**ABSTRACT:** Variation in structural and magnetic properties with changing valence electron count (VEC) has been studied well in the family of Heusler compounds, while such changes in VEC resulting in half-Heusler (HH) and full-Heusler (FH) composites have not been reported to observe their effect on the magnetic properties. Herein, we have synthesized the composite of HH and FH phases in Ni$_{1+x}$MnSb ($x = 0.0, 0.3,$ and $0.6$) via changing VEC from 22 to 28 in order to investigate the structural and magnetic properties. Interestingly, a transition from half-metallic ferromagnetic to normal ferromagnetic was revealed in Ni$_{1+x}$MnSb ($x = 0.0, 0.3,$ and $0.6$) materials with increasing VEC. The structural investigations of these materials were performed using a X-ray diffraction technique and analyzed by Rietveld refinement software for all the samples. Rietveld analysis reveals the presence of a significant amount of the NiSb paramagnetic impurity phase in the HH NiMnSb system, while in the case of Ni$_{1+x}$MnSb ($x = 0.3$ and $0.6$), no such impurity phase was observed. Only FH and HH phases in Ni$_{1+x}$MnSb ($x = 0.3$ and $0.6$) samples were noticed. The magnetic measurement performed on samples employing a vibrating sample magnetometer reveals the ferromagnetic ordering in all samples. A weak hysteresis loop with saturated magnetic moments $\mu_B \sim 2.99$ and $2.98$ at room temperature was observed for NiMnSb and Ni$_{1.3}$MnSb, respectively, while a strong hysteresis loop with lower magnetic moment of $0.88 \mu_B$ was observed in the Ni$_{1.5}$MnSb composite. Furthermore, the observed magnetic moments for the composite Ni$_{1.3}$MnSb have been explained on the basis of the Slater–Pauling rule in relation to VEC.

**INTRODUCTION**

Half-Heusler (HH) materials have been promising candidates to be used in spintronic applications such as spin injection devices, shape-memory alloys, giant magnetoresistance spin valves, and magnetic tunnel junctions. The experimental and theoretical band structure calculations of several very high Curie temperature Heusler alloys have demonstrated the strong ferromagnetic behavior with 100% spin polarization inducing near Fermi surface. The first half-metallic ferromagnetic NiMnSb HH alloy was proposed by de Groot and Mueller using electronic band structure calculations in 1983. Usually, two spin channels exist in half-metallic ferromagnetic, one spin-up channel with metallic band gap and other a spin-down channel with a band gap of 0.5 eV for NiMnSb alloy. The band structure calculation suggests that 9 electrons out of 22 valence electron count (VEC) in NiMnSb occupy the spin-down channel, and the magnetic moment was found to be localized at the Mn site rather than the Ni site. This compound is known experimentally to be of a high Curie temperature around 730 °C, which is much higher than several other half-metallic ferromagnetic materials. The high Curie temperature and half-metallic behavior of NiMnSb make it a potential candidate for the spintronic device application. Several groups have also worked on the thin films of NiMnSb using different approaches, and they found that the spin polarization reduces from bulk to thin film. Few experimental evidences show that the spin polarization of NiMnSb was observed only to be $58 \pm 2.3\%$ using Andreev reflection method rather than theoretically predicted yield of 100%. Almost all the experimental approaches suggest that it is very difficult to produce 100% spin polarization at the Fermi surface of NiMnSb HH alloy.

The NiMnSb crystallizes in the C1$_b$ structure which has four interpenetrating FCC lattices with equal spacing along the body diagonal. The Sb at A (0,0,0), Mn at B (0.5,0.5,0.5), and Ni at C (0.25,0.25,0.25) are occupied forming three of the lattices filled, while the fourth sublattice at D (0.75,0.75,0.75) is vacant in the case of HH compound. On the other hand, in the case of FH Ni$_{1}$MnSb compound, excess nickel occupies the vacant D (0.75,0.75,0.75) site forming all the four sublattices filled. The formation of FH from the HH structure can be understood with the help of schematic diagram (Figure 1).
FH Ni$_2$MnSb shows the ferromagnetic property, and the magnetic moment is localized at the Mn ($m = 3.71$ $\mu_B$) site rather than the nickel ($m = 0.0$ $\mu_B$) site as reported. Furthermore, the magnetic behavior can be found interesting if a HH/FH composite material is developed by exploiting the advantage of HH and FH structure, as discussed above. Taking the advantage of the HH structure, one can take excess Ni to fill the vacant D site, and after subsequent reactions, an inclusion of FH can be precipitated within the HH matrix forming HH/FH composites as reported in our previous work. Moreover, there is a small mismatch in the lattice parameters of HH and FH phases which minimizes the defect at the interface and enhances the magnetic properties. With this in mind, we have investigated the magnetic behavior of the composite Ni$_{1+x}$MnSb ($x = 0.0, 0.3$, and $0.6$) containing both HH and FH which has not been reported so far. Such composites were derived on the basis of changing VEC from 22 to 28. Herein, we have synthesized the bulk HH/FH composite Ni$_{1+x}$MnSb ($x = 0.0, 0.3$, and $0.6$) and studied their magnetic properties. Our experimental observations show that the composite material Ni$_{1.3}$MnSb does not exhibit any significant change in magnetic moment as compared to that of bare NiMnSb half-metallic composition. However, a drastic change in magnetic moment was noticed in the case of the Ni$_{1.6}$MnSb composite phase which will be discussed in the forthcoming section of the manuscript.

