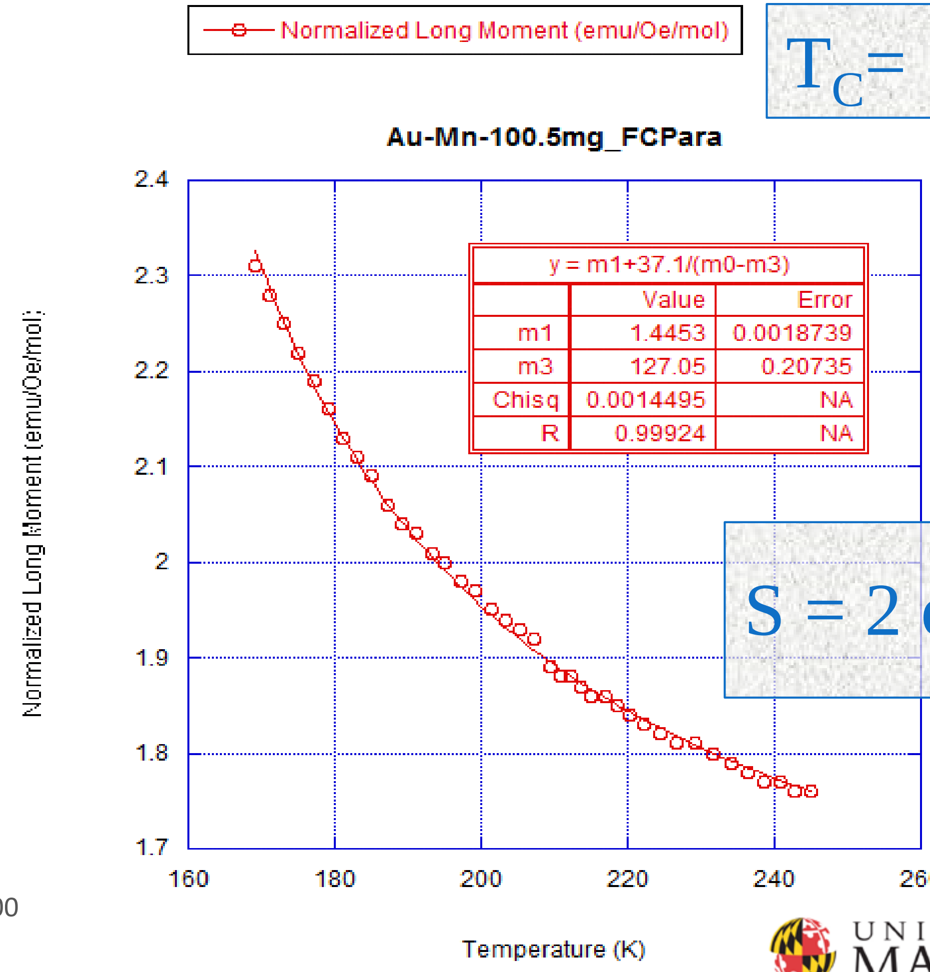
Magnetic Susceptibility

Magnetic response of a sample to an applied field

$$X_P = \frac{C}{T - \Theta}$$



$T_C = 130$ K



$S = 2$ or $\frac{5}{2}$

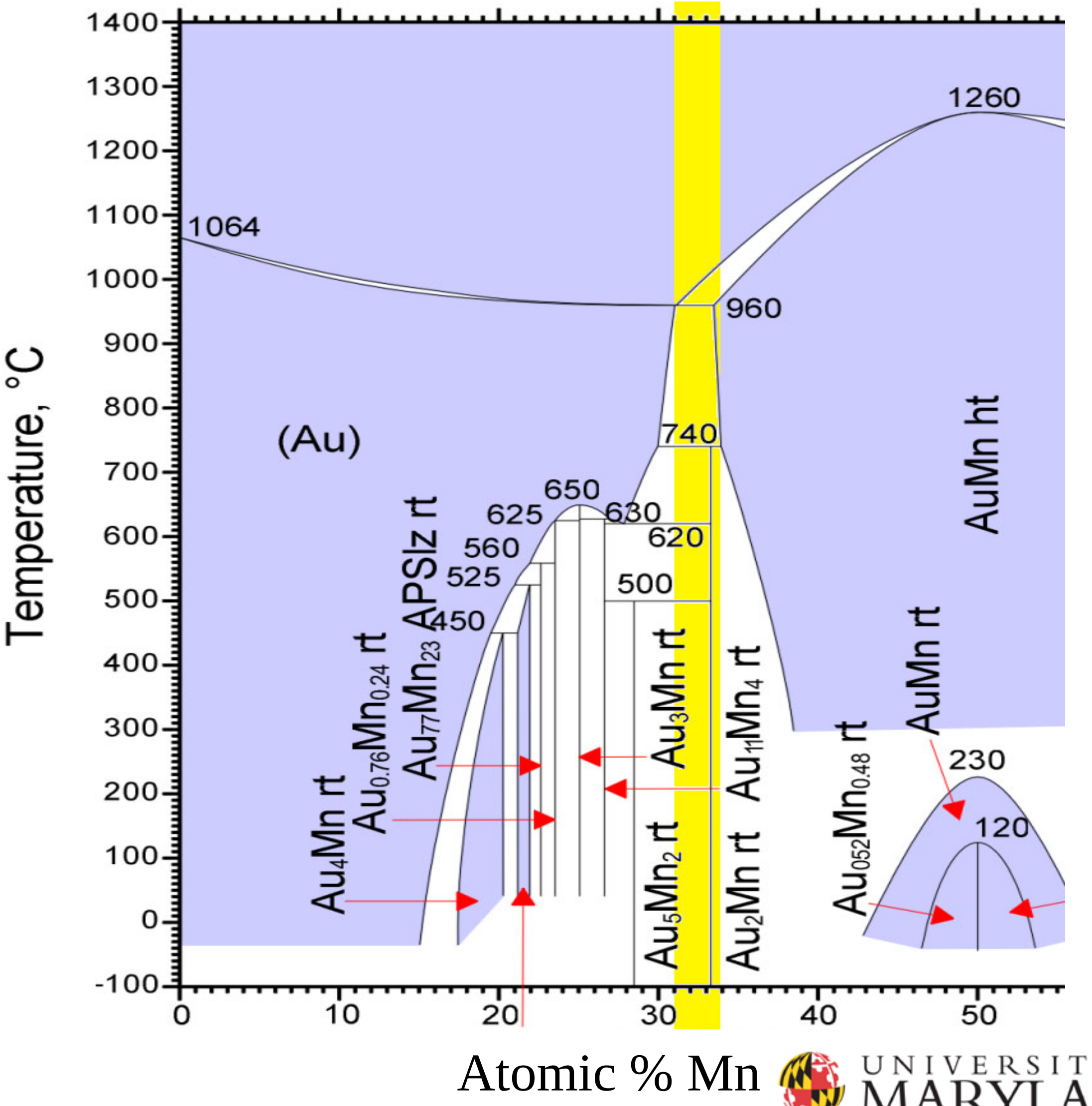
Au_2Mn Crystal Fabrication

Anneal at 730°C

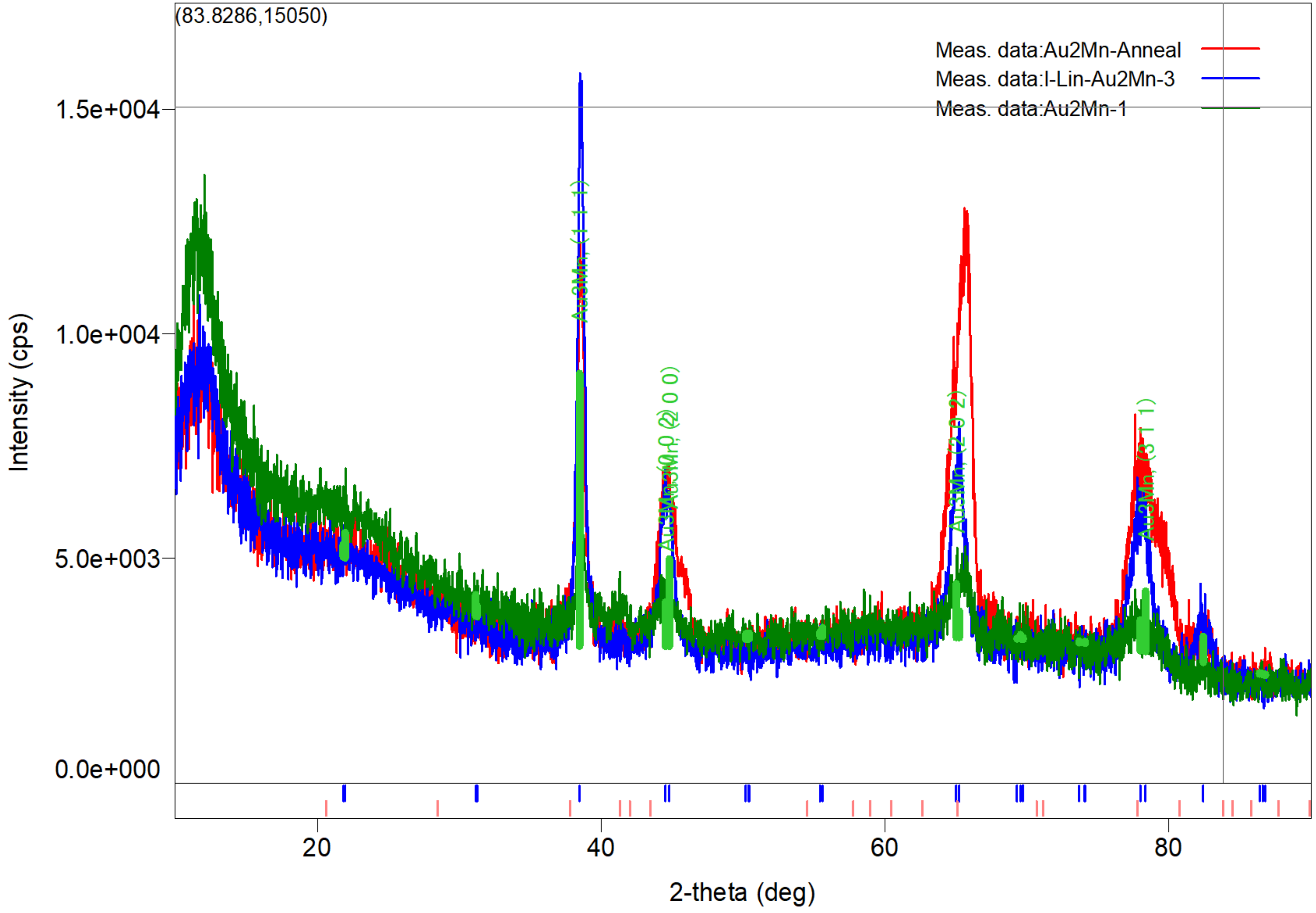
Why?

- Concerned about existence of different phases
- Encourage steady state diffusion
- Obtain Au_2Mn
- Increase Grain Size

Au-Mn Phase Diagram (1990 Massalski T.B.)



