科技部補助專題研究計畫報告

二維硒化銦的自旋軌道耦合及參雜的研究

報 告 類 別 ： 成果報告
計 畫 類 別 ： 個別型計畫
計 畫 編 號 ： MOST 107-2112-M-003-002-
執 行 期 間 ： 107年08月01日至109年12月31日
執 行 單 位 ： 國立臺灣師範大學物理學系（所）

計 畫 主 持 人 ： 陳鴻宜

計畫參與人員： 此計畫無其他參與人員

本研究具有政策應用參考價值：■否 □是，建議提供機關
（勾選「是」者，請列舉建議可提供施政參考之業務主管機關）
本研究具影響公共利益之重大發現：□否 □是

中 華 民 國 110 年 04 月 14 日

中 文 摘 要 ： 在本計劃中，首先，我打算持續研究金屬硫化物的電子特性，並考慮自旋軌道交互
作用及電子電子間的庫倫作用力。自旋軌道偶合可以有效的將K點的價帶簡併能階
分裂，並造成在自旋極化態有著不一樣的行為。因為電子能夠被線性和圓偏極光所
激發，在磁光光譜中，選擇律可以被決定出來。特別的是，吸收譜線可以提供自旋
軌道偶合的直接證據。其次，在螢光實驗中，能帶結構必須被更加仔細的考慮，尤
其是導帶的電子質量，電洞質量及激子質量，更是用來解釋實驗中觀測到的電子躍
遷譜線。最後，我將利用緊束縛態的方法來研究二維的環形費米面，此一費米面來
自於當費米能接近價帶時所產生。在費米能級附近，計算磁矩隨著電洞增加而發生
的變化。當磁矩增大時，會引發費米面的不穩定，進而產生像變化從順磁態變成鐵
磁態。

中 文 關 鍵 詞 ： 金屬硫化物，硒化銦，自旋軌道交互作用

英 文 摘 要 ： In this project, first, I intend to continue our study of the electronic
properties of metal chalcogenide materials with the spin-orbit coupling
and electron-electron interactions using tight-binding method. The
onsite spin-orbit coupling effectively removes the spin degeneracy in
the valence band edges around the K points and causes these spin-
polarized states having quite different behaviors. Since the electrons
can be excited by linearly and circularly polarized light, in magneto-
optical spectra, selection rules can be effectively determined as well.
Particularly, absorption lines can be used to provide a direct evidence
of the spin-orbit coupling. Next, in order to account for the
luminescence experiments, the behavior of the band structure should be
deepened understanding through the band structure parameters and
selection rules of the 2D InSe. Therefore, the masses of electron, hole

and exciton should be well understood to interpret the experimentally
observed transitions. Moreover, I will study the ring shape of the Fermi
surface based on the tight-binding calculation. The Fermi surface ring
is attributed to the Fermi energy across the valence band edge. The
emergent magnetic moment as increasing the hole doping in InSe may lead
to the instability of the Fermi surface and makes the phase transition
from the paramagnetism to ferromagnetism.

英文關鍵詞：metal chalcogenide, InSe, spin-orbit coupling

科技部專題研究計畫成果報告撰寫格式

一、說明

科技部基於學術公開之立場，鼓勵一般專題研究計畫主持人發表其研究成果，但主持人對於研究成果之內容應負完全責任。計畫內容及研究成果如涉及專利或其他智慧財產權、違異現行醫藥衛生規範、影響公序良俗或政治社會安定等顧慮者，應事先通知科技部不宜將所繳交之成果報告蒐錄於學門成果報告彙編或公開查詢，以免造成無謂之困擾。另外，各學門在製作成果報告彙編時，將直接使用主持人提供的成果報告，因此主持人在繳交報告之前，應對內容詳細校對，以確定其正確性。

成果報告繳交之期限及種類（期中進度報告及期末報告），應依本部補助專題研究計畫作業要點及專題研究計畫經費核定清單之規定辦理。至報告內容之篇幅，期中進度報告以 4 至 10 頁為原則，並應忠實呈現截至繳交時之研究成果，期末報告不得少於 10 頁。