**RESULTS AND DISCUSSION**

Figure 2a−c shows the X-ray diffraction (XRD) patterns of Ni$_{1+x}$MnSb ($x = 0.0, 0.3$, and $0.6$) materials. XRD diffraction peaks corresponding to the sample of NiMnSb (78.78%) exhibit a single phase of HH with a significant amount of the NiSb ($\sim$21.22%) paramagnetic impurity phase. On the other hand, the XRD pattern of Ni$_{1.4}$MnSb ($x = 0.3$ and $0.6$) (Figure 2b,c) reveals the formation of HH and FH phases, forming the composite materials.

The Rietveld refinement using FullProf software was performed on XRD of all samples. The lattice constant and other parameters obtained from refinements using this technique are given in Table 1. A small mismatch in the experimental lattice parameter with respect to the reference value (Table 1) is observed in Rietveld analysis for NiMnSb.

The increase in the lattice parameter of the HH phase with increasing Ni concentrations is evident from the small peak shift to the lower angle side, that is, from $2\theta = 43.02$ to $2\theta = 42.9$, as shown in Figure 2a−c, as per Bragg’s law. Furthermore, the peaks corresponding to HH and FH phases are closely spaced as there is very small mismatch ($\sim$1%) in their lattice parameters. One can clearly see the most intense peak of HH and FH of the magnified image, as shown in the inset of Figure 2b,c.

The morphological details of the best performing composition Ni$_{1.3}$MnSb was studied by scanning electron microscopy (SEM) along with energy dispersive X-ray analysis (EDAX). Figure 3a,d shows the SEM image of the HH/FH composite Ni$_{1+x}$MnSb, Ni$_{1.3}$MnSb. The SEM image corresponding to the sample Ni$_{1.3}$MnSb (Figure 3a) exhibits two phase contrast marked by dotted circle. The overall composition was measured using EDAX, as shown in Figure 3c, and quantification results show a composition similar to the nominal composition Ni$_{1.3}$MnSb. EDAX analysis corresponding to the minor phase marked as dotted circle (Figure 3a) reveals a FH phase in the HH matrix phase which is consistent with the XRD result. Figure 3d shows the SEM image obtained from the sample Ni$_{1.3}$MnSb which exhibits again a composite phase. The overall composition measured by EDAX analysis, as shown in Figure 3e, reveals consistency with its nominal composition.

In order to further confirm the detailed crystallographic and magnetic domain structure of such a composite phase, the neutron diffraction technique may be used, which is not part of this investigation.

The magnetic measurement performed on the NiMnSb sample using a vibrating sample magnetometer (VSM), as shown in Figure 4a, exhibits the weak hysteresis confirming the soft ferromagnetic behavior with a saturated magnetic moment of 2.99 $\mu_B$ at room temperature (300 K). The low value of magnetic moment can be primarily attributed to the presence of the NiSb paramagnetic impurity phase in this sample. A
similar decrease in magnetic moment due to presence of NiSb impurity phase has also been reported.\textsuperscript{16,17} Furthermore, it is worth to mention here that the room temperature magnetic moment of 2.99 $\mu_B$ for NiMnSb is much smaller than that of NiMnSb ($m = 4 \mu_B$) measured at 5 K. We notice here that such a significant decrease in magnetic moment is because of the impurity phase and poor effect of thermal fluctuation of spin of electrons (random spin flipping) near the Fermi level at 300 K (above 5 K).