X-Ray Diffraction



Annealed Sample: Primarily Au_3Mn

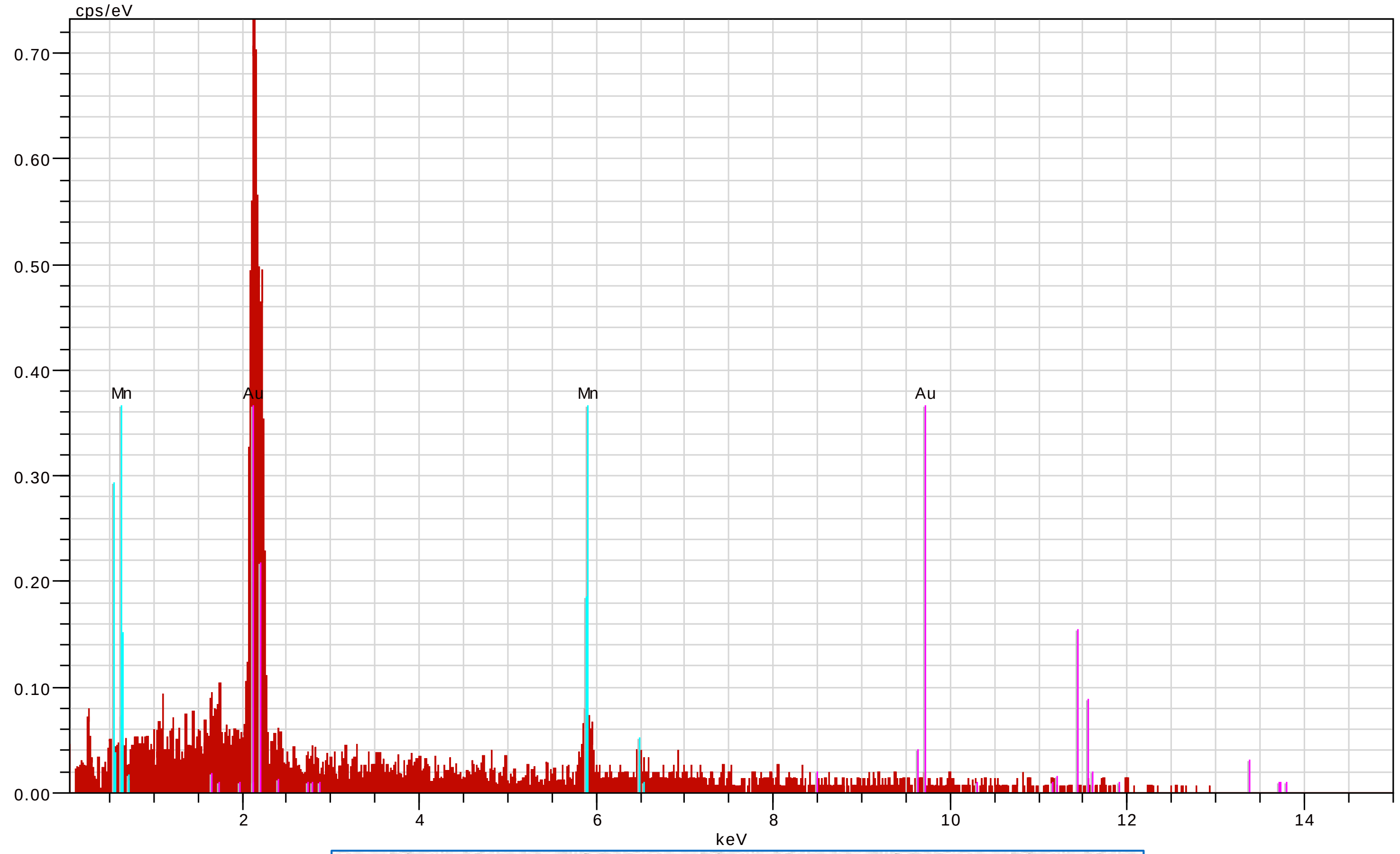
Remember… Potentially unreliable!

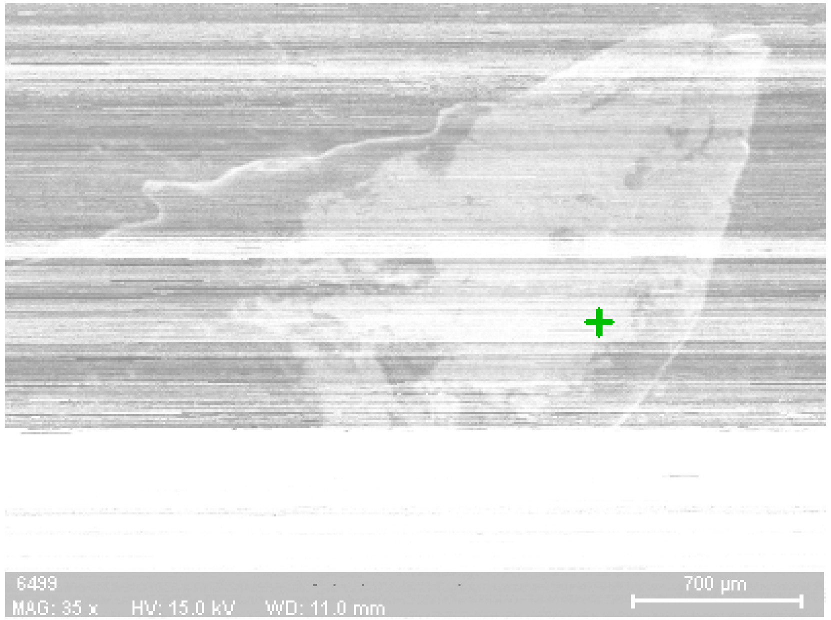
Nave, R. HyperPhysics: Quantum Physics. “Bragg’s Law”. http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/bragg.html

Energy Dispersive Spectroscopy

Annealed Au-Mn Crystal

Proportions vary slightly depending on the location in the material





Spectrum: AuMn_1 283

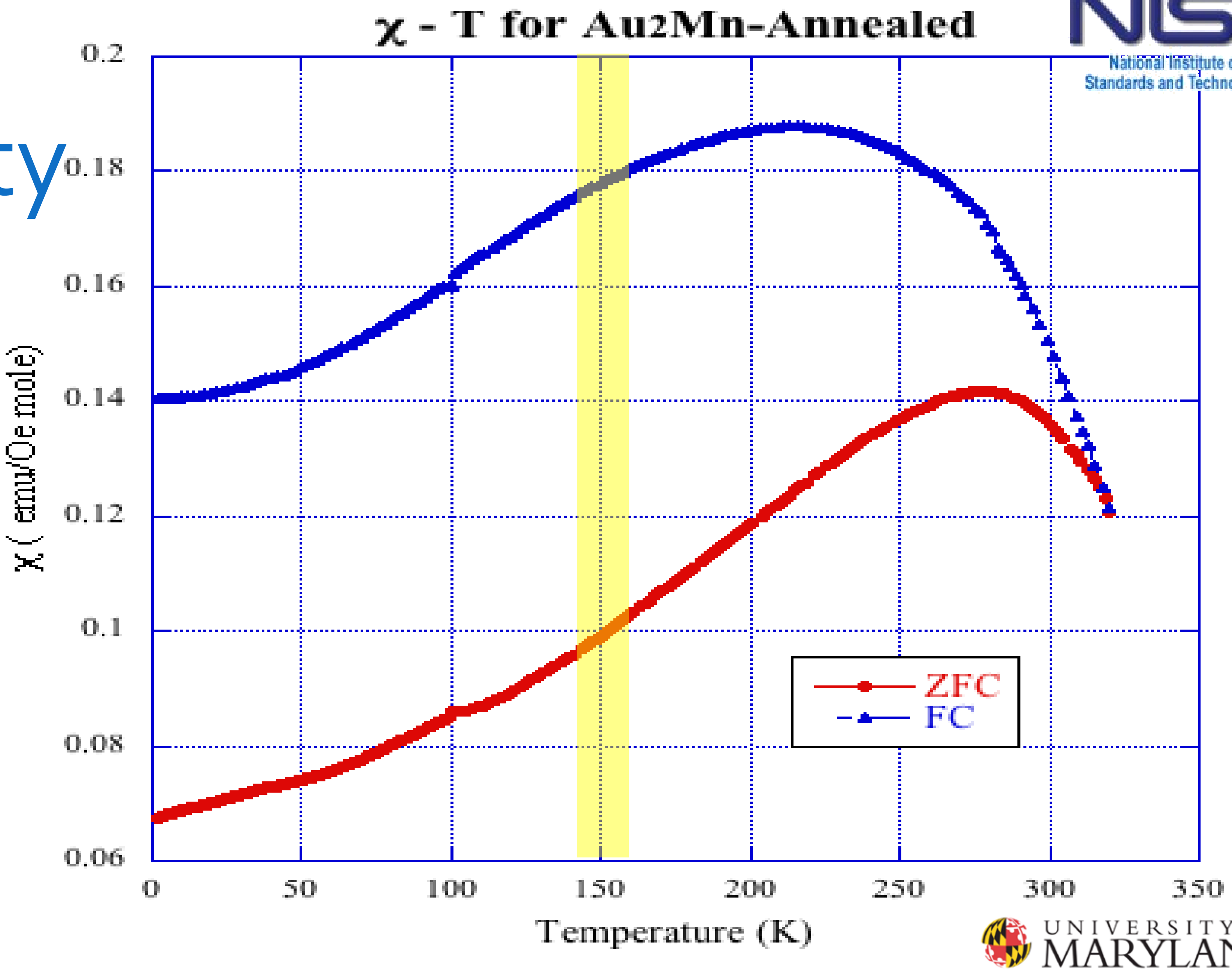
El	AN	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Au	79	M-series	88.65	86.35	63.84	3.9
Mn	25	K-series	14.01	13.65	36.16	1.1
		Total:	102.66	100.00	100.00	

Looks like Au_2Mn!