二、報告格式：依序為封面、目錄、中英文摘要及關鍵詞、報告內容、參考文獻、可供推廣之研發成果資料表、附錄。

(一)報告封面：請至本部網站（https：//most.gov.tw）線上製作（格式如附件一）。

(二)中、英文摘要及關鍵詞 (keywords)。

(三)報告內容：包括前言、研究目的、文獻探討、研究方法、結果與討論（含結論與建議、執行計畫過程遇到之困難或阻礙）等。

(四)頁碼編寫：請對摘要及目錄部分用羅馬字Ⅰ、II、 III……標在每頁下方中央；報告內容至附錄部分請以阿拉伯數字 1.2.3.……順序標在每頁下方中央。

(五)附表及附圖可列在文中或參考文獻之後，各表、圖請說明內容。

(六)可供推廣之研發成果資料表：

1.研究計畫所產生之研發成果，應至科技部科技研發成果資訊系統(STRIKE)（自科技部學術研發服務網登入後連結 STRIKE 系統）填列研發成果資料表（如附件二），循執行機構行政程序，由研發成果推廣單位（如技轉中心）線上繳交送出。

2.每項研發成果填寫一份。

(七)成果彙整表(如附件三) ：請至本部網站線上填寫。

(八)若該計畫已有論文發表者(須於論文致謝部分註明補助計畫編號)，得作為成果報告內容或附錄，並請註明發表刊物名稱、卷期及出版日期。若有與執行本計畫相關之著作、專利、技術報告、或學生畢業論文等，請在參考文獻內註明之。

(九)該計畫若列屬國際合作研究，應將雙方互訪及合作研究情況、共同研究成果及是否持續雙方合作等，於報告中重點式敘明。

三、計畫中獲補助國外差旅費，出國進行國際合作與移地研究、出席國際學術會議或出國參訪

及考察者，每次均須依規定分別撰寫出國心得報告（其中，出席國際學術會議者須另附發表之論文全文或摘要，但受邀專題演講或擔任會議主持人者不在此限），並至本部網站線上繳交電子檔，出國心得報告格式如附件四、五、六。

四、計畫中獲補助國外學者來臺費用，每次均須分別撰寫國外學者來臺訪問成果報告，並至本部網站線上繳交電子檔，報告格式如附件七。

五、研究計畫涉及臨床試驗且進行性別分析者，成果報告應一併繳交性別分析報告，說明性別分析之結果，報告格式如附件八。

六、報告編排注意事項

(一)版面設定：A4 紙，即長 29.7 公分，寬 21 公分。

(二)格式：中文打字規格為每行繕打（行間不另留間距），英文打字規格為 Single Space。

(三)字體：以中英文撰寫均可。英文使用 Times New Roman Font，中文使用標楷體，字體大小以 12 號為主。

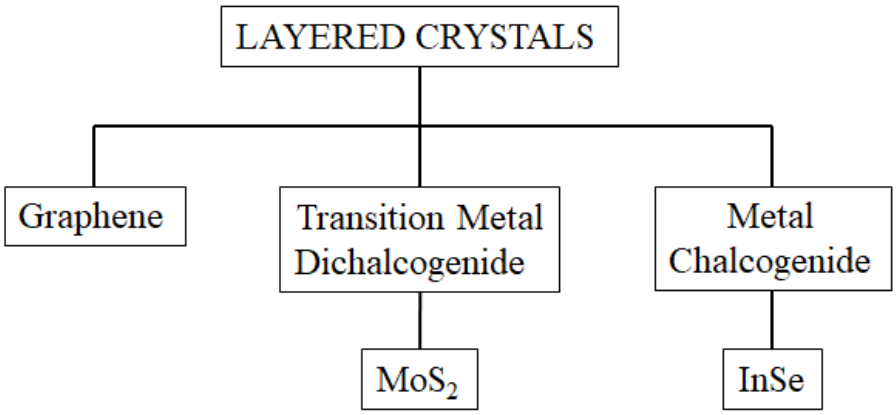
七、成果報告除敏感科技研究計畫外，應供立即公開查詢。但涉及專利、其他智慧財產權、論文尚未發表者，得延後公開，最長以計畫執行期滿日起算 2 年為限，繳交送出前應填寫公開方式，如需延後公開，應註明原因及延後時間。

