Supplementary Information for
Field driven evolution of periodic antiferromagnetic skyrmion in non-centrosymmetric semiconducting monolayer

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Colinear magnetic configuration

The ground state colinear magnetic configuration is obtained by calculating the total energies of 5 magnetic configuration as shown in the Figure S1. Energies of the each of the system shown with corresponding figures. From the data, it is evident that the strip Antiferromagnetic (AFM) arrangement AFM1 and AFM3 has the lowest energy. These sigifies that these strip AFM configuration is the most stable magnetic configuration of the system.

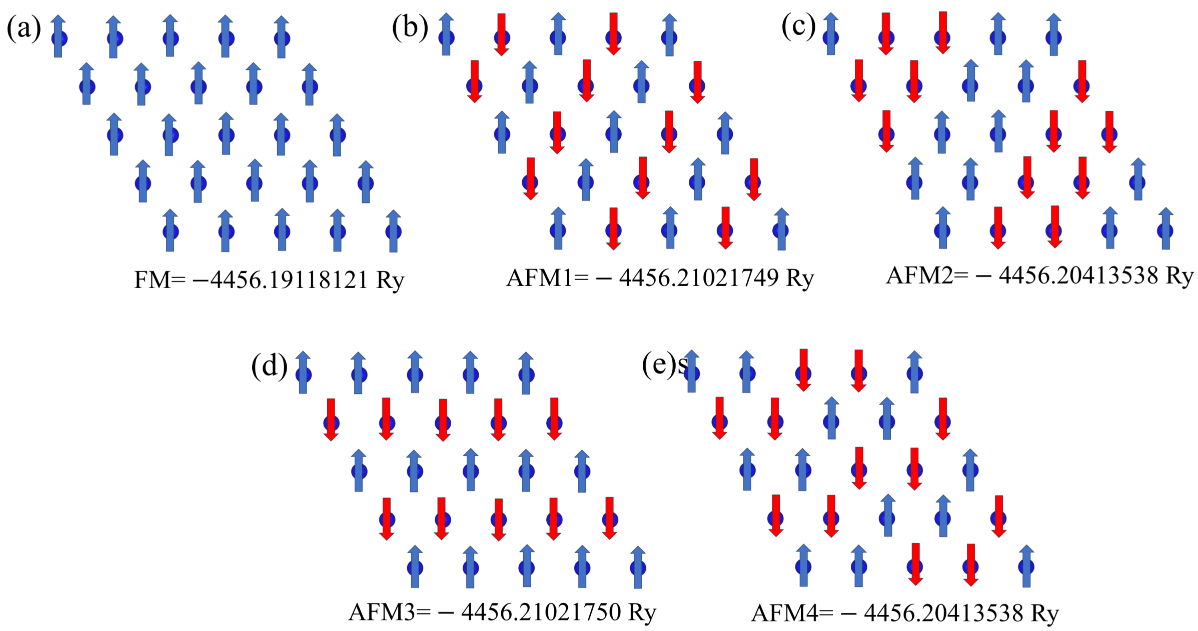

FIG. S1. Magnetic configuration considered for calculation of ground state magnetic configuration. (a) Ferromagnetic configuration of magnetic atoms. (b) Strip Antiferromagnetic configuration. (iii) Double strip Antiferromagnetic configuration. (d) Strip Antiferromagnetic configuration. (e) Zigzag AFM configuration. Small Blue dots represents magnetic atom Mn. Blue and red arrow represent magnetic moment along positive z axis and negative z axis respectively.

Calculation of Heisenberg Exchange parameters

The Figures shows the four configuration used to calculate the Heisenberg Exchange parameter (j) as discussed in the reference [1]. Energies of the different magnetic configurations are calculated by first principle calculation and then the energy values are used to calculate the parameters using the formula used in the main text, which were discussed in ref [1].