Magnetic Susceptibility

Annealed Sample:
T_C= above 320 K

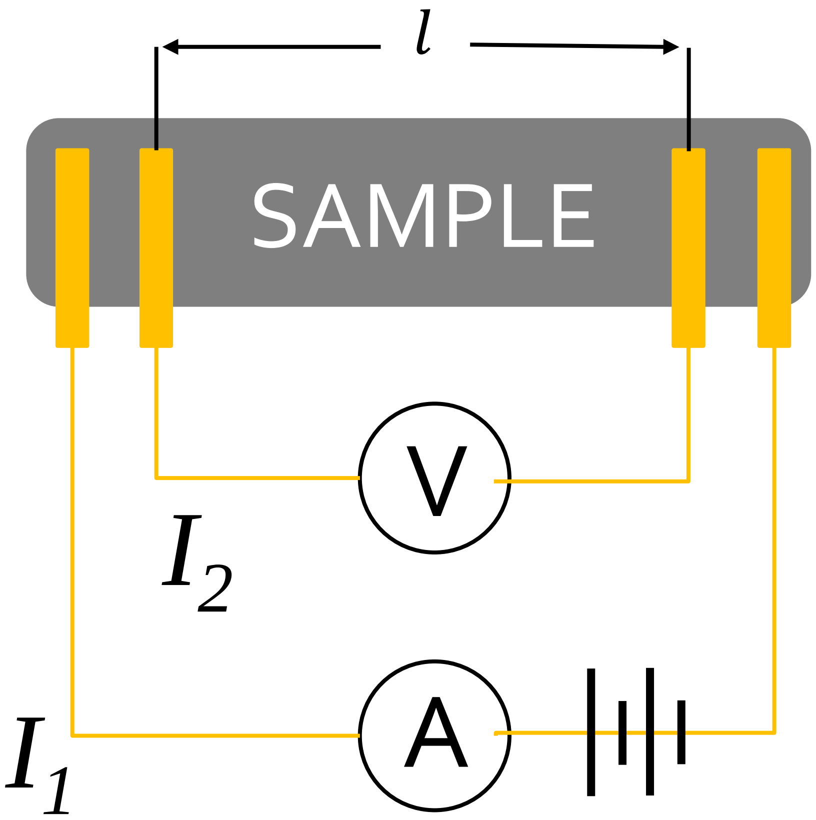
Irreversibility implies magnetic ordering



Electrical Resistivity

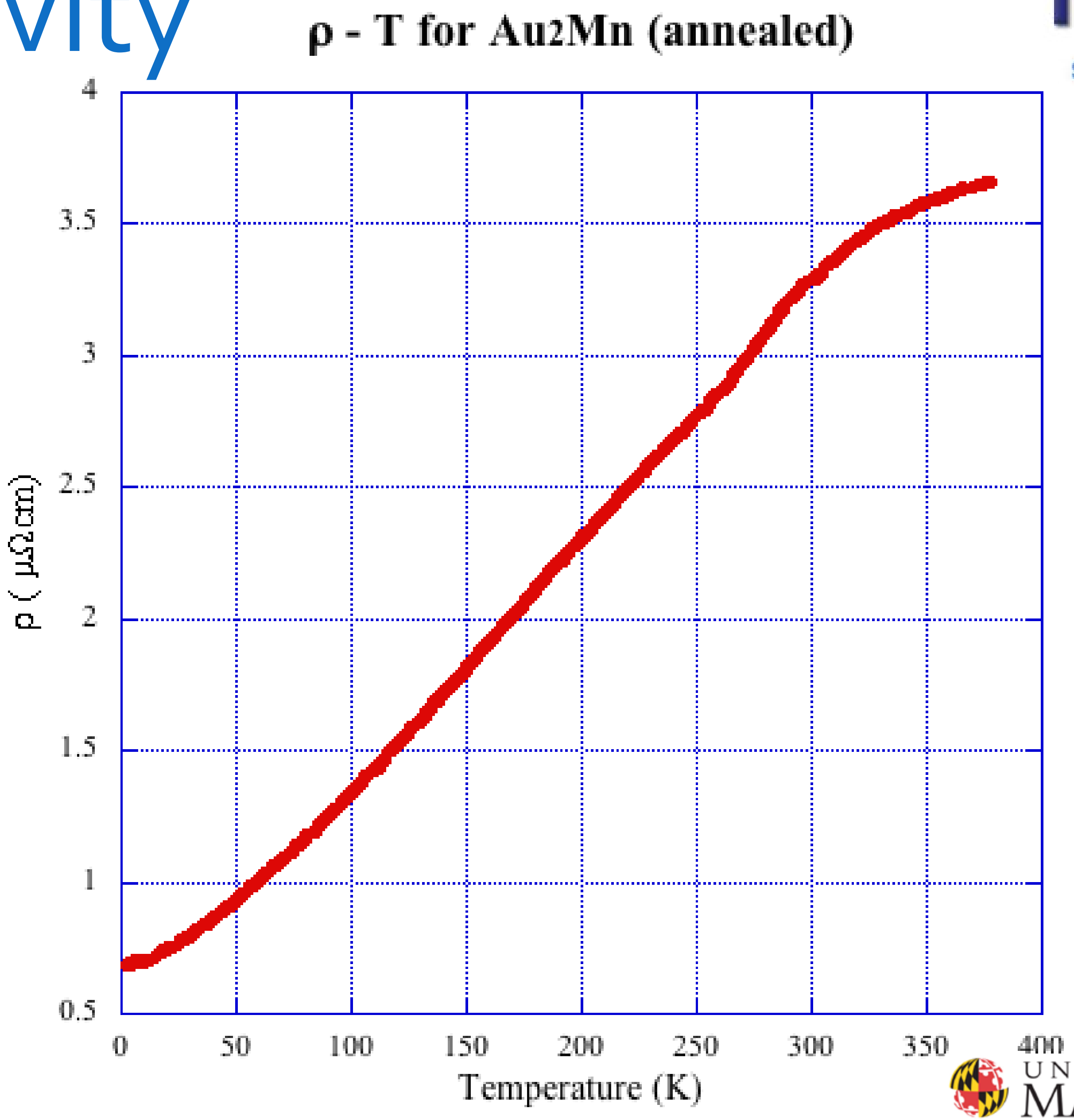
- The intrinsic property of a material to prevent the flow of electricity
- Calculated using the $\rho = \frac{RA}{l} = \frac{VA}{I*l}$

4 Point Test



Electrical Resistivity

Physical **P**roperty
Measurement **S**ystem



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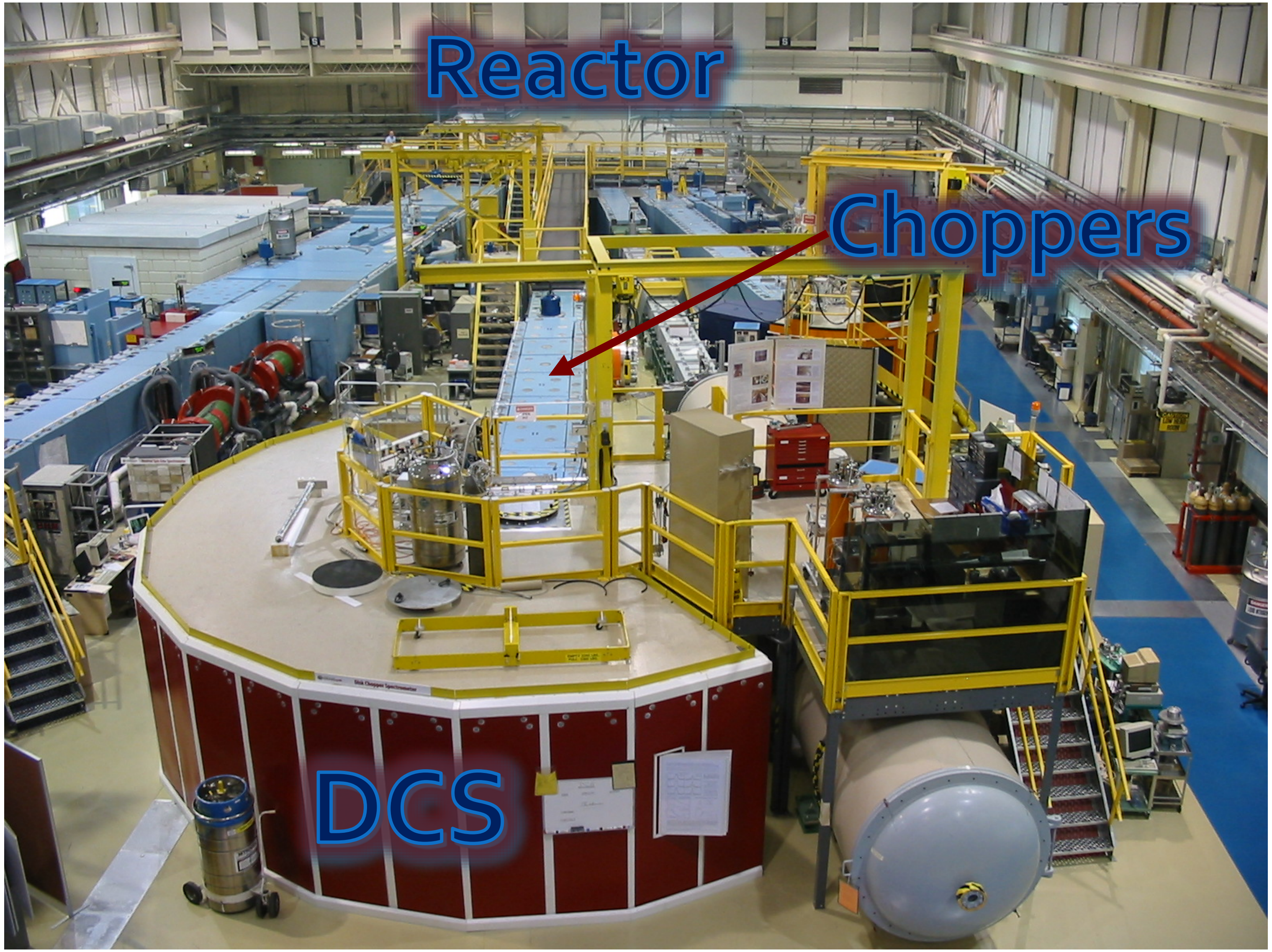
Neutron Scattering

Disc Chopper Spectrometer



- Cold Neutron Instrument
- Time of Flight Spectrometer
- Closed Cycle Refrigerator: base temperature 2.6 K

1.56 g

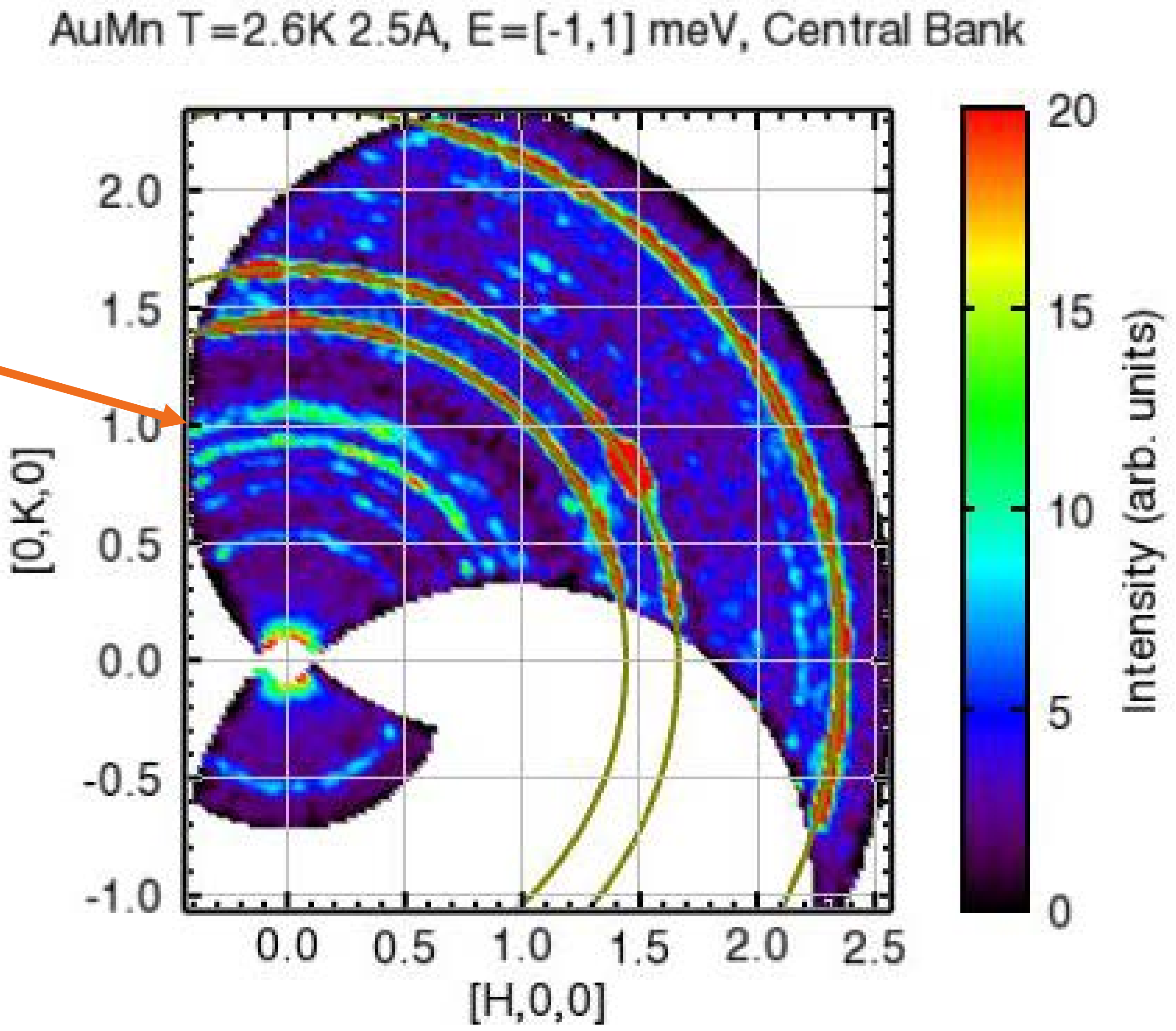
NIST NCNR Web Page for DCS https://www.ncnr.nist.gov/instruments/dcs/

Neutron Diffraction

Disc Chopper Spectrometer

NIST National Institute of Standards and Technology

Powder Diffraction Rings



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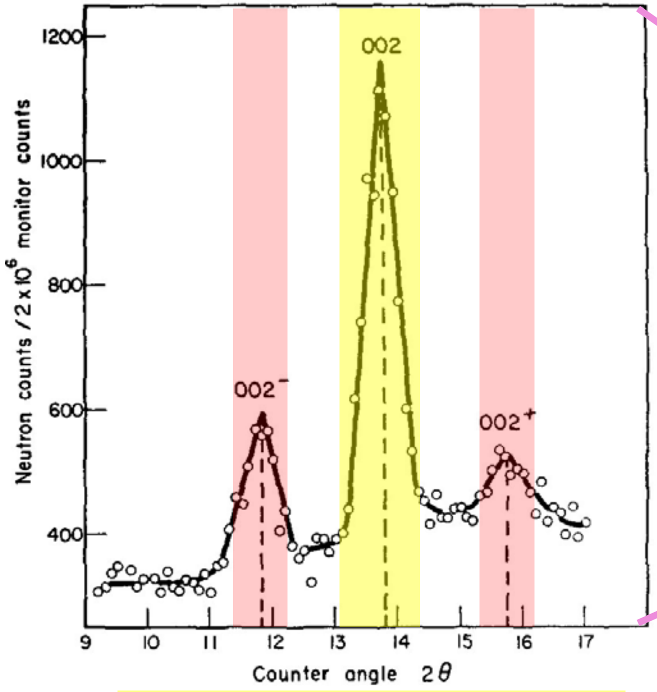
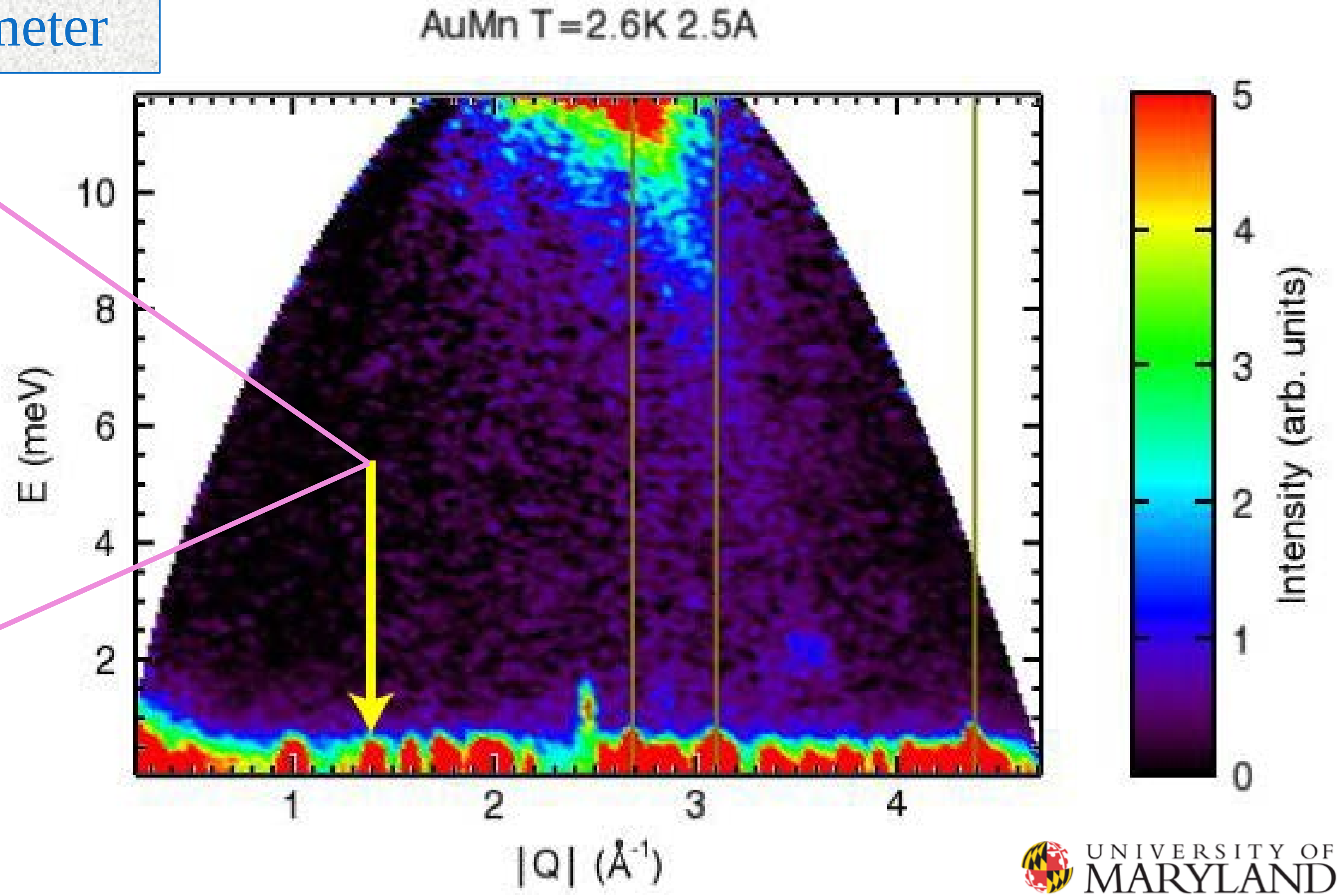
Neutron Spectroscopy

Disc Chopper Spectrometer



Structural Peak

Magnetic Peaks

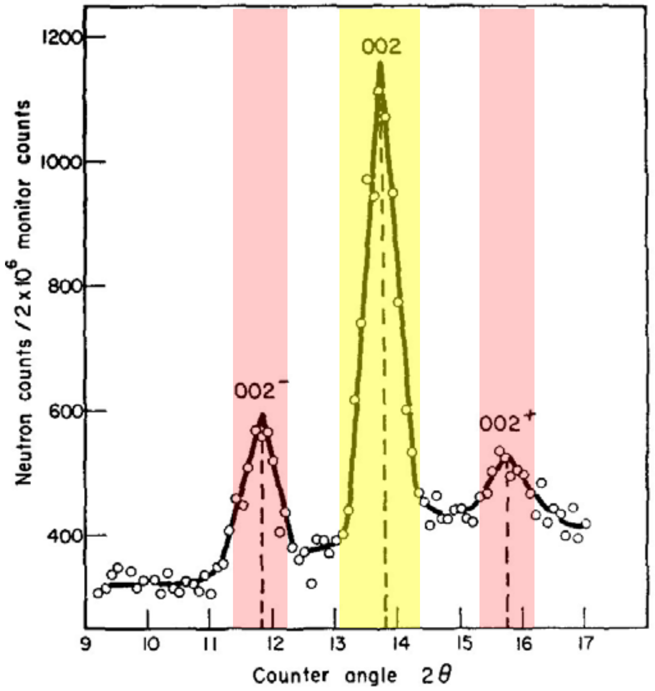


Smith F. A., Bradley C. C., Bacon G. E. *Journal of the Physics and Chemistry of Solids* 27(928) 1965

Neutron Diffraction

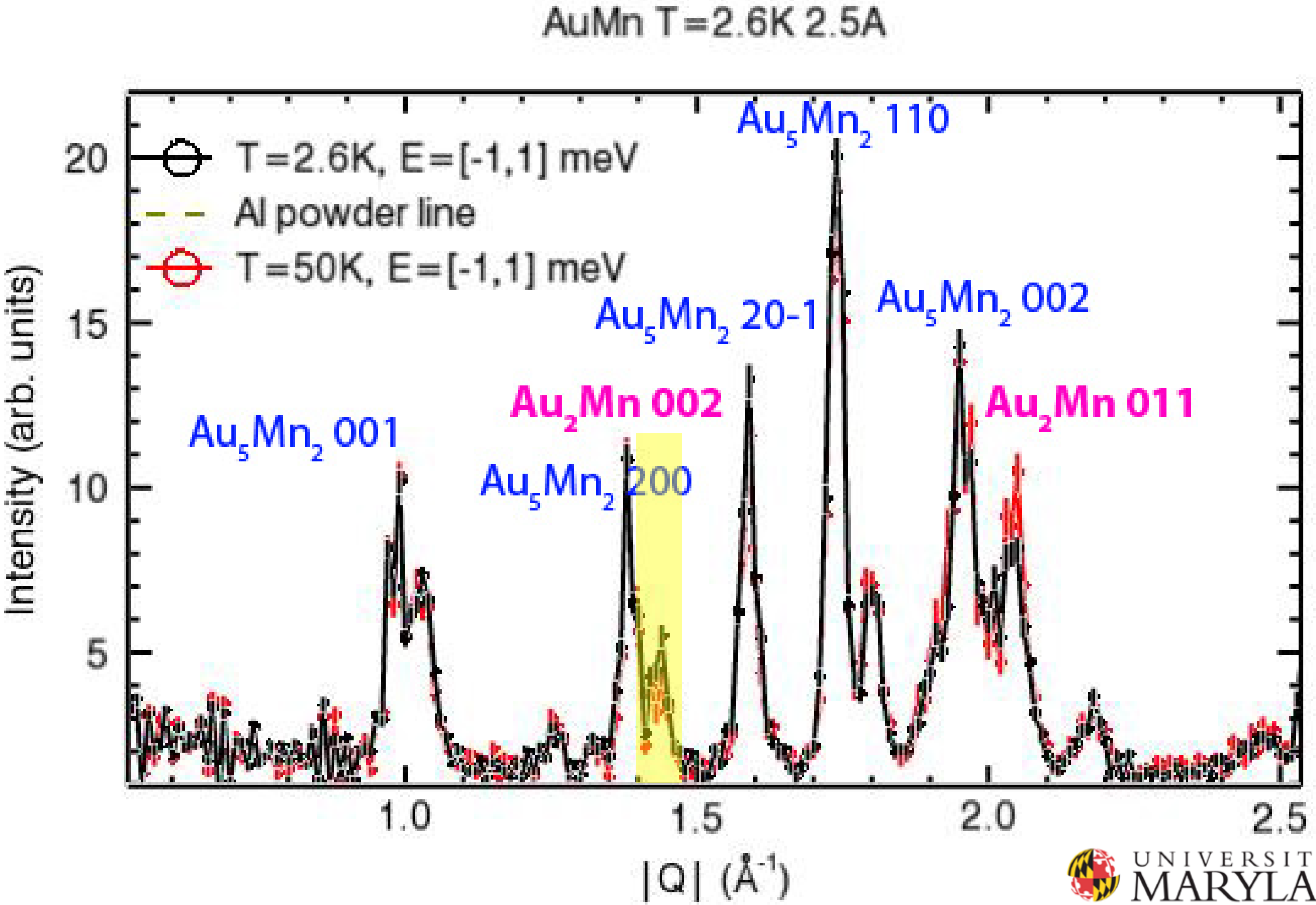
Disc Chopper Spectrometer

National Institute of Standards and Technology



Structural Peak

Magnetic Peaks



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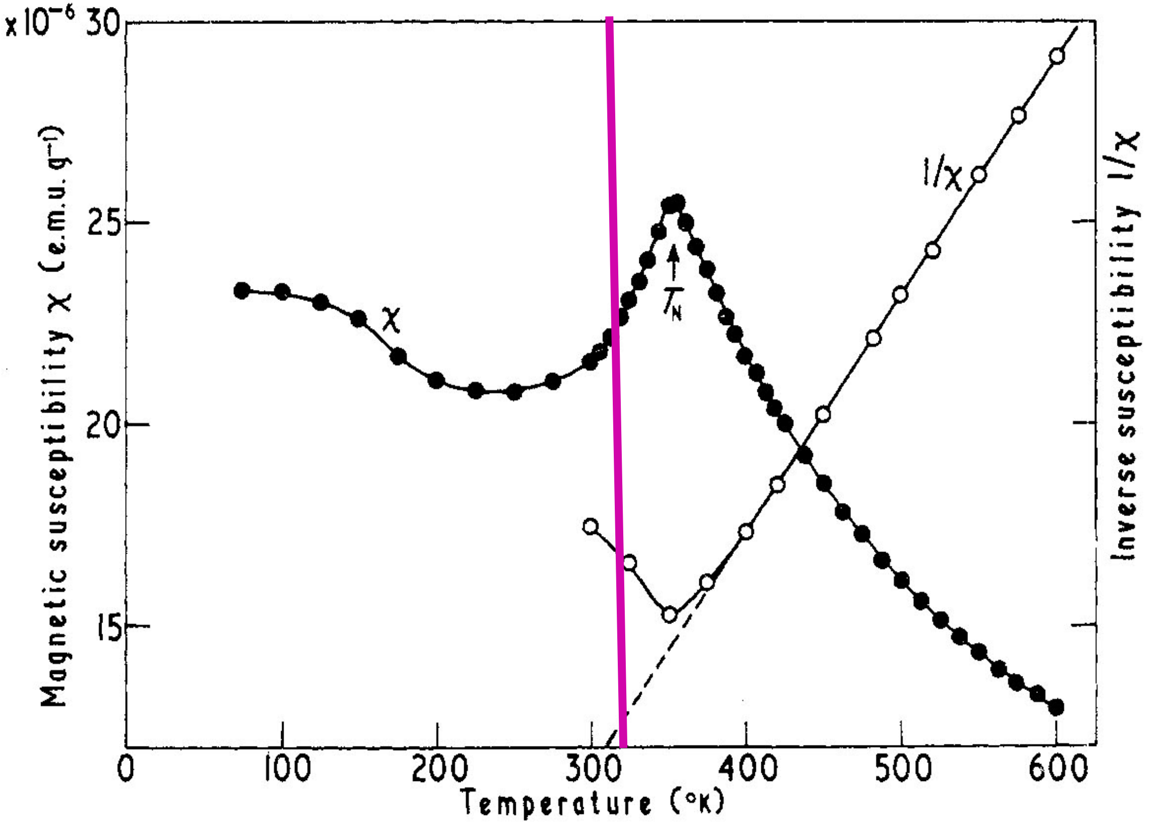
Smith F. A., Bradley C. C., Bacon G. E. *Journal of the Physics and Chemistry of Solids* 27(928) 1965

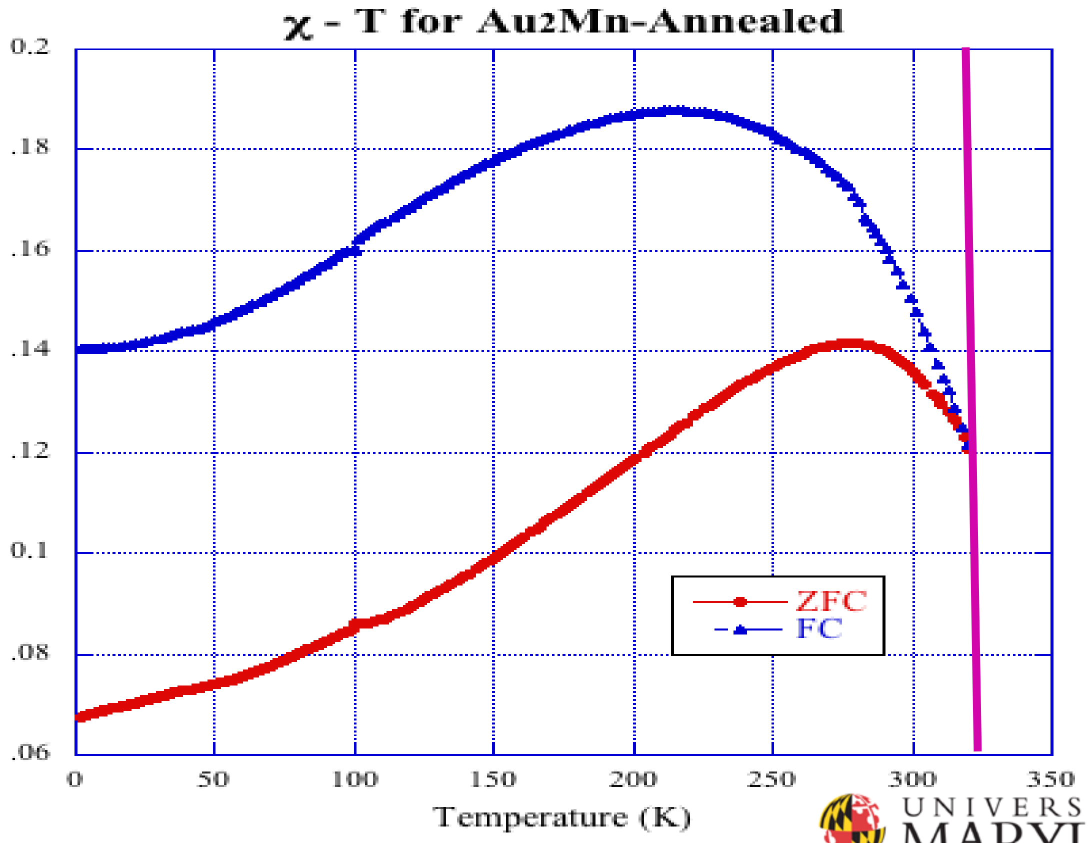
Au_5Mn_2: Continuity and Contrast

	Au_5Mn_2	Au_2Mn
T Order	354	365
At % Au	71	66

EDS

	C Atom. [at.-%]	C Error [%]
Au	63.84	3.9
Mn	36.16	1.1

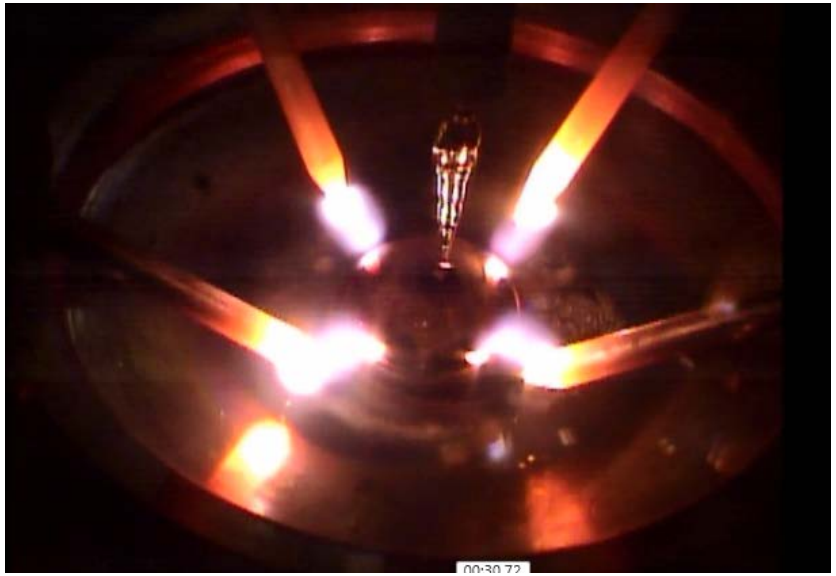


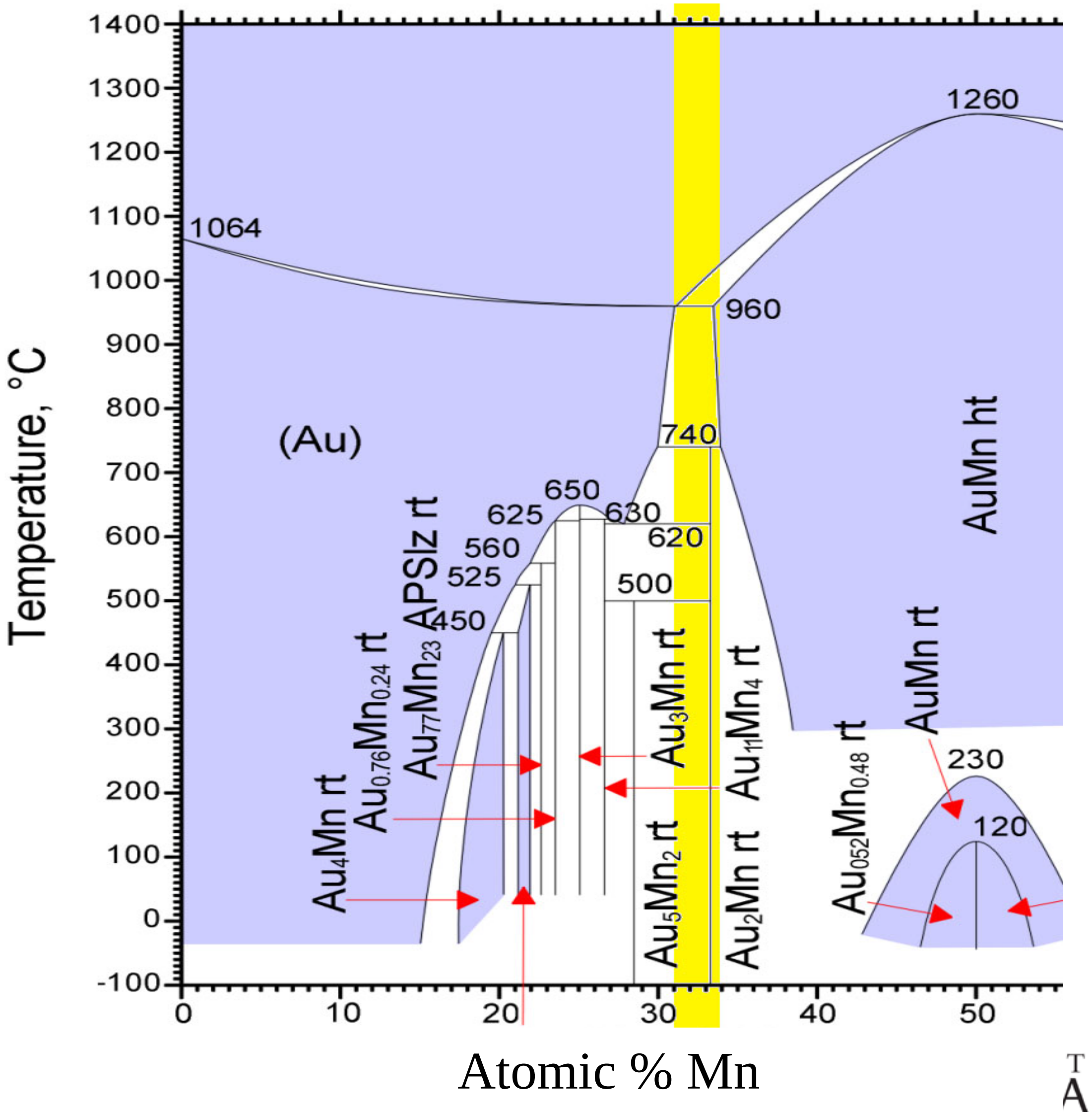


Smith J.H., Wells P. “Antiferromagnetism in Au5Mn2” *Journal of the Physics and Chemistry of Solids* 2:2(375) 1969

Conclusions and Outlook

- Structural phase homogeneity is a prevalent challenge
- Fabricate a new sample
- Upcoming Experiment – Pressure and temperature dependence of spin angle using BT4 triple axis





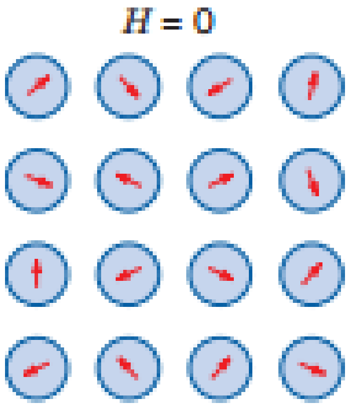
THANK YOU!

Mentor: Nicholas Butch

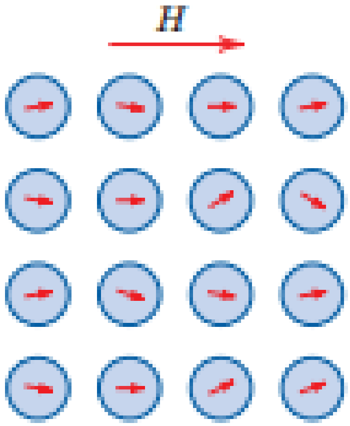
Acknowledgements: I-Lin Liu, Kefeng Wang

Susceptibility

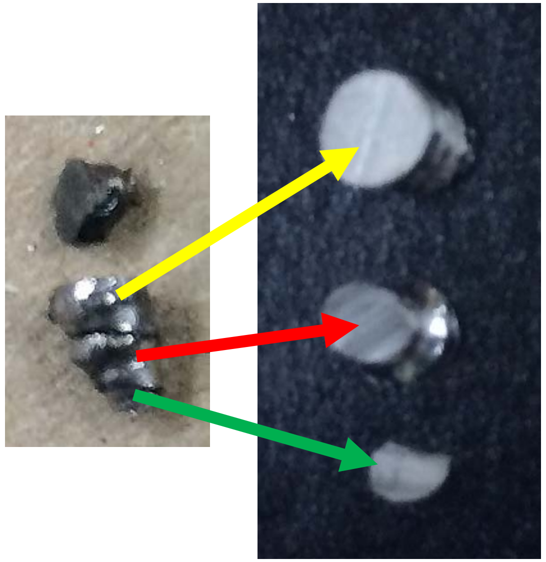
- The tendency of the magnetic moments (spins) within a material to become aligned with an applied magnetic field
- Higher susceptibility = easier to redirect the spins



Prior to applied Field



Field Applied



100.5 mg

27.1 mg

Callister D. William, Rethwisch G. David. Fundamentals of Materials Science and Engineering: An Integrated Approach. "Magnetic Properties". John Wiley & Sons, Inc. 2012. pg W25. http://phys.thu.edu.tw/~hlhsiao/mse-web_ch20.pdf

X-Ray Diffraction

- X-Rays interact with electrons to reveal
  - Atomic structure and Lattice Parameters
  - Phases and Orientations
  - Thermal Expansion
- Advantages
  - Can use small samples
  - Little effect on sample
- Disadvantage
  - Difficult to distinguish atoms of similar atomic number
  - Hydrogen is virtually invisible

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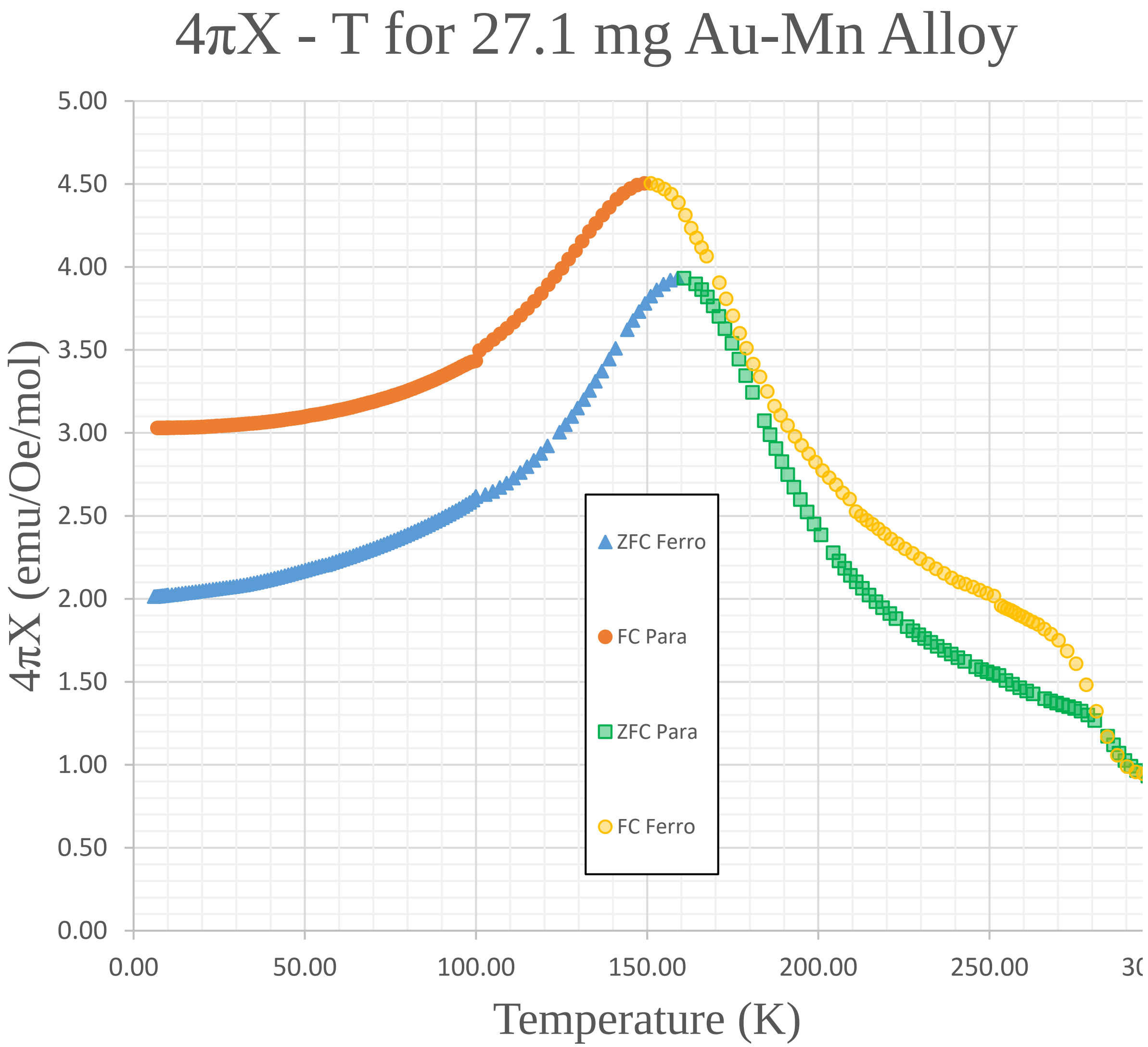
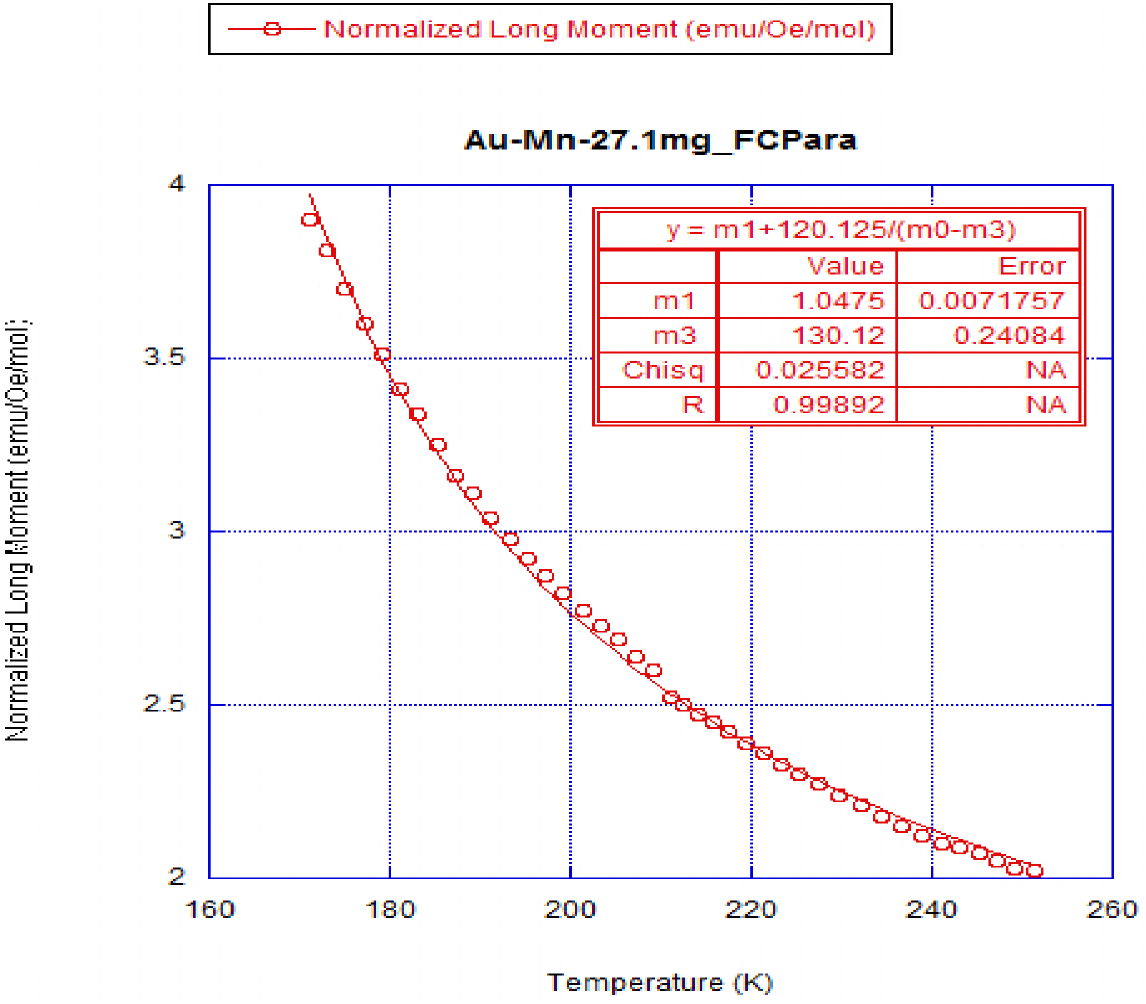
Susceptibility





Susceptibility

Transition (K)	Grown: Top - 100.5 mg	Grown: Middle - 27.1 mg	Annealed
ZFC T_c 1	-70.56 AFM	110.87 FM	
ZFC T_c 2	34.81 FM	229.92 FM	
FC T_c 1	-115.31 AFM	81.30 FM	
FC T_c 2	195.58 FM	227.11 FM	

Energy Dispersive Spectroscopy

National Institute of Standards and Technology

Annealed Sample

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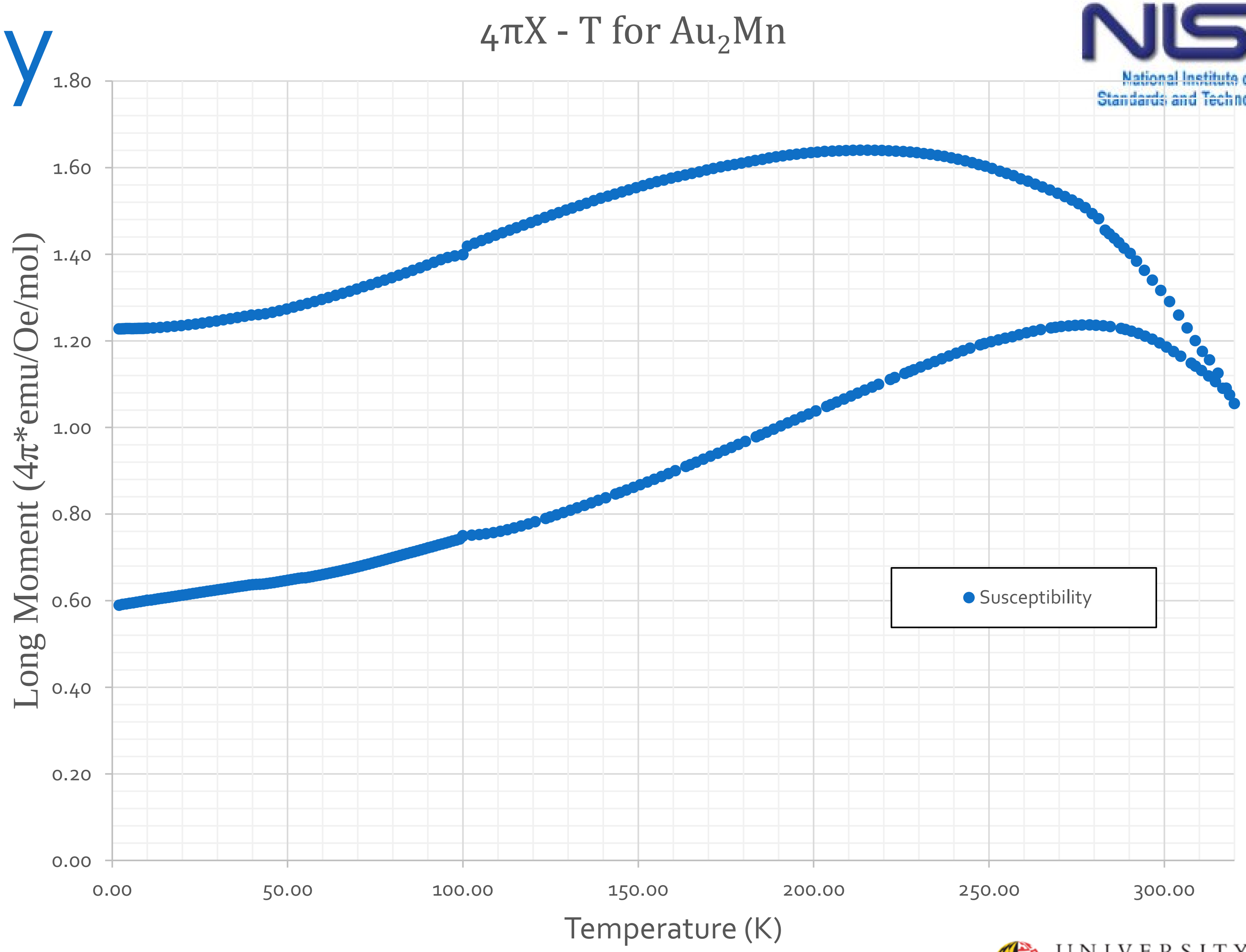
Susceptibility

Annealed Sample:
T_C= above 320 K

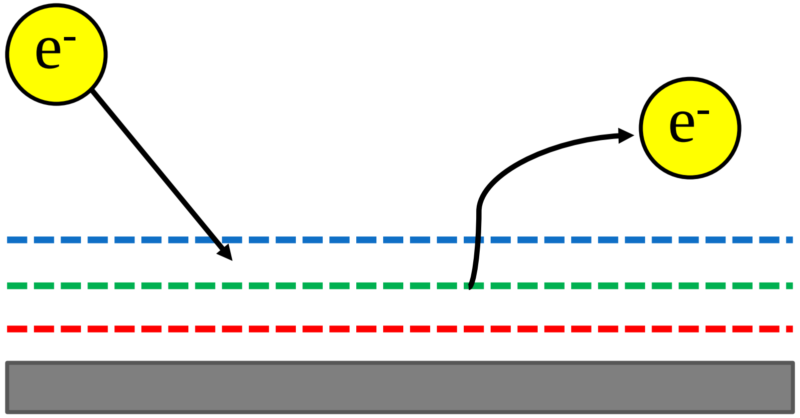


Energy Dispersive Spectroscopy

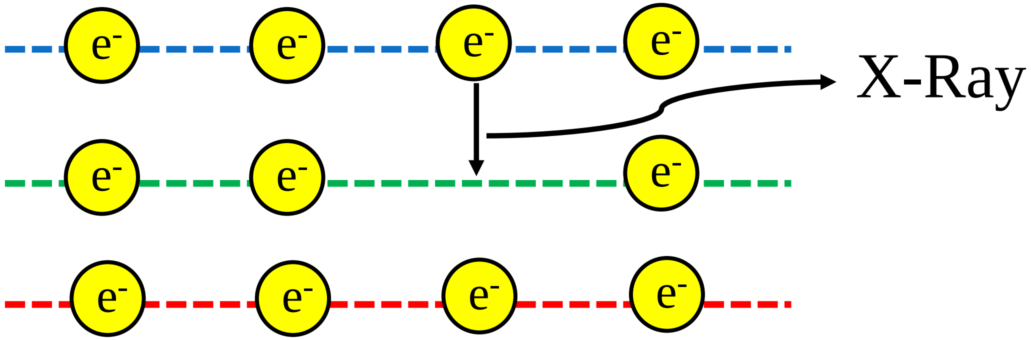
National Institute of Standards and Technology

How does EDS work?

1.



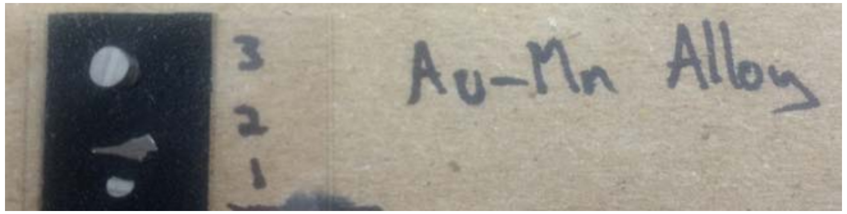
2.