As shown in Figure 4b, the magnetization is steeply reducing and fluctuating with temperature indicating that the impurity of the NiSb paramagnetic phase suppresses severely the magnetization more rapidly with increasing temperature rather than the pure matrix ferromagnetic phase.\textsuperscript{17,18} This may be because of the interaction of spin of the large fraction of the impurity phase and ferromagnetic matrix phase. The curve fitted by quadratic fitting from 10 to 80 and 80 to 300 K indicates that the half metallicity loses around 80 K and only the ferromagnetic phase exists above 80 K temperature.\textsuperscript{19} For the composite Ni$_{1.3}$MnSb with 30% FH and 70% HH (Figure 4c), no significant change was observed in the magnetic moment ($m = 2.98 \mu_B$) and also the nature of hysteresis loop. This could be because of the absence of the paramagnetic NiSb phase in this sample. A slight change in the magnetic moment can be attributed to the magnetic interaction of HH and FH phases at the interfaces. At room temperature, both Ni$_3$MnSb and NiMnSb exhibit ferromagnetic behavior. However, in the composite, the defect and exchange coupling of spin at the interface reduce the magnetic moment. In the case of Ni$_{1.3}$MnSb, the composite containing 30% FH as the minor phase, the size of few of the FH grains lie in the nanoscale regime which can preserve the superparamagnetic behavior which in-turn compensates the reduced magnetic moment because of the defect resulting in a negligible change in net magnetic moment. The low coercivity ($H_c$) at room temperature is observed because of superparamagnetic nature of nano-sized Ni$_3$MnSb (zero $H_c$) inclusion present in the ferromagnetic NiMnSb matrix (finite $H_c$). The exact information about such interactions can be revealed by the first-principle calculation on the electronic structure of these materials. Interestingly, one can see from Figure 4d that the magnetization varies slowly with temperature rather than that observed in Figure 4b confirming the ferromagnetic behavior of the Ni$_{1.3}$MnSb composite. Furthermore, one can notice in the case of the composite Ni$_{1.3}$MnSb containing 60% FH of ferromagnetic nature and 40% HH of half-metallic nature at low temperature, asymmetrically distributed large hysteresis loop with coercivity (0.146 and 0.137 T for both side) and remanence magnetization (9.002 and 8.587 emu/g for both side) were observed. With increasing amount of the FH phase,

| Ni$_{1+x}$MnSb lattice parameter ($a$) | reference value ($a$) | $\chi^2$ | Ni($X,Y,Z$) | Mn($X,Y,Z$) | Sb($X,Y,Z$) | Occ | Bragg R-factor | RF-factor |
|-----------------------------|----------------|---------|------------|------------|------------|-----|---------------|----------|
| X = 0.0                    | 5.9397         | 3.16    | (0.25,0.25,0.25) | (0.5,0.5,0.5) | (0.0,0.0,0.0) | 1   | 3.61          | 2.35     |
| X = 0.3                    | 5.9498         | 4.35    | (0.25,0.25,0.75) | (0.5,0.5,0.5) | (0.0,0.0,0.0) | 1   | 12.1          | 7.46     |
| X = 0.6                    | 6.0334         | 3.67    | (0.25,0.25,0.75) | (0.5,0.5,0.5) | (0.0,0.0,0.0) | 1   | 16.5          | 13.4     |
| NiSb $a = 3.9382, k = 3.9383, c = 5.139$ | 3.16          |         | (0.33,0.67,0.25) | (0.0,0.0,0.0) | (0.084,0.079) | 13.5 | 11.5          |          |

Figure 3. (a) SEM image of the HH/FH composite of Ni$_{1.3}$MnSb, (b) EDAX spectrum from the minor phase of FH, (c) overall composition obtained from the sample of Ni$_{1.3}$MnSb showing the composition similar to nominal composition taken, (d) SEM image of the Ni$_{1.3}$MnSb HH/FH composite phase, and the (e) corresponding EDAX spectrum showing overall composition.
nano-sized grains change to micron-sized grains causing the loss of superparamagnetic behavior which results in a decrease in magnetic moment. In HH NiMnSb, spin-up electrons lie at the Fermi level while a band gap exists at the Fermi level for the spin-down electrons. On the other hand, in the case of the composite, the energy states of spin-down electrons occur near the Fermi level because of the interface, which reduces the half metallicity and hence decreases the magnetic moment. Moreover, the antiferromagnetic coupling occurs at the interfaces which also reduces the magnetic moment and enhances coercivity ($H_c$). The asymmetric nature of hysteresis curve reveals the antiferromagnetic coupling at the interface of HH and FH composites, which in turn lowers the saturation magnetization. It is worth mentioning that complete saturation magnetization could not be achieved up to 1 T (Figure 4e), and more field will be required for its complete saturation. The increased field will contribute to orient the antiferromagnetic coupling spin moment toward the external magnetic field direction. The magnetic moment for this composite was observed to be 0.882 $\mu_B$/formula unit. Variation in magnetization with temperature demonstrates the ferromagnetic character because of the major contribution from the FH phase and disorder at the HH/FH interface caused by a small mismatch in the lattice parameter of HH and FH phases. As shown in Figure 4b,d, magnetic moment varies continuously with temperature which shows that the transition temperature from ferromagnetic to paramagnetic lies above the room temperature, while small hump is observed around 270 K, as shown in Figure 4f, indicating the magnetic transition temperature. Usually, the mixture of the two ferromagnetic phases with different critical temperatures evolves the hump at the point of lower critical temperature which can be easily seen in the Figure 4f.