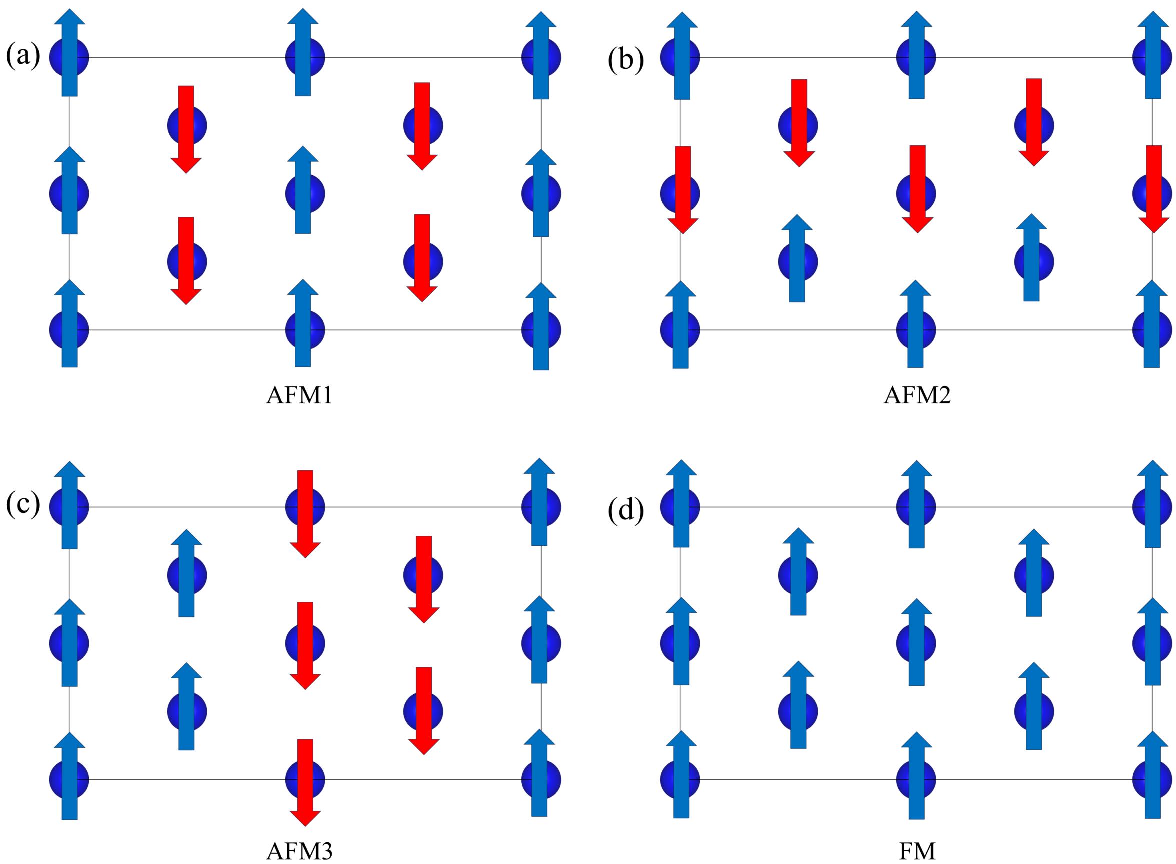

FIG. S2. Different configuration of magnetic moments, used for the exchange energy calculation. (a) Antiferromagnetic-1 configuration. (b) Antiferromagnetic-2 configuration. (c) Antiferromagnetic-3 configuration. (d) Ferromagnetic configuration.

Magnetic Texture under higher magnetic field

The figure shows the magnetic texture of the system under applied magnetic field higher than 1.4T. From the figure, it is obvious that, the magnetic moments completely aligned with the applied field after a certain value of the applied field.