3. Output energies and their quantities are recorded

Note:
The difference between electron levels is atom specific

4. Reports elements which are present and their proportional quantities



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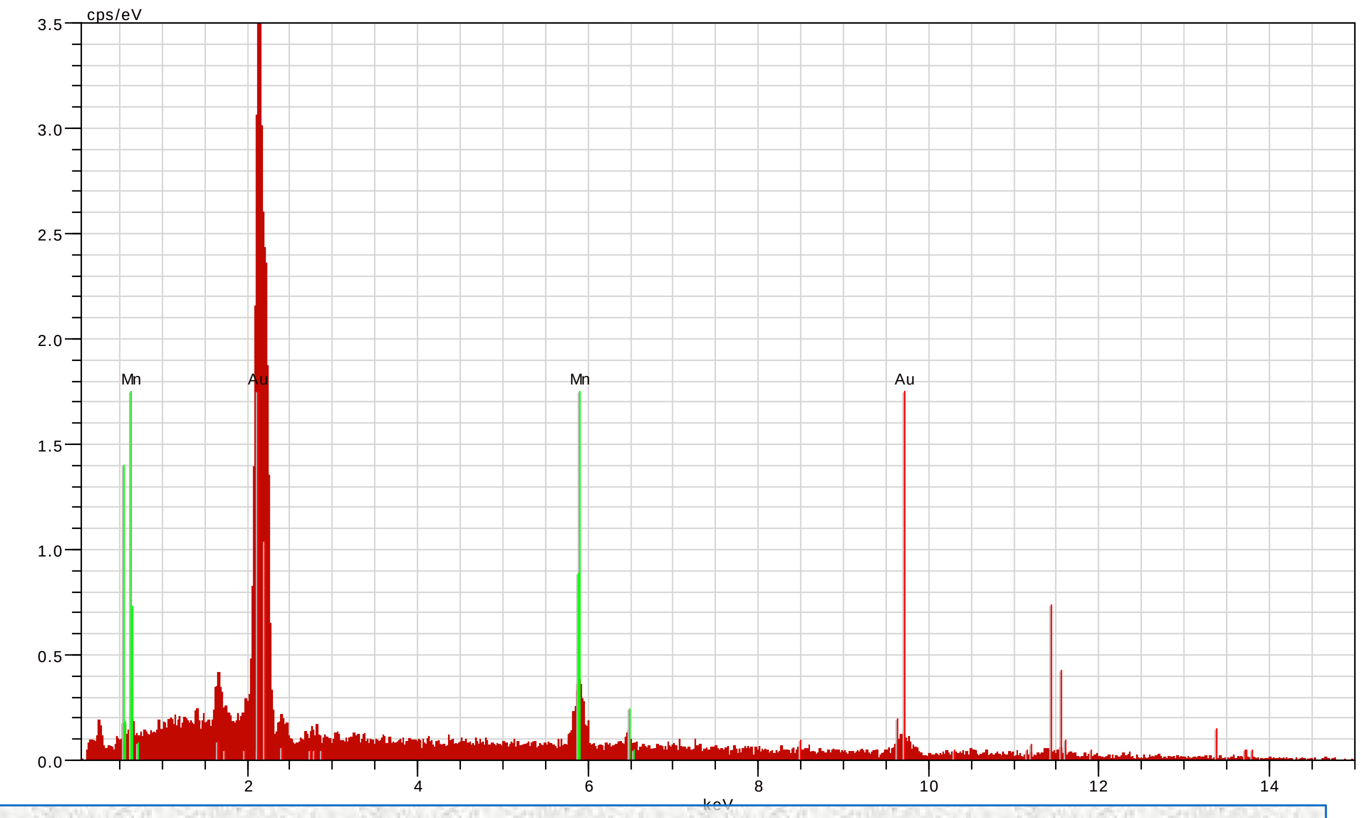
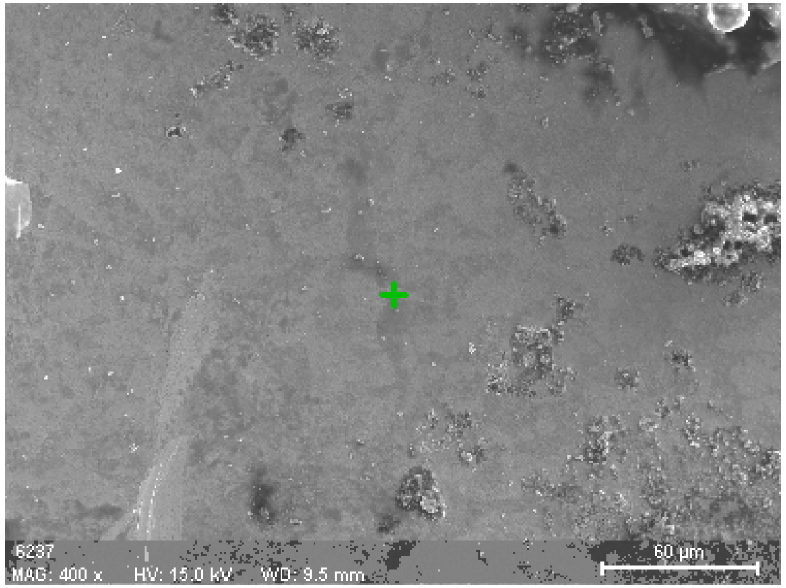
Energy Dispersive Spectroscopy

Pulled Au-Mn Crystal

- Properties and Proportions vary depending on the location in the material





El	AN	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Au	79	M-series	80.44	84.94	61.14	3.2
Mn	25	K-series	14.26	15.06	38.86	0.6
		Total:	94.70	100.00	100.00	

Surface – Likely mix of Au_3Mn and AuMn

NIST National Institute of Standards and Technology

UNIVERSITY OF MARYLAND

Reference

Gold-Manganese Binary Diagram (1990 Massalski T.B.)

Publication year: 1990
Diagram type: binary phase diagram
Concentration range: full composition; 0-100 at.% Mn
Temperature: -100 - 1400 °C

Nature of investigation: experimental
Authors: Massalski T.B., Okamoto H.
Title: Au-Mn (Gold-Manganese)
APDIC diagram: No

My Materials Textbook!
http://phys.thu.edu.tw/~hlhsiao/mse-web_ch20.pdf

Callister D. William, Rethwisch G. David. Fundamentals of Materials Science and Engineering: An Integrated Approach. "Magnetic Properties". John Wiley & Sons, Inc. 2012. pg W25. http://phys.thu.edu.tw/~hlhsiao/mse-web_ch20.pdf

Hand - http://www.animationmagazine.net/people/british-animation-icon-john-coates-dies-at-85/

Yellow Submarine
https://garinglenn.wordpress.com/2013/10/18/magic-wand-and-quick-select-tools/

Wilson M. N., Karhu E. A., Lake D. P., Quigley A. S., Meynel S., Bogdanov A. N., Fritzche H., Rößler U. K., Monchesky T. L. "Discrete Helicoidal States in Chiral Magentic Thin Films", *Physical Review B* 88(21) (2013):

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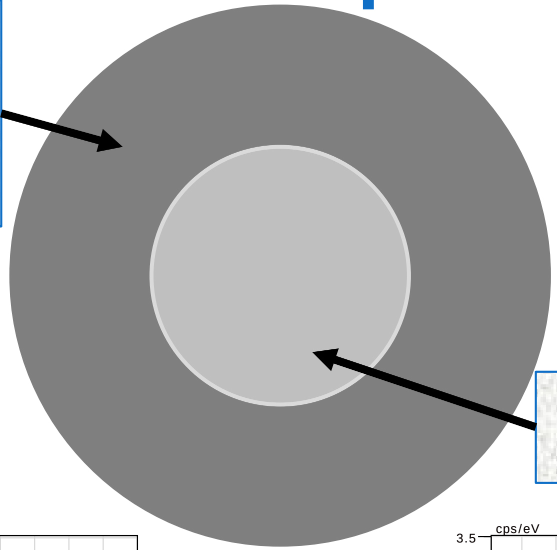
Electron Diffraction Spectroscopy

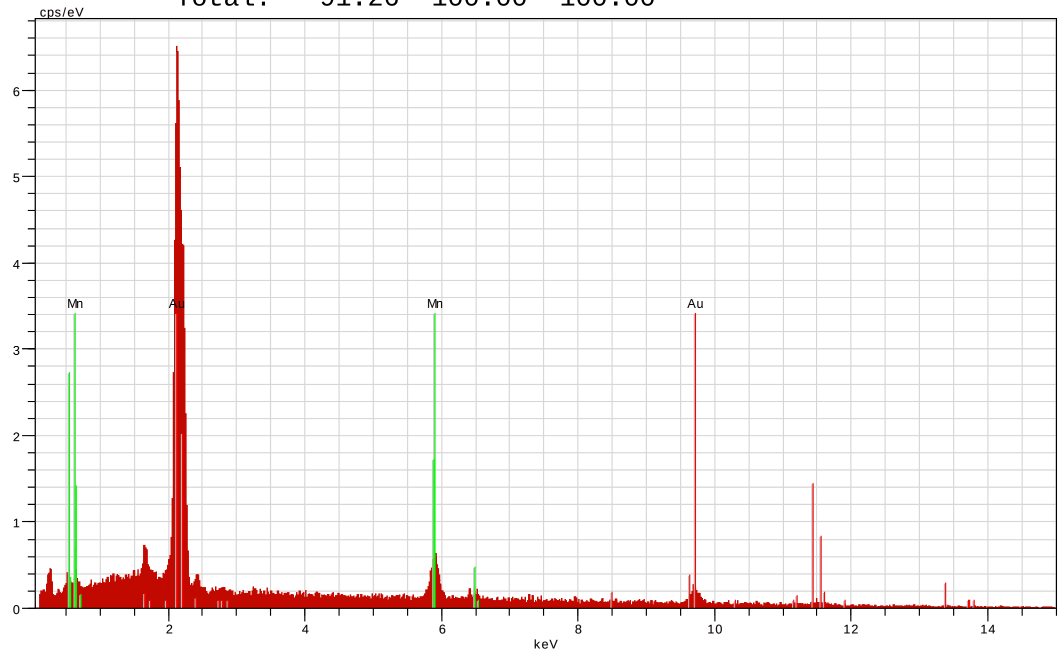
Outer Core – Likely Au_3Mn and AuMn



Inner Core – Primarily Au_2Mn

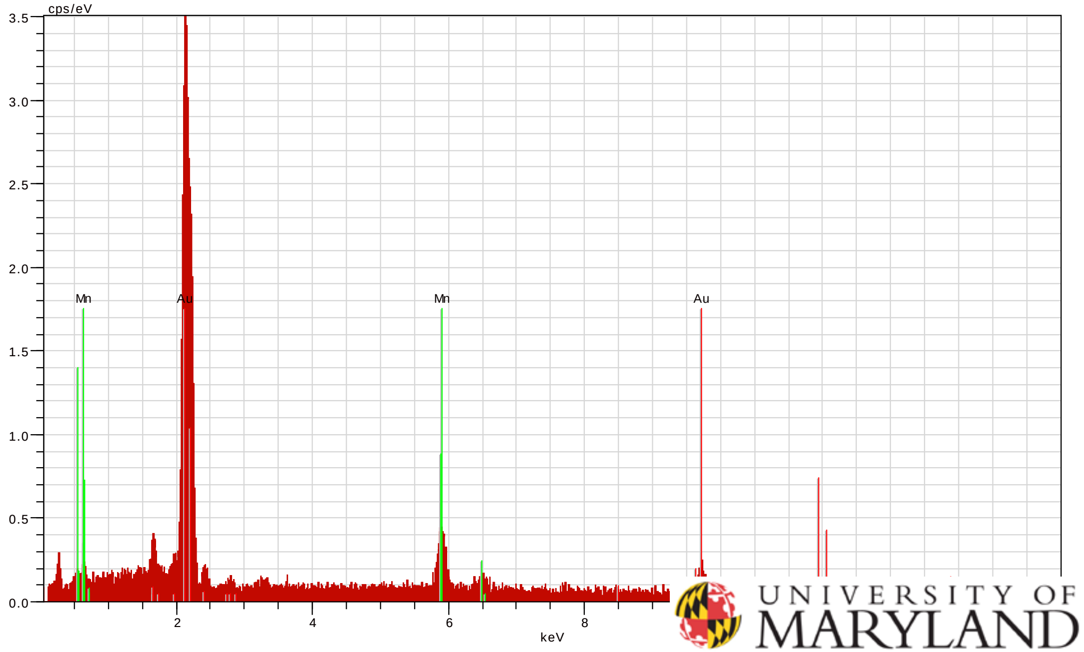
Outer core

El	AN	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Au	79	M-series	77.71	85.15	61.52	3.0
Mn	25	K-series	13.55	14.85	38.48	0.5
		Total:	91.26	100.00	100.00	



Inner core

El	AN	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Au	79	M-series	94.04	87.09	65.29	3.7
Mn	25	K-series	13.95	12.91	34.71	0.6
		Total:	107.99	100.00	100.00	



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