In all the cases, the magnetic moment at room temperature is found to be less than that of the other reported value measured at 5 K. In our work, it is also evident that the magnetic moment decreases as the temperature increases from 5 K to room temperature.

The reduction in magnetic moment can also be explained based on the Slater–Pauling rule relating to varying VECs (increasing Ni concentrations). The magnetic moment, as suggested by the Slater–Pauling rule, can be expressed as $M = N_{V} - 18$ for HH and $M = N_{V} - 24$ for the FH phase, where $N_{V}$ is the total VEC. One can estimate the magnetic moment for HH NiMnSb based on the Slater–Pauling rule to be the maximum of 4.0 $\mu_B$ at low temperature. In our experimental observation, reduced magnetic moment (2.99 $\mu_B$) corresponding to NiMnSb HH was observed at room temperature. This reduced magnetic moment can be expected with increasing temperature above 5 K, which is in agreement with the other reports. Moreover, the reduction in magnetic moment can also be found because of contribution from the appreciable fraction of the minor NiSb paramagnetic impurity phase. On the other hand, in the case of the composite Ni$_{1+x}$MnSb, the magnetic moment estimated based on the Slater–Pauling rule was observed to be 3.0 $\mu_B$ (VEC = 25), which is consistent with the observed value. However, the magnetic moment calculated for Ni$_{1.6}$MnSb (60% FH and 40% HH) based on this model is estimated to be zero, which deviates from the observed value of magnetic moment $\sim 0.88 \mu_B$/formula unit. We understand that the model is purely based on the VEC and does not include the effect of defects on the magnetization. The composition Ni$_{1.6}$MnSb with VEC = 28...
forming a composite containing the major portion of the FH phase associates with a large amount of defect and strain which causes the large number of energy states at the Fermi level and reduces the magnetic moment. Furthermore, the reduction in magnetic moment has also been explained above in terms of the increasing size of the FH phase.

■ CONCLUSIONS
Compositions Ni$_{1+x}$MnSb ($x = 0.0, 0.3$, and $0.6$) were successfully synthesized, and magnetic properties of these materials were studied. Unfortunately, the magnetic moment of the NiMnSb sample was observed to be decreased, and this decrease in magnetic moment is primarily attributed to the appreciable fraction ($\sim 21\%$) of the minor NiSb paramagnetic phase. With increasing Ni concentrations (increasing FH inclusion), half-metallic ferromagnetic properties are observed to be deteriorated, while ferromagnetic properties were found dominated. The reduced magnetic moment in the case of the HH/FH nanocomposite materials is attributed to the antiferromagnetic coupling at the interfaces. As shown in Figure 3, $M-T$ curves exhibit the normal ferromagnetic behavior for NiMnSb and Ni$_{1.3}$MnSb, measured up to room temperature while a paramagnetic transition for Ni$_{1.6}$MnSb was noticed around 270 K which is because of presence of the mix phase of two ferromagnetic materials with different critical paramagnetic temperatures. From the present study, we strongly believe that the composites of FH and HH can have strong magnetic properties and will be the future avenue of research.

■ EXPERIMENTAL PROCEDURE
The powder of Ni, Mn, and Sb with 99.99% purity were taken in correct stoichiometric composition of Ni$_{1+x}$MnSb ($x = 0.0, 0.3$, and $0.6$). The stoichiometric compositions were grounded using mortar and pestle about an hour to make an homogeneous mixture. Samples were sealed in an evacuated quartz tube under high vacuum of the order 10$^{-5}$ mbar to prevent from undesired oxidation with the environment during the furnace reaction. The sealed samples were then kept in an automatic programmable furnace at around 1000 °C for 10 days, as suggested by other researchers for HH alloys system.$^{23,24}$ Consequently, the sealed quartz tubes were broken, and reacted samples were ground again using mortar and pestle for the characterization purpose. The gross structural characterization was performed using an X-ray diffractometer (MXRD; Rigaku ultima IV), and morphological and elemental analyses were performed employing a scanning electron microscope equipped with EDAX. The magnetic properties of the composites were measured using VSM (PPMS-14T, Cryogenics).

■ AUTHOR INFORMATION
Corresponding Author
Dinesh Kumar Misra – CSIR-National Physical Laboratory, New Delhi 110012, India; Email: misradk@nplindia.org

Authors
Bal Govind – CSIR-National Physical Laboratory, New Delhi 110012, India; AcSIR, Academy of Scientific & Innovative Research, Ghaziabad, Uttar Pradesh 201002, India; orcid.org/0000-0003-0762-0053
Ashish Kumar – CSIR-National Physical Laboratory, New Delhi 110012, India; AcSIR, Academy of Scientific & Innovative Research, Ghaziabad, Uttar Pradesh 201002, India
Sahiba Bano – CSIR-National Physical Laboratory, New Delhi 110012, India; AcSIR, Academy of Scientific & Innovative Research, Ghaziabad, Uttar Pradesh 201002, India
Aman Bhardwaj – CSIR-National Physical Laboratory, New Delhi 110012, India; AcSIR, Academy of Scientific & Innovative Research, Ghaziabad, Uttar Pradesh 201002, India

Complete contact information is available at: https://pubs.acs.org/10.1021/acsomega.9b03386

Notes
The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS
The authors are grateful for financial support from the Ministry of Commerce and Industry project (GAP-180932). One of the authors B.G. acknowledges the CSIR-SRF (Budget Head-90807) for financial support.

■ REFERENCES
(1) Schmidt, G.; Ferrand, D.; Molenkamp, L. W.; Filip, A. T.; van Wees, B. J. Fundamental obstacle for electrical spin injection from a ferromagnetic metal into a diffusive semiconductor. Phys. Rev. B: Condens. Matter Mater. Phys. 2000, 62, R4790.
(2) Snyder, G. J.; Toberer, E. S. Complex thermoelectric materials. Nat. Mater. 2008, 7, 105–114.
(3) Dieny, B.; Speriosu, V. S.; Parkin, S. S. P.; Gurney, B. A.; Willhoit, D. R.; Mauri, D. Giant magnetoresistive in soft ferromagnetic multilayers. Phys. Rev. B: Condens. Matter Mater. Phys. 1991, 43, 1297.
(4) Julliere, M. Tunneling between ferromagnetic films. Phys. Lett. A 1975, 54, 225.
(5) Moodera, J. S.; Kinder, L. R.; Wong, T. M.; Meservey, R. Large Magnetoresistance at Room Temperature in Ferromagnetic Thin Film Tunnel Junctions. Phys. Rev. Lett. 1995, 74, 3273.
(6) de Groot, R. A.; Mueller, F. M.; Engen, P. G. v.; Buschow, K. H. J. Phys. Rev. Lett. 1983, 50, 2024.
(7) Kang, J.-S.; Park, J.-G.; Olson, C. G.; Youn, S. J.; Min, B. I. Valence band and Sb 4d core level photoemission of the XMnSb-type Heusler compounds (X=Pt,Pd,Ni). J. Phys.: Condens. Matter 1995, 7, 3789.
(8) Youn, S. J.; Min, B. I. Effects of the spin-orbit interaction in Heusler compounds: Electronic structures and Fermi surfaces of NiMnSb and PtMnSb. Phys. Rev. B: Condens. Matter Mater. Phys. 1995, 51, 10436.
(9) Ristoiu, D.; Nozières, J. P.; Borca, C. N.; Komesu, T.; Jeong, H.-k.; Dobwen, P. A. The surface composition and spin polarization of NiMnSb epitaxial thin films. Europhys. Lett. 2000, 49, 624–630.
(10) Soulen, R. J. Measuring the Spin Polarization of a Metal with a Superconducting Point Contact. Science 1998, 282, 85.
(11) Graf, T.; Felser, C.; Parkin, S. S. P.; Stuart, S. P. Simple Rules for understanding of Heusler Compounds. Prog. Solid State Chem. 2011, 39, 1–50.
(12) Sztuta, A.; Koeoedsiejczyk, A.; Rzany, H.; Todoricov, J.; Wanic, A. Atomic and Magnetic Structure of the Heusler Alloys Ni$_2$MnSb, Ni$_2$MnSn, and Co$_2$MnSn. Phys. Status Solidi A 1972, 11, 57–65.
(13) Wang, F.; Fukuhara, T.; Maezawa, K.; Nishimura, K.; Shimizu, F.; Masubuchi, S. Synthesis and Characterization of Single Crystal NiMnSb. J. Appl. Phys. 2010, 99, 025502.
Bhardwaj, A.; Chauhan, N. S.; Sancheti, B.; Pandey, G. N.; Senguttuvan, T. D.; Misra, D. K. Panoscopically optimized thermoelectric performance of a half-Heusler/full-Heusler based in situ bulk composite Zr0.7Hf0.3Ni1+xSn: an energy and time efficient way. Phys. Chem. Chem. Phys. 2015, 17, 30090.