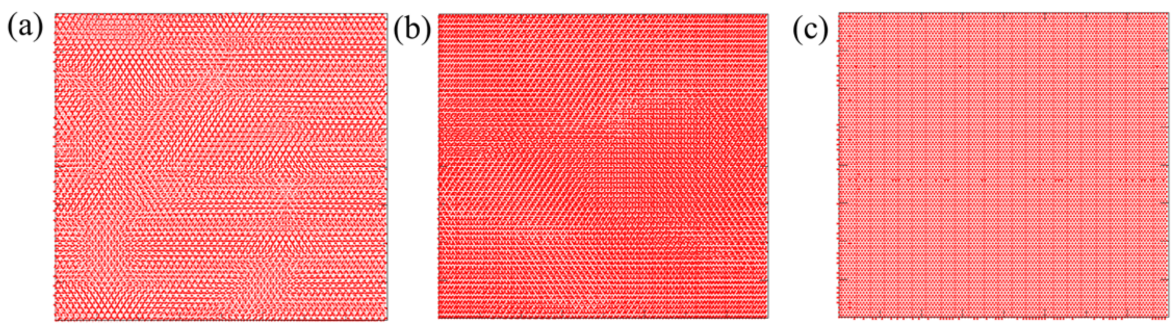

FIG. S3. Magnetic Texture under higher magnetic field. (a) Magnetic texture under 1.5T field. (b) Magnetic texture under 2.0T field and (c) Magnetic texture under 4.0T applied field. Red dots represents that the magnetic moments are aligned in the positive z direction.

Evolution of skyrmion structure before formation of periodic AFM skyrmion structures

The AFM skyrmion structure nucleated from applied field 0.5T. The figure 2(a) shows the magnetic texture of the system at a applied field of 0.5T. The magnetic moments in the system are separated based on their contribution towards positive and negative z components. Moments having positive z contribution is shown in the figure 2(b), while 2(c) show the moments with negative z components. The figure 2(c) shows a zoomed in view of the arrangement of magnetic moments with negative z components. This figure clearly indicated the nucleation of center of skyrmion like structure in the domains. However, these structure are not periodic.

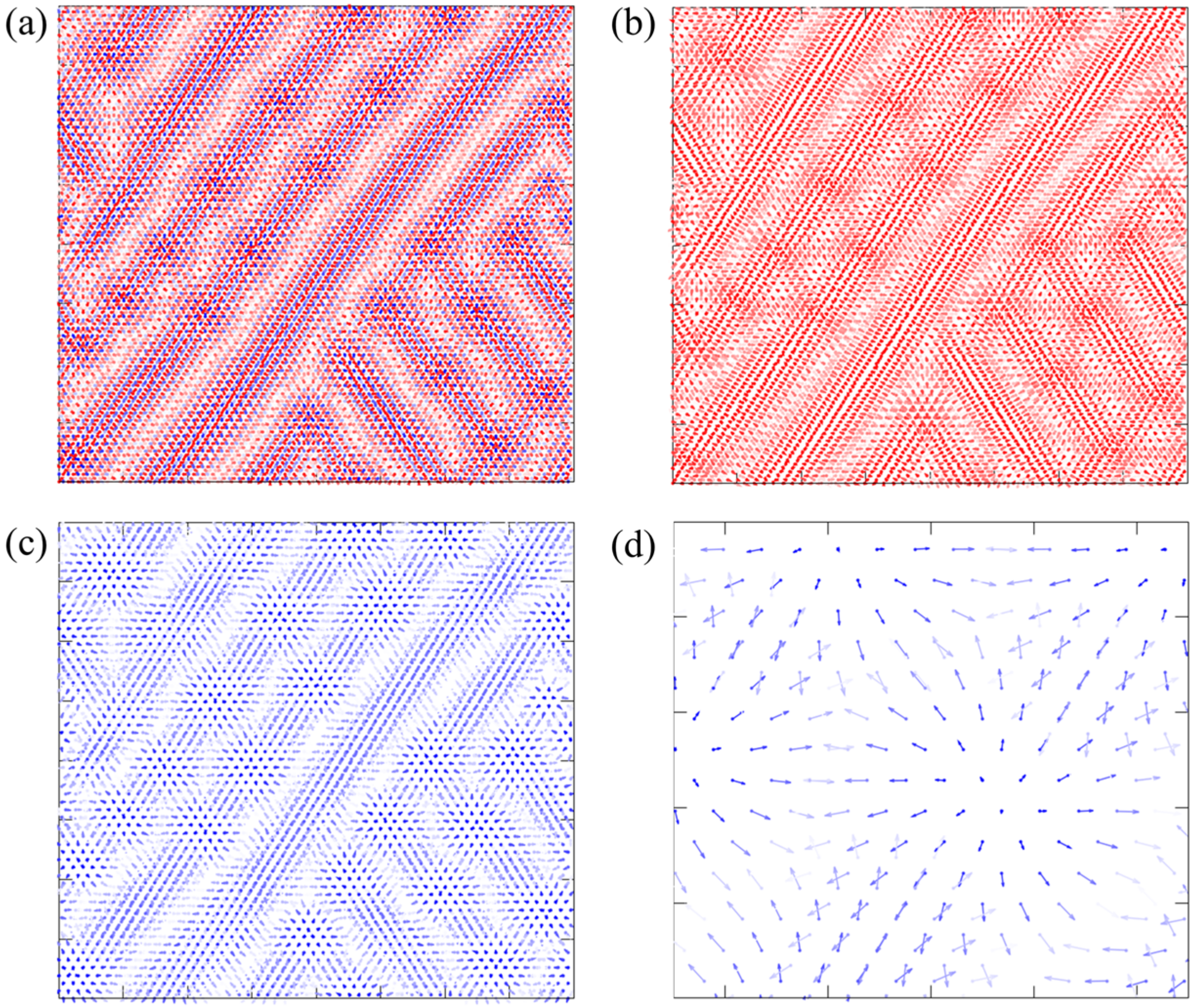

FIG. S4. (a) Magnetic texture of the system under 0.5T applied magnetic field. (b) Configuration of magnetic moments with positive z contribution. (c) Configuration of magnetic moments with negative z contribution. (d) A zoomed in view of the magnetic moments with negative z components. This figures shows that, skyrmion like structure started to grow from a applied field of 0.5T. However, the skyrmions are not nucleated in a regular periodic fashion.

Influence of thermal fluctuation of lifetime of skyrmions

The figure presents the influence of thermal fluctuation on skyrmion. Figures shows the magnetic configuration at different time-steps. Along the x-axis, numbers in the axis title in the format A/B represents the (strength of applied magnetic field)/(thermal fluctuation). Along y-axis, a non-uniform scale of lifetime in the unit of nanosecond is shown. The first column (0.7/0) represents the magnetic texture under magnetic field 0.7T and 0 thermal fluctuation. Similar magnetic texture at different time scale demonstrates infinite lifetime of skyrmions under magnetic field. Second column (0.0/0) represents the magnetic textures under 0 applied field and 0 thermal fluctuation. Gradual transformation of skyrmion from periodic antiferromagnetic feature to strip domain signifies the transient nature of the AFM skyrmions. From third to eight column, magnetic textures under 0.7 magnetic field and different thermal fluctuation is depicted. At very small thermal fluctuation, skyrmion feature persist for very long time, similar to magnetic phase in the unperturbed system (0.7/0). With increasing temperature, thermal fluctuation destabilizes skyrmion at a faster rate.

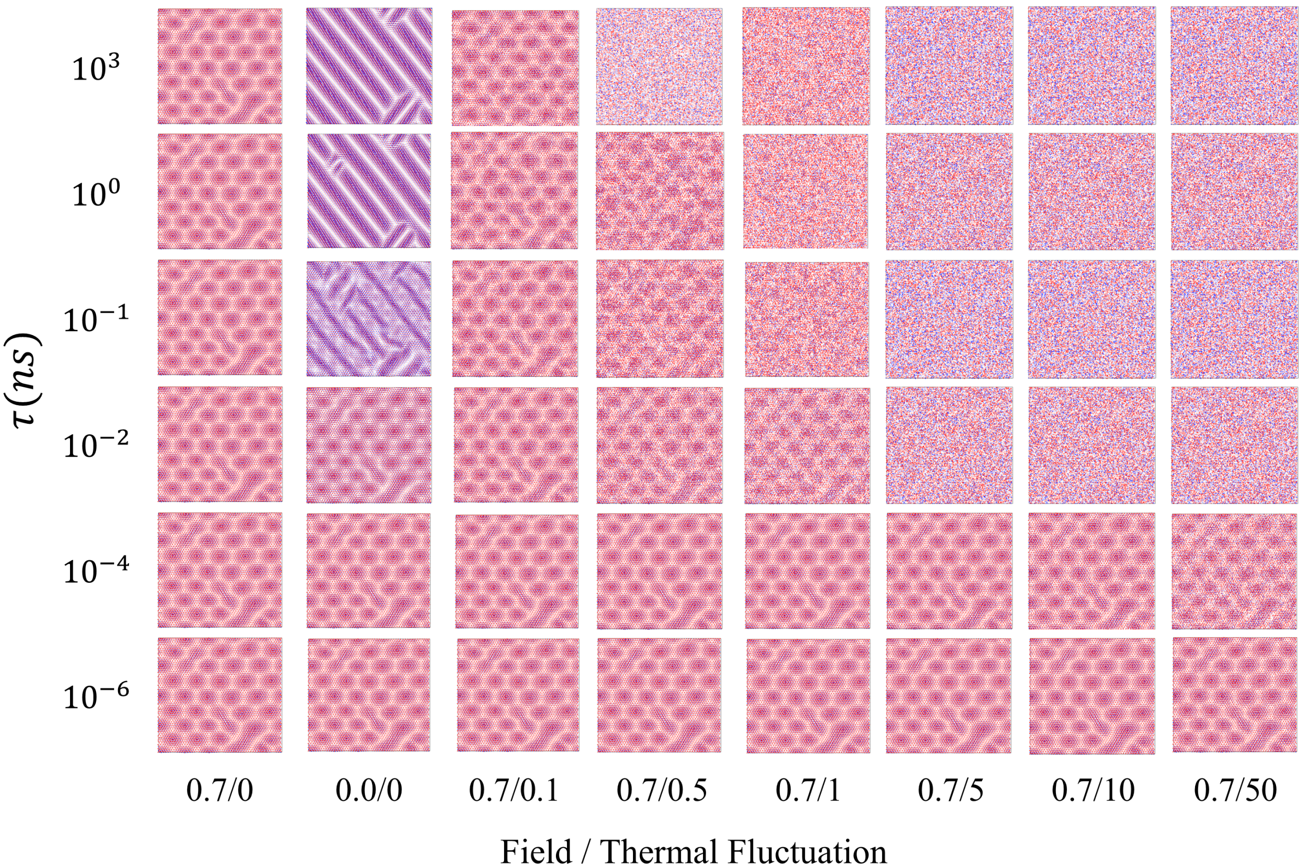

FIG. S5. Magnetic Texture of the system under different thermal fluctuation at applied field strength 0.7 T.

Four sublattice decomposition under magnetic field in negative z direction

The figures show the skyrmion structure in the four sublattice under a magnetic field in the negative z direction. The behavior of the system under magnetic field in negative z direction is similar to that in the positive direction. In the four sublattices, skyrmions are formed in the opposite direction to the applied magnetic field, which is similar when the magnetic field applied in the positive z direction. The signifies the magnetic states can be simultenously switched by switching the external magnetic field.

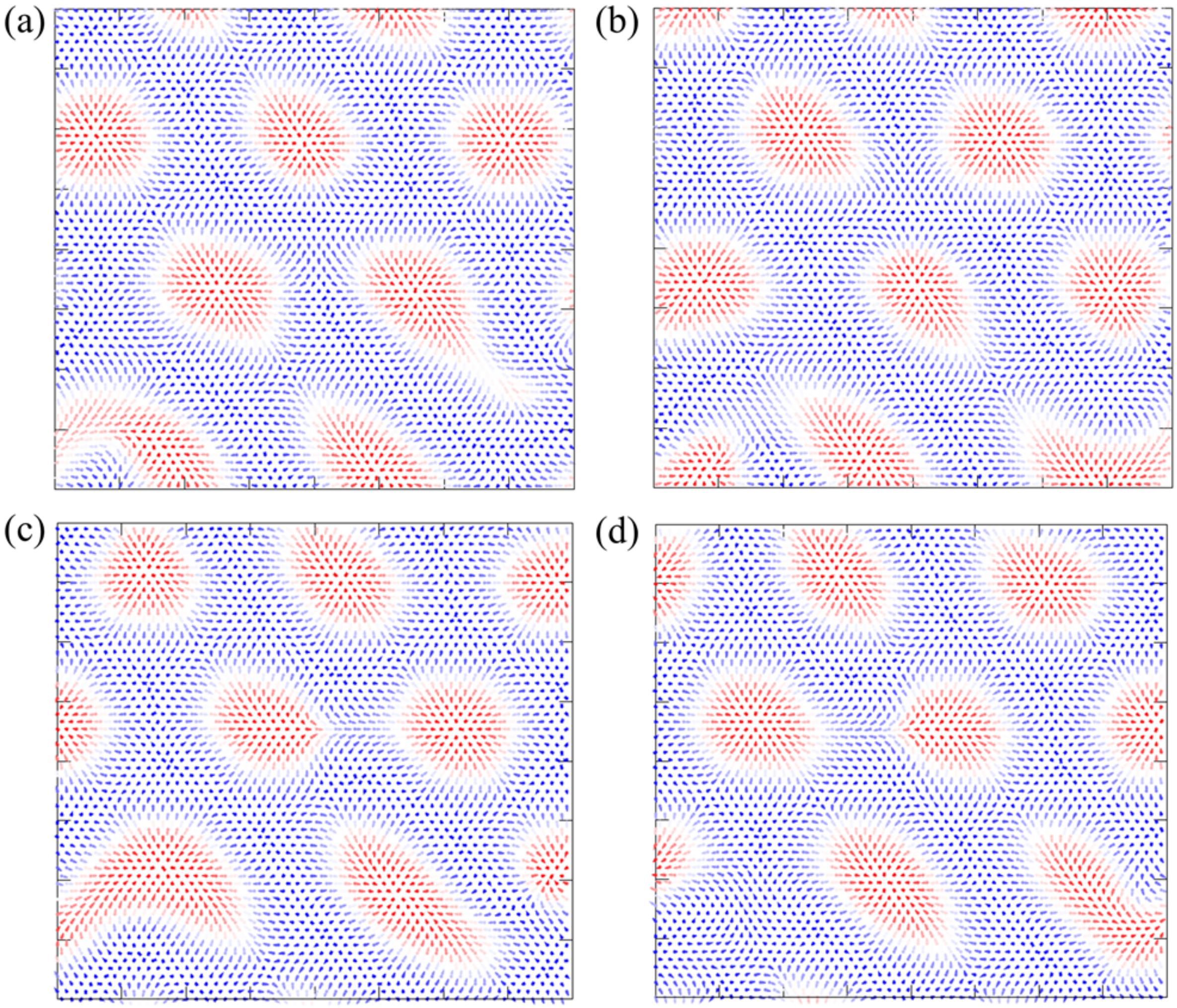

FIG. S6. Four sublattice decomposition under magnetic field in negative z direction.

Magnetic Texture of four sublattices in absence of magnetic field

The figure shows the stripe domain magnetic texture of the four-sublattices in absence of external magnetic field. From the figure, it is obvious that, each sublattice is stabilized in a stripe domain structure.

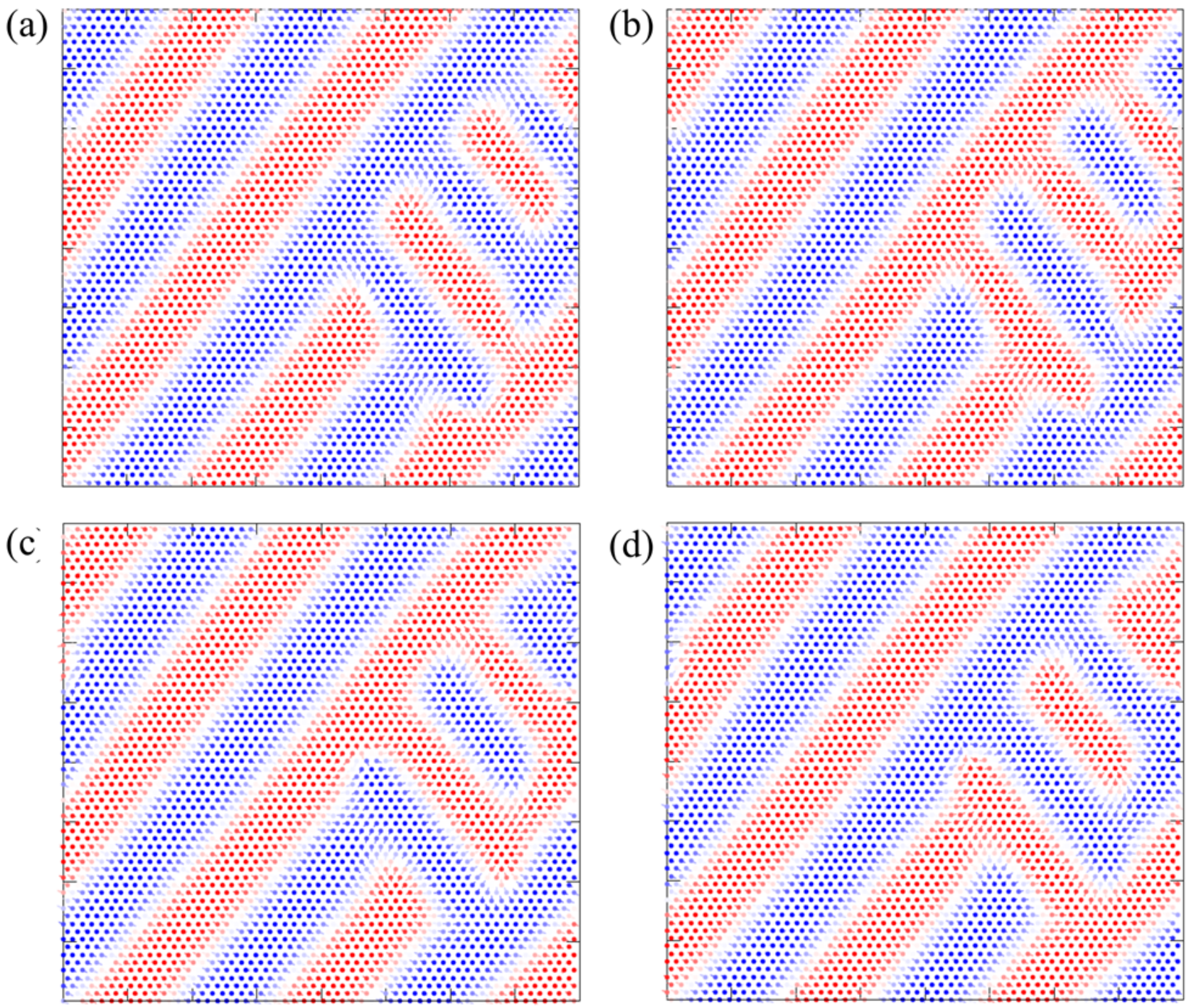

FIG. S7. Magnetic Texture of four sublattices in absence of magnetic field. (a,b,c,d) Magnetic texture of sublattice 1, 2, 3, and 4.

Reference:

1. R Caglayan, A Mogulkoc, Y Mogulkoc, M Modarresi, and AN Rudenko. Dzyaloshinskii-moriya interaction and nontrivial spin textures in the janus semiconductor monolayers vxy (x= cl, br, i; y= s, se, te). Physical Review B, 110(9):094440, 2024.