(三) 報告內容：

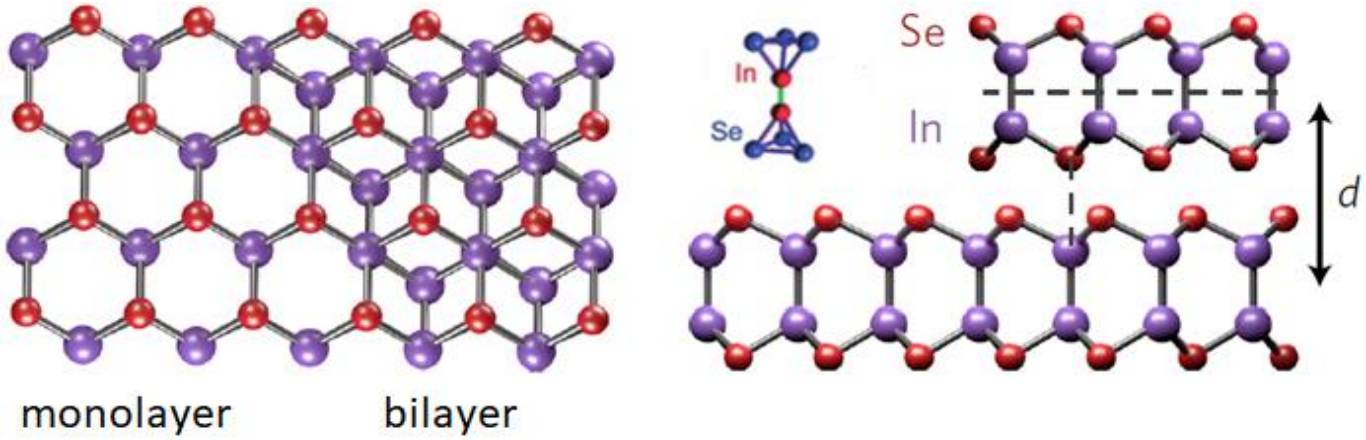
A. 研究目的

B. 文獻探討

For a decade, a wide variety of two-dimensional (2D) van der Waals crystals have been investigated, such as Graphene and MoS_2 [1]. The discovery of monolayer graphene and transition metal dichalcogenides show the novel physical phenomena when a bulk crystal is reduced to one atomic layer and the honeycomb structure which renewed interest in two-dimensional materials. These two dimensional flakes of layered materials are formed with strong in-plane bonding and weak Van-der-Waals attraction between two-dimensional layers of single unit cell thickness. Among the van der Waals crystals, the layered hexagonal metal monochalcogenide III-VI compound, InSe has emerged as a promising 2D semiconductor [2]. Like MoS_2 monolayer, InSe monolayer also possesses the optical properties that make them well suited for use in photodetectors and other optical or optoelectronic applications. The electron mobility at room temperature was measured at $10^3\ cm^2/Vs$, which compares with silicon at 1,400 cm^2/Vs. Moreover, carrier mobilities are found to exceed $10^4\ cm^2/Vs$ at liquid-helium temperature. These properties of InSe monolayer are distinctly different from those of the graphene and MoS_2.

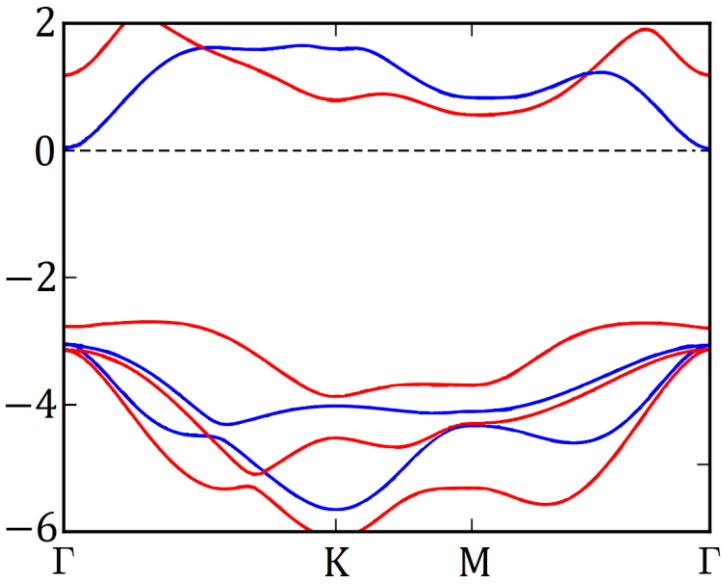


An InSe monolayer is composed of four atomic layers, two layers of Indium atoms sandwiched by two Selenide layers where both the Indium and Selenide layers form a 2D triangular lattice. Each Indium atom interacts with one neighboring Indium atom, as well as three neighboring Selenide atoms (as shown in the figure). The outermost shells of the Indium atom are $5s^2 5p^1$ orbitals and those of the Selenide are $4s^2 4p^4$ orbitals. The structure of few layers is the A-B-C stacking of monolayers which breaks the mirror-plane symmetry of the monolayer.



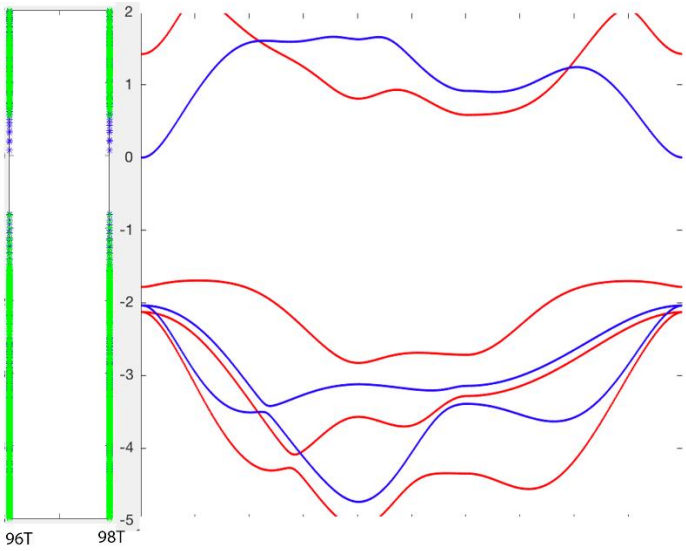
(Denis A. Bandurin et. al. *Nature Nanotechnology*, 2017)

From the results of the first principle calculation, the conduction and valence band edges near the Γ point are non-degenerate due to the s and p_z orbitals of both metal and chalcogen atoms. Since the discovery of the 2D InSe, our group has paid a lot of attentions in the study. We have used the tight-binding method [3] successfully reproduced the band structure as the first principles calculation. The electrical bands near the Fermi level are mostly contributed from *p*-orbitals of Indium atoms and few from *p*-orbitals of Selenide atoms. The conduction electrons occupy a single 2D subband and have a small effective mass. Photoluminescence spectroscopy reveals that the bandgap increses by more than $0.5\ \text{eV}$ with decreasing the thickness from bulk ($1.25\ \text{eV}$) to monolayer InSe ($1.9\ \text{eV}$). G. W. Mudd et. al. recently has also reported that the bandgap of InSe transforms from a direct to an indirect bandgap semiconductor as the number of layers is reduced [4].



(Yi-Hua Wang and Hong-Yi Chen, *in progress*, 2017)

The 2D metal chalcogenides, such as $InSe$, have rather large bandgaps that change from direct to indirect in single layers. The γ-polytype phase of $InