Mössbauer study of $Y_3Al_5O_{12}$ (YAG), $Y_3Fe_5O_{12}$ (YIG) and $Gd_3Ga_5O_{12}$ (GGG) single crystal garnets following dilute implantation of $^{57}Mn^+$.

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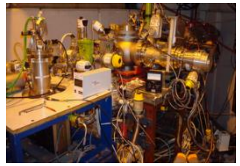
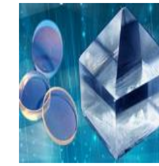


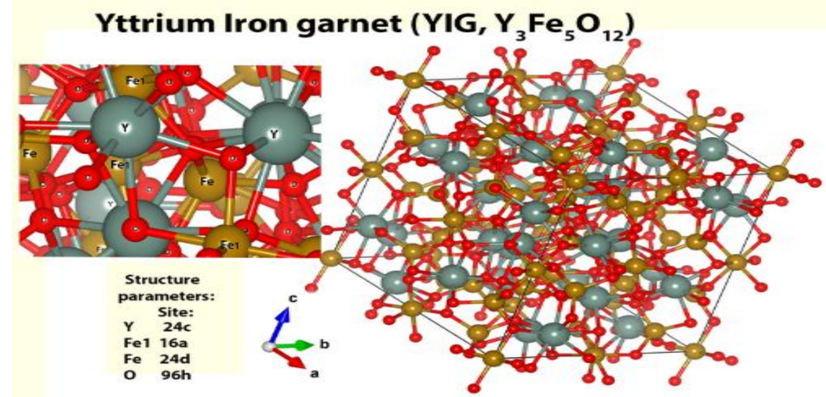
Motivation

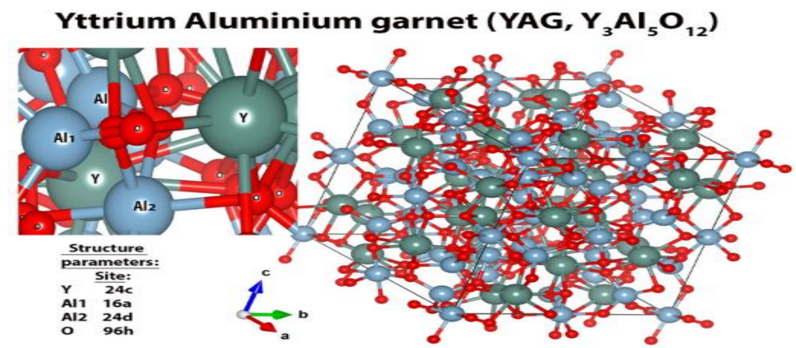


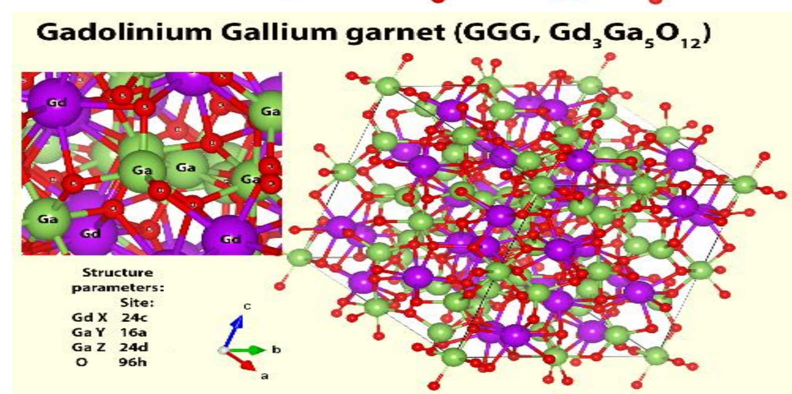


Synthetic crystalline garnets: Yttrium aluminium garnet (YAG, $Y_3Al_5O_{12}$), Yttrium iron garnet (YIG, $Y_3Fe_5O_{12}$) and Gadolinium Gallium Garnet (GGG, $Gd_3Ga_5O_{12}$) are commonly used as a host materials in solid-state lasers, data storage, acoustic transmitters and numerous nonlinear optics applications (light-emitting diodes, scintillators, magneto–optical films etc.).

Despite the similar chemical structure the three garnets types posses different physical properties. In order to normalize our research we use only single crystal layers without additional dopant ions concentrations.

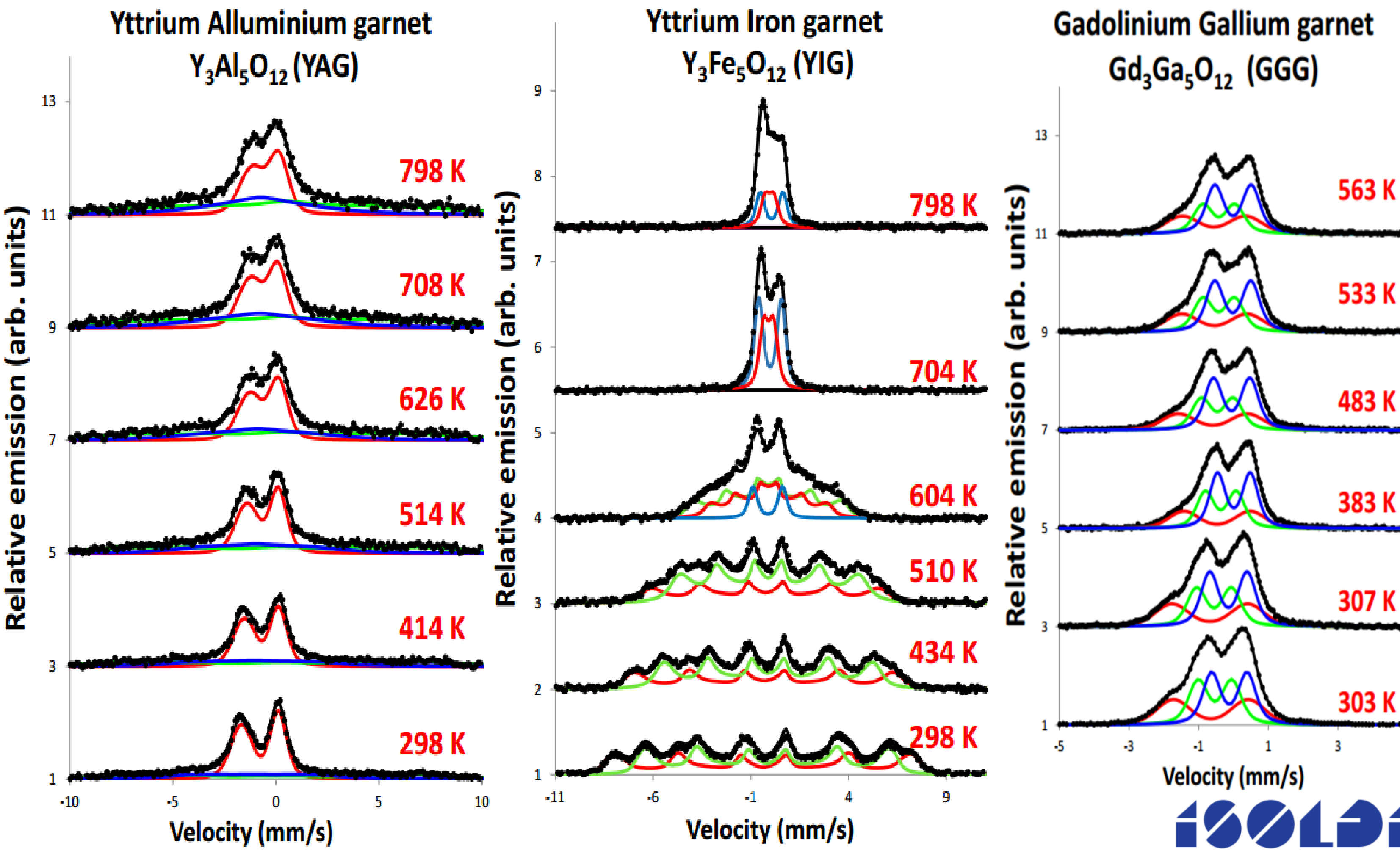






Preliminary view

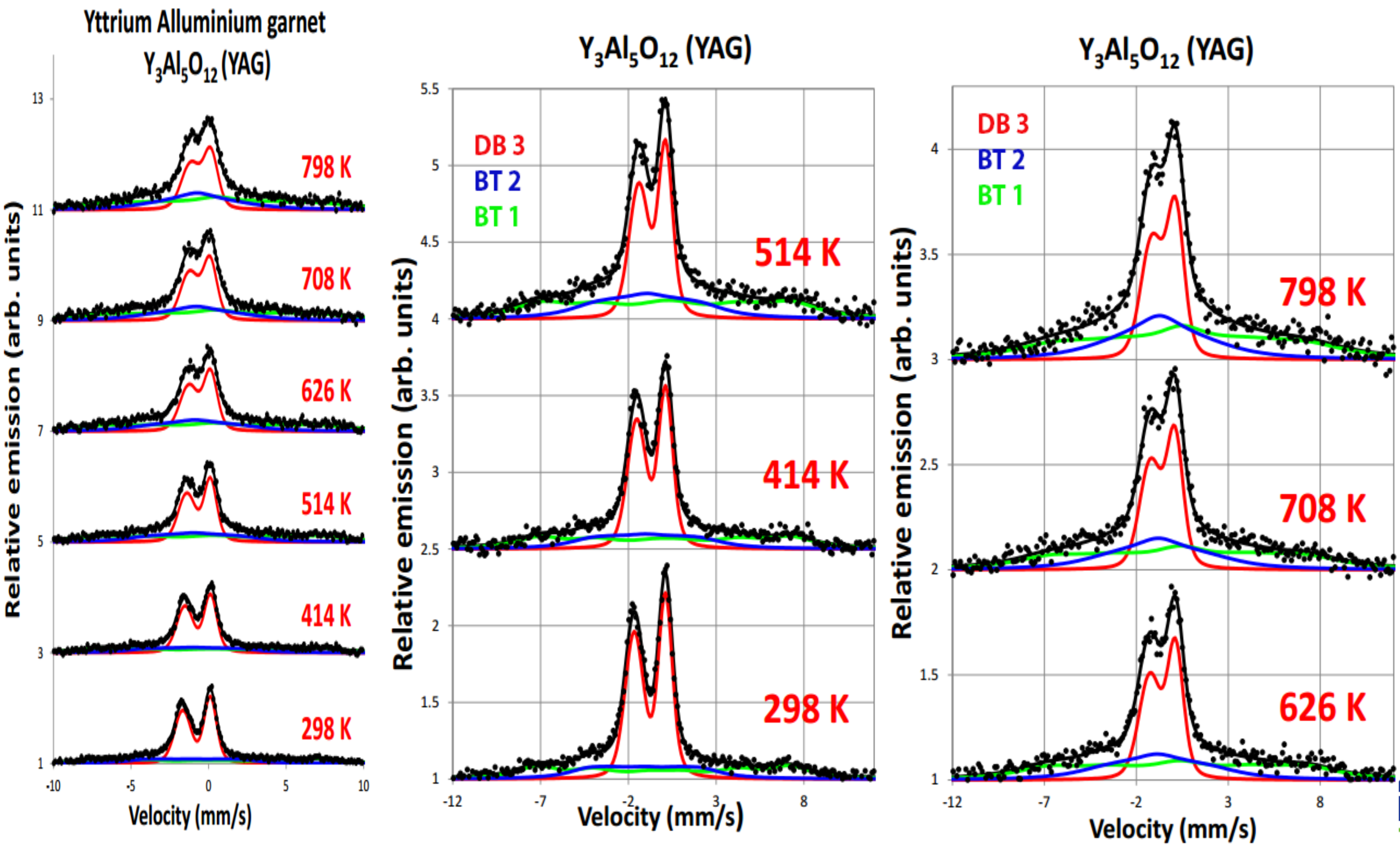
All the spectra in this presentation have been fitted with “Vinda” software. Spectra calibration have been provided with SS detector test. Velocity calibration gives emission temperature dependant scale relative to α-Fe.



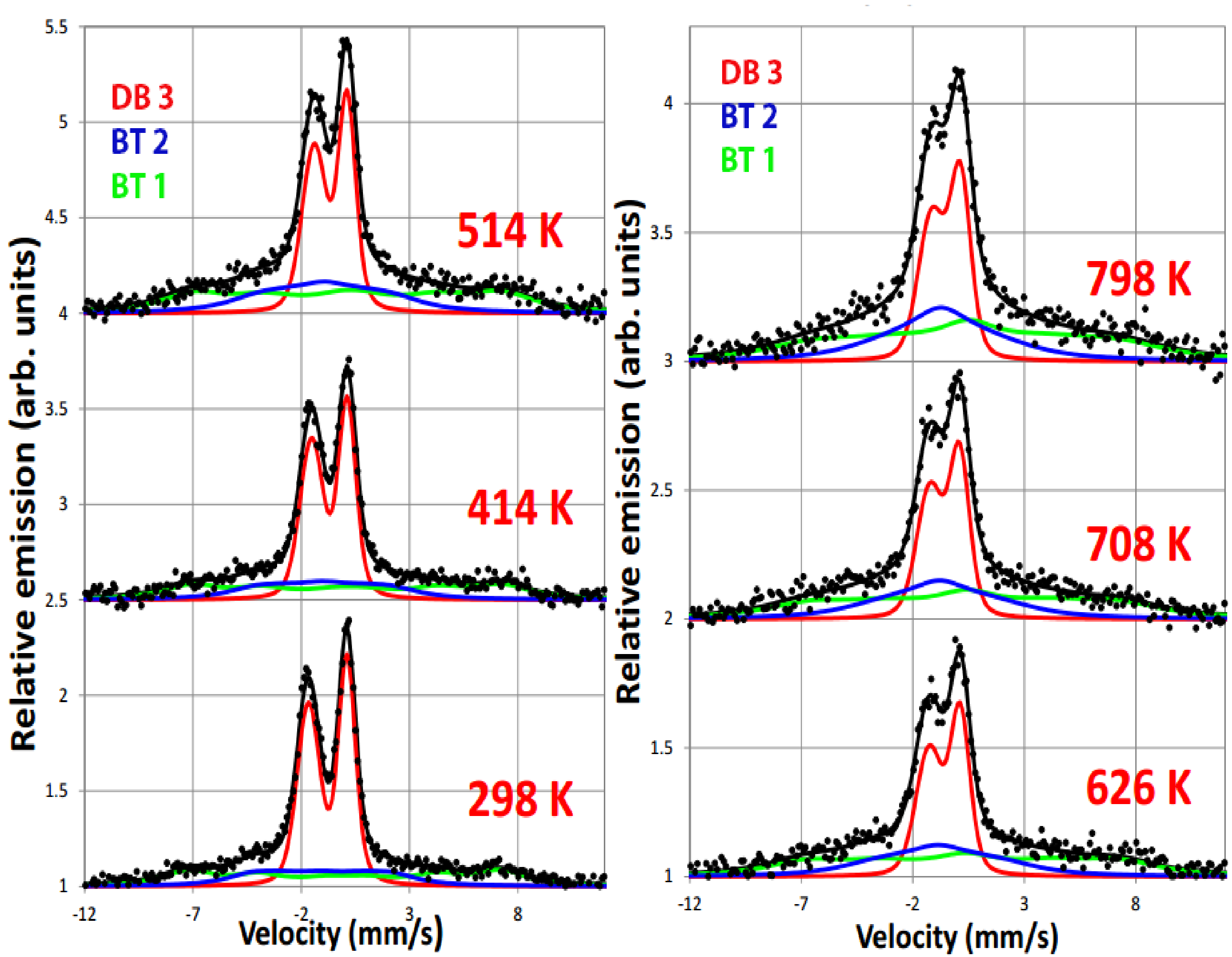
$Y_3Al_5O_{12}$ (YAG)

DB 3,"**Voigt lines shape**": Specific of the this model doublet is the possibility two legs of the quadrupole are allowed to have different Gaussian broadening.

BT1 and **BT2**, “**Blume-Tjoin line-shape**” doublets. This model describe the ^{57}Fe emission Mössbauer relaxation spectra for the indicated relaxation times in a magnetic hyperfine field.



Spectra analysis YAG



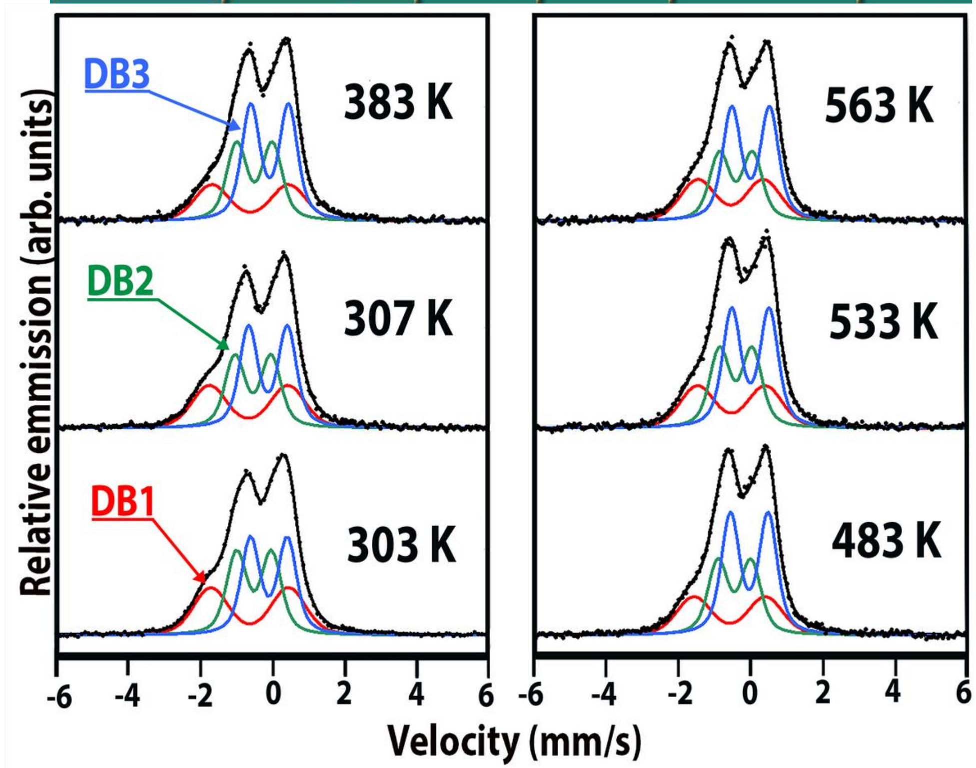
DB3 associated with Fe^{3+} in YAG garnet could be assigned to the slow spin relaxation.

$Gd_3Ga_5O_{12}$ (GGG)

- **DB1** suggest Fe in highly distorted lattice environment.
- **DB2** Probably DB2 is due to intersitial Fe.
- **DB3** hyperfine parameters are consistent with an assignment to high-spin Fe^{3+}.

- There is no annealing stage between RT and 563 K is observed.
- High-spin Fe^{3+} shows fast spin relaxation, presumably due to exchange interactions with Gd^{3+}.

Component	Assignment	δ_{RT} (mm/s)	Q_{RT} (mm/s)	dQ/dT (mm/(s.K))	σ (mm/s)
Doublet 1 (DB1)	Fe^{2+} damage	0.65 (1)	2.15 (4)	$-120 (20) \times 10^{-5}$	0.40 (1)
Doublet 2 (DB2)	Interstitial Fe	0.53 (1)	0.97 (1)	$-34 (5) \times 10^{-5}$	0.19 (1)
Doublet 3 (DB3)	Fe^{3+} on Ga_T sites	0.12 (1)	1.02 (1)	$-3 (4) \times 10^{-5}$	0.17 (1)



YAG spectra analysis

		DB3			BT1 + BT2
T (°C)	Corr.T.	δ (mm/s)	Area (%, mm/s)	dSOD	Area
27	298.3	-0.77959	-308.2740326	-0.237	-250.975
105	414	-0.70446	-247.6635388	-0.316	-240.96
183	514.4	-0.6485	-205.5799355	-0.387	-285.834
280	626.9	-0.57475	-177.2230961	-0.467	-278.179
355	708.7	-0.57187	-163.4152994	-0.526	-284.459
440	798.1	-0.51005	-142.9932144	-0.591	-285.136

Corrected temperature:

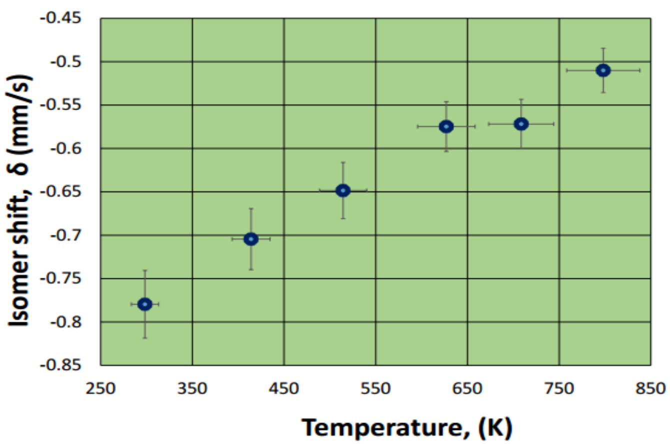
Corr.T. = $\sigma_0 + \sigma_{SOD}$ [T (K), Θ_D]

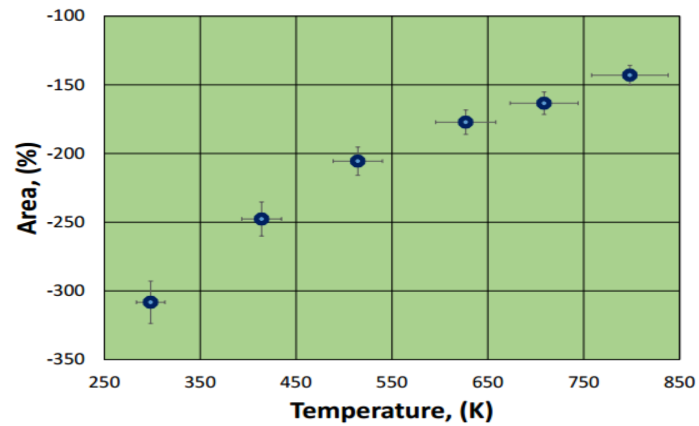
Where:

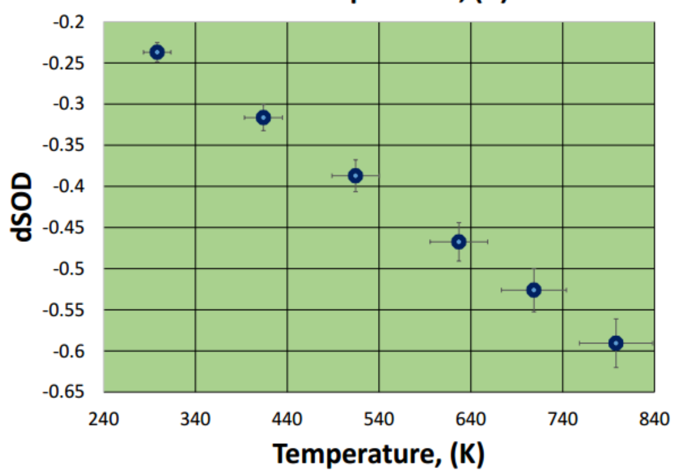
σ_0: …

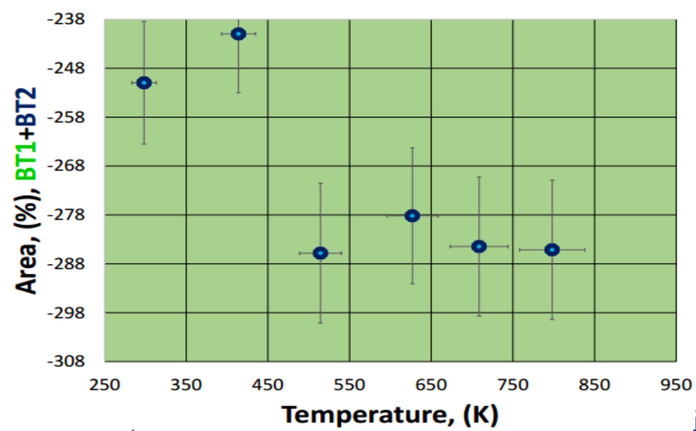
σ_{SOD}..

Θ_D -





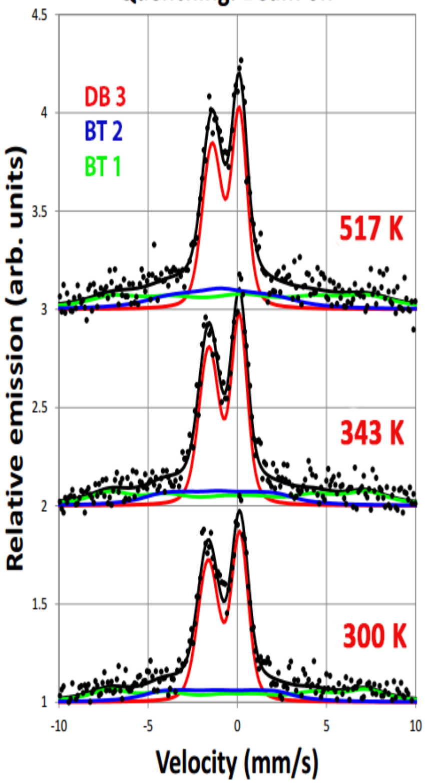




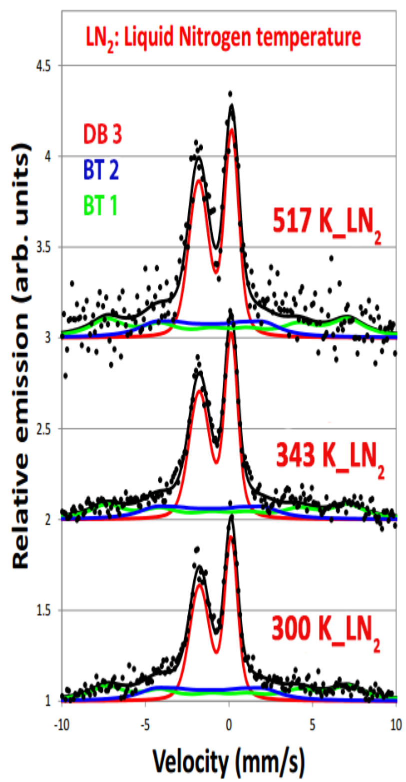
Quenching Spectra_YAG

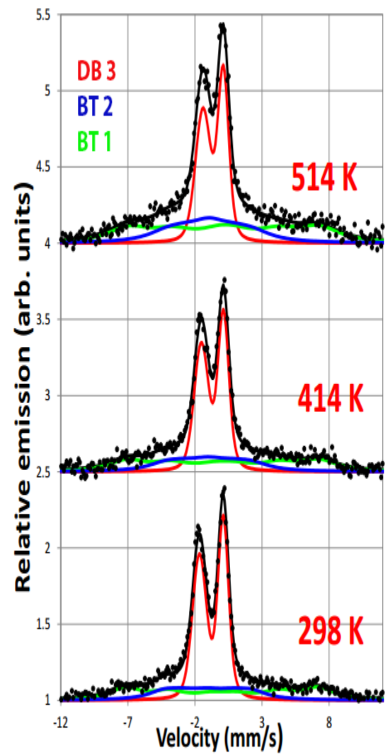
			DB3								BT1 + BT2
T (°C)	Corr.T.	Bck	δ (mm/s)	ΔEQ (mm/s)	σs(δ) (mm/s)	σp(δ) (mm/s)	Area (%, mm/s)	Bscale	dSOD	p	Area
RT	300	0.505	-0.74898	1.7762229	0.396546534	0.505065461	-253.9839174	1	-0.238	0.251	-191.6144
LN_2_RT	110	1.074	-0.82391	1.90131086	0.310070863	0.509220693	-226.0838609	1	-0.127	0.034	-215.757
3,2A	343.6	0.672	-0.74496	1.71105056	0.368821652	0.478184123	-244.2782615	1	-0.268	0.329	-200.6874
LN_2_3,2A	110	1.258	-0.82631	1.91906488	0.315147475	0.534034122	-233.4107599	1	-0.127	0.034	-190.8429
6,0A	517.6	0.734	-0.65381	1.53633502	0.361109233	0.470246915	-192.3856868	1	-0.389	0.747	-183.4272
LN_2_6,0A	110	0.236	-0.8325	1.98047189	0.3515473	0.51802749	-215.2768744	1	-0.127	0.034	-186.5385

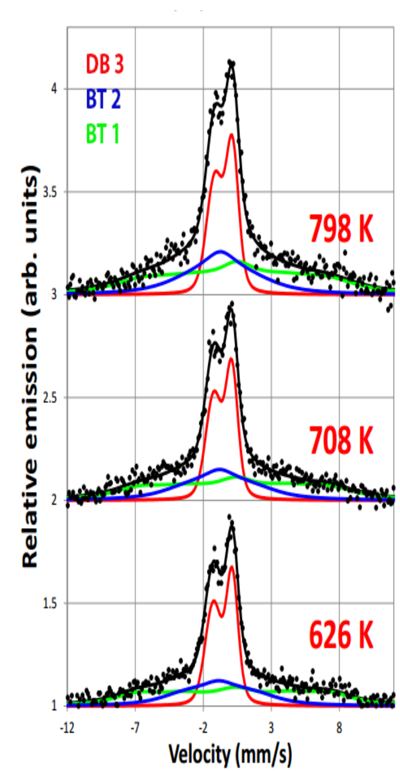
Quenching: Beam on



Quenching: Beam off

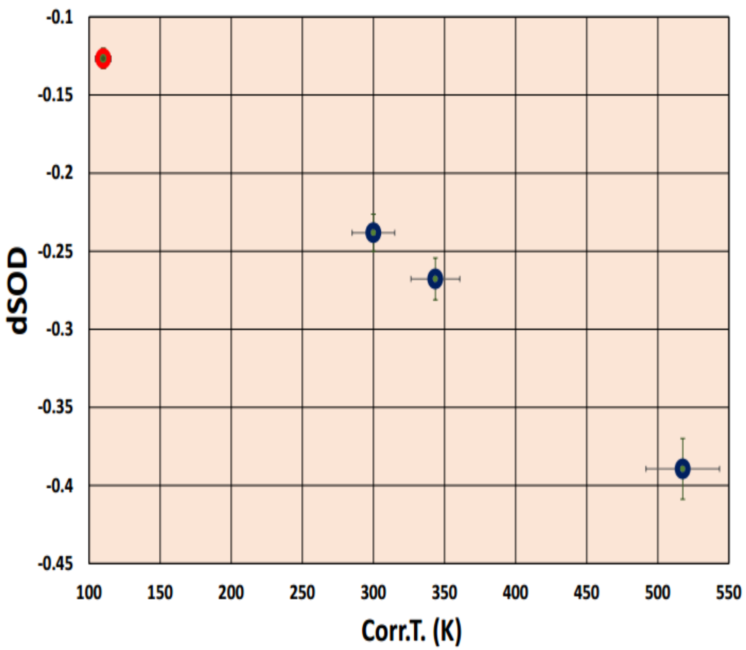


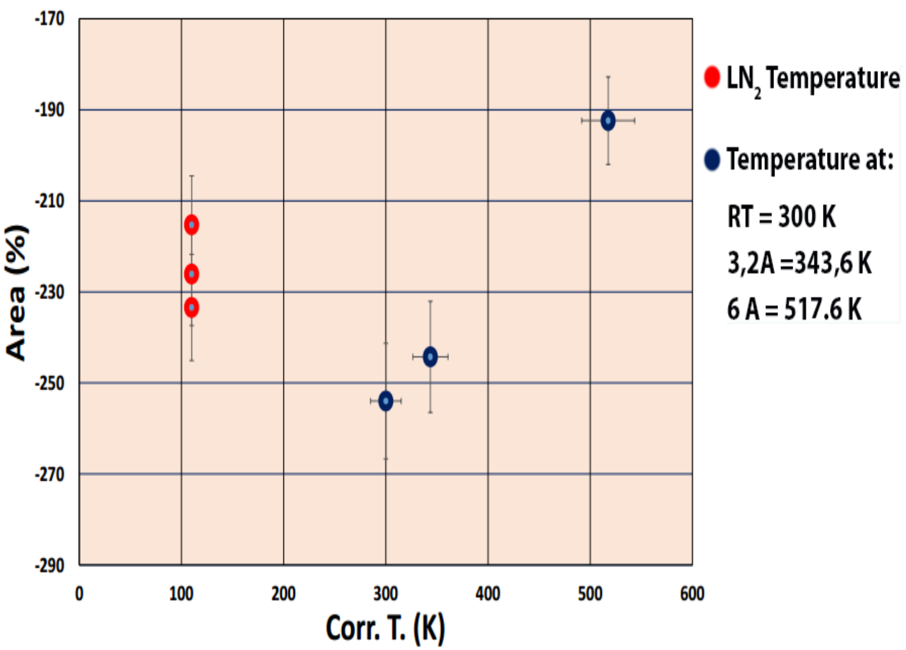




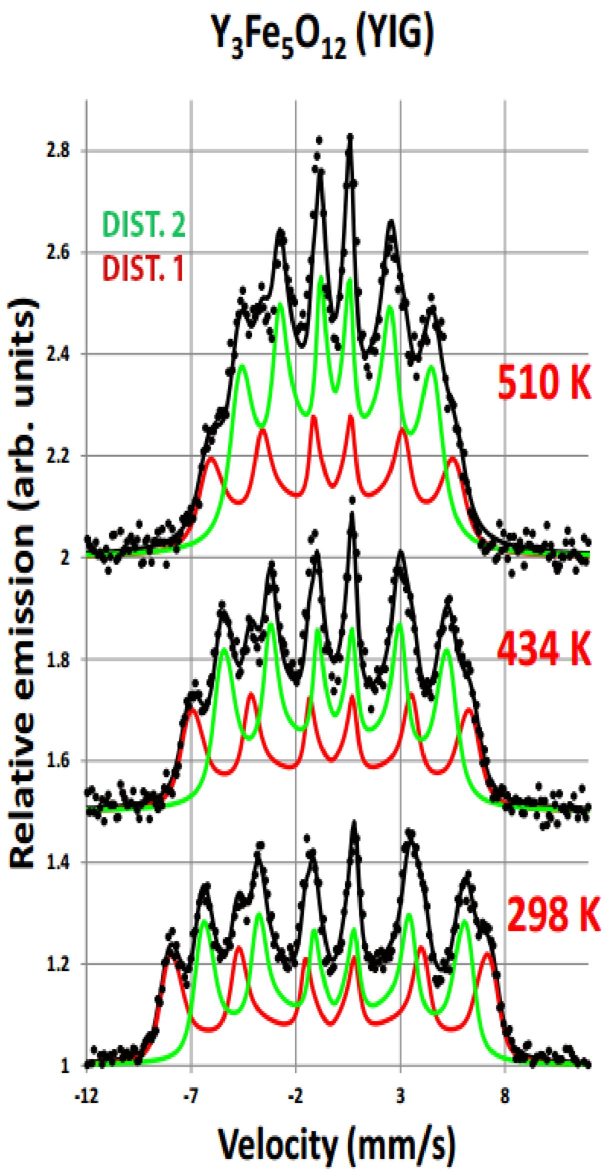
YAG: Data from Mössbauer spectra parameters

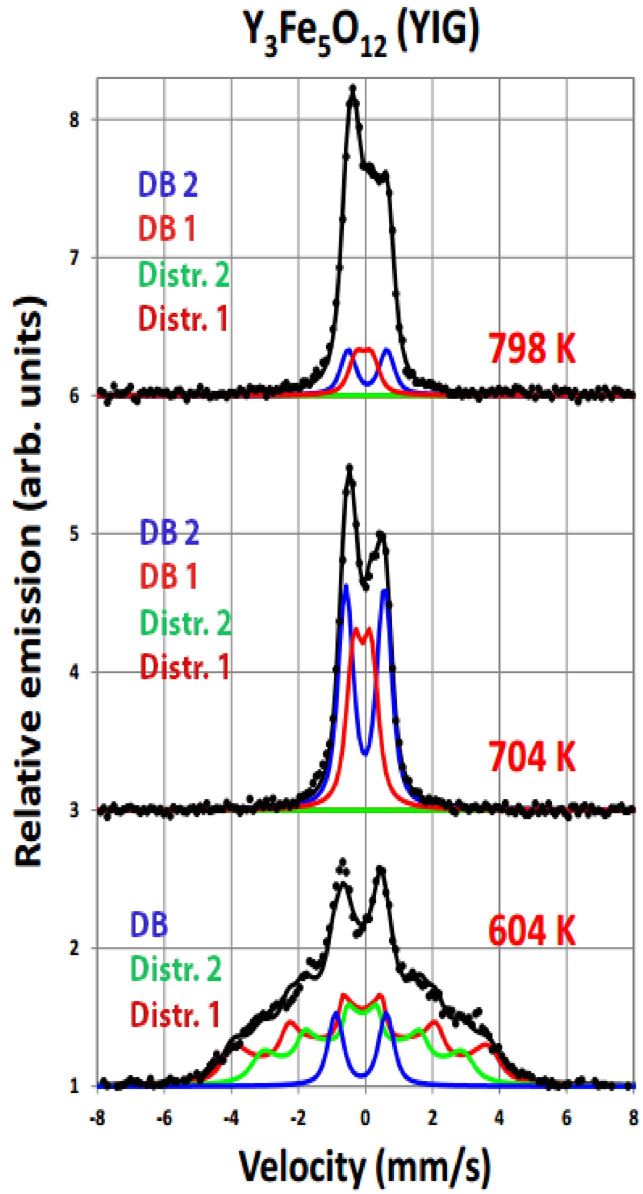
			BT1 + BT2
T (ºC)	Corr.T.	dSOD	Area
RT	300	-0.238	-191.6144
LN_2_RT	110	-0.127	-215.757
3,2A	343.6	-0.268	-200.6874
LN_2_3,2A	110	-0.127	-190.8429
6,0A	517.6	-0.389	-183.4272
LN_2_6,0A	110	-0.127	-186.5385





Spectra analysis YIG



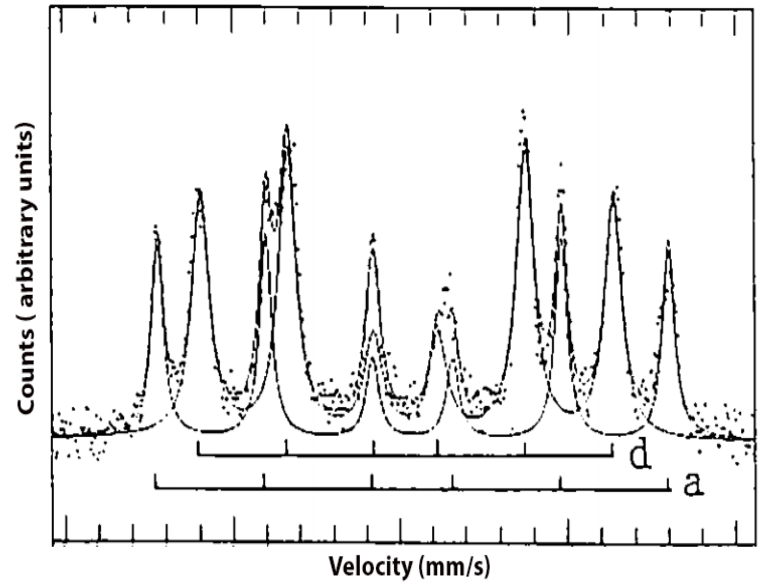


Complex Mössbauer spectra fiited with two distribution models DIST.1 and DIST.2 at temperature range 298 K ÷ 798 K. An additional two doublets have been added to accomplish the fitting analysis at 704 K and 798 K.

Spectra analysis YIG

		Distr. 1				
				B (T)		
T (°C)	Corr.T.	δ0 (mm/s)	ΔEQ,0 (mm/s)	δ0 (mm/s)	δ1 (mm/s/T)	ΔEQ,0 (mm/s)
27	298	-0.37734	-0.04005487	51.64139	47.373188	41.4756903
120	434	-0.32336	-0.03441624	45.28105	41.538534	36.3673933

		Distr. 2				
				B (T)		
T (°C)	Corr.T.	δ0 (mm/s)	ΔEQ,0 (mm/s)	δ0 (mm/s)	δ1 (mm/s/T)	ΔEQ,0 (mm/s)
27	298	-0.16292	0.01310834	42.57108	39.052549	34.1908897
120	434	-0.11501	0.02082842	36.52132	33.502805	34.1908897



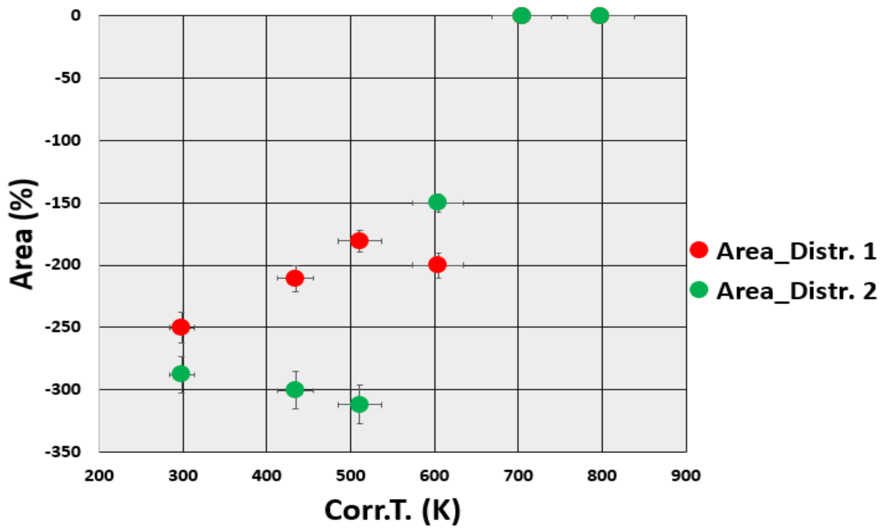
CEM spectra of YIG; K. Nomura et al.; Hyperfine Interactions 84(1994)421-426

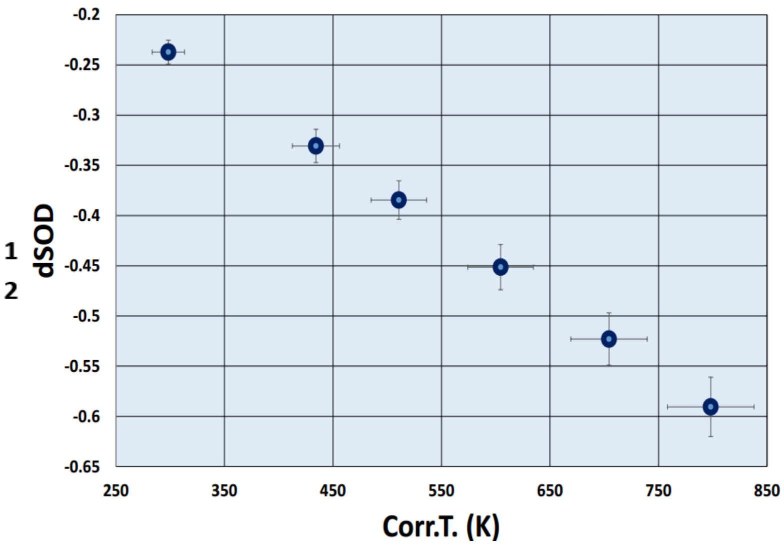
Hyperfine fields (H_{in}, T), isomer shifts (IS, mm/s), quadrupole splitting (QS, mm/s), linewidths (*W*, mm/s), intensity ratio of magnetic peaks (PR = $P_{2,5}/P_{1,6}$), area ratio (16a/24d) of the octahedral (a) and tetrahedral (d) sublattices, and lattice constant (Å) of YIG films.

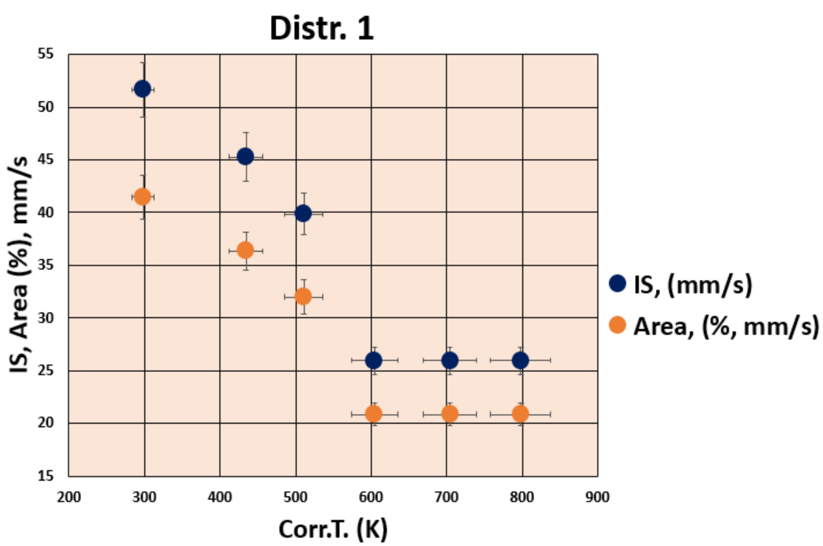
	Films	H_{in}(a)	H_{in}(d)	IS(a)	IS(d)	QS(a)	QS(d)	W(a)	W(d)	PR(a)	PR(d)	16a/24d	Lattice C
1.	YIG	47.9	38.7	0.32	0.16	0.02	−0.01	0.42	0.56	1.06	1.20	0.53	12.3744
2.	$Bi_{0.2}Y_{2.8}Fe_5O_{12}$	49.2	39.7	0.36	0.15	−0.02	0.01	0.35	0.54	1.06	1.30	0.53	12.3802

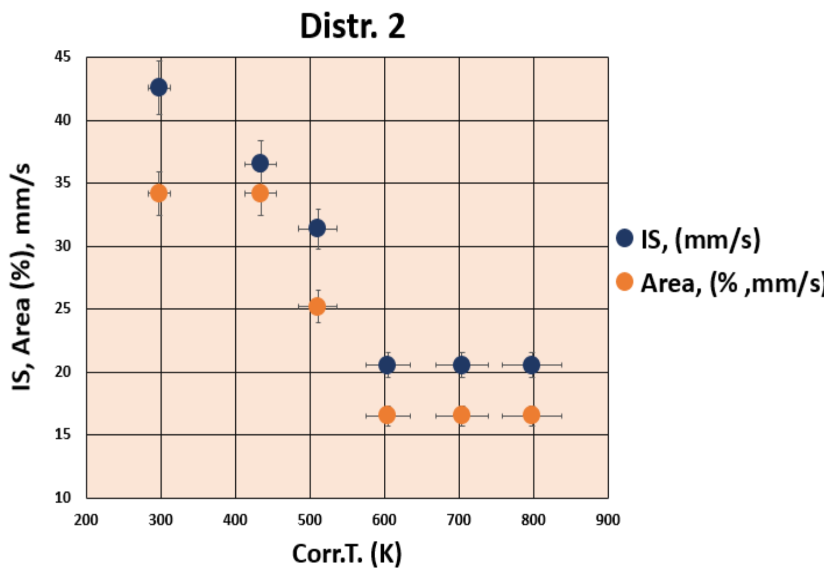
K. Nomura et al. / Conversion electron Mössbauer spectroscopy of YIG Hyperfine Interactions 84(1994)421−426

YIG: data from Mössbauer spectra parameters









Summarize of the results

Summarize of the result for YAG

- Definite signs of an annealing stage with temperature range RT to 440 ^{o}C are not observed. Annealing at higher temperature is needed to incorporate all ions on regular lattice sites.
- High spin Fe^{3+} in this material shows slow spin relaxation presumably due to exchange interaction of Fe ions with Al^{3+}.

Summarize of the result for YIG

- Although limited to six ranges, the temperature dependence of the Isomer shifts and Quadrupole splitting's of the YIG garnet without impurity atoms concentration are consistent with the values for iron (III).
- The YIG single crystal garnet show clear temperature dependence at temperatures above the RT. Temperature range from 298K to 798 K is indicative for changes in crystal structure. Curie temperature for YIG is 560 K. After 604 K we observe cleary shrinking of the two line shapes distributions and predomination of the paramagnetic structure.