Makongo, J. P. A.; Misra, D. K.; Zhou, X.; Pant, A.; Shabetai, M. R.; Su, X.; Uher, C.; Stokes, K. L.; Poudre, P. F. P. Simultaneous Large Enhancements in Thermopower and Electrical Conductivity of Bulk Nanostructured Half-Heusler Alloys. J. Am. Chem. Soc. 2011, 133, 18843–18852.

Poudre, P. F. P.; Makongo, J. P. A.; Liu, Y.; Misra, D. K.; Sahoo, P.; Stokes, K. L. Thermoelectric behaviour of nanostructured Zr0.25Hf0.75NiCoSn half-Heusler alloys. Sci. Adv. Today 2015, 1, 25209.

Maskery, I.; Burrows, C. W.; Walker, M.; Singh, R. P.; Balakrishnan, G.; Duffy, J. A.; Bell, G. R. Bulk crystal growth and surface preparation of NiSb, MnSb, and NiMnSb. J. Vac. Sci. Technol. 2015, 34, 041219.

Borca, C. N.; Komesu, T.; Jeong, H. K.; Dowben, P. A.; Ristoiu, d.; Hordequin, Ch.; Nozieres, J. P.; Pier, J.; Stadler, S.; Idzerda, Y. U. Evidence for temperature dependent moments ordering in ferromagnetic NiMnSb(100). Phys. Rev. B: Condens. Matter Mater. Phys. 2001, 64, 052409.

Gardelis, S.; Androulakis, J.; Migakis, P.; Giapintzakis, J.; Clowes, S. K.; Bugoslavsky, Y.; Branford, W. R.; Miyoshi, Y.; Cohen, L. F. Synthesis and physical properties of arc melted NiMnSb. J. Phys. 2004, 95, 8063.

Ritchie, L.; Xiao, G.; Ji, Y.; Chen, T. Y.; Chien, C. L.; Zhang, M.; Chen, J.; Liu, Z.; Wu, G.; Zhang, X. X. Magnetic, structural, and transport properties of the Heusler alloys Co2MnSi and NiMnSb. Phys. Rev. B: Condens. Matter Mater. Phys. 2003, 68, 104430.

Baral, M.; Chattopadhyay, M. K.; Jangir, R.; Chakrabarti, A.; Ganguli, T. Presence of atomic disorder and its effect on the magnetic and electronic Properties of NiCrGa half Heusler alloy. J. Magn. Magn. Mater. 2019, 475, 675–682.

Snair, A.; Venkateswara, Y.; Suresh, K. G. Study of Heusler alloys for spintronic application. Int. J. Mech. Prod. Eng. 2016, 4, 2320–2092.

Müller, R. A.; Desilets-Benoit, A.; Gauthier, N.; Lapointe, L.; Bianchi, A. D.; Maris, T.; Zahn, R.; Beyer, R.; Green, E.; Wosnitza, J.; Yamani, Z.; Kenzelmann, M. Magnetic structure of the antiferromagnetic half-Heusler compound NdBiPt. Phys. Rev. B: Condens. Matter Mater. Phys. 2015, 92, 184432.

Keshavarz, S.; Naghibolashrafi, N.; Jamer, M. E.; Vinson, K.; Mazumdar, D.; Dennis, C. L.; Ratcliff, W.; Borchers, J. A.; Gupta, A.; LeClair, P. Fe2MnGe: A hexagonal Heusler anologue. J. Alloys Compd. 2019, 771, 793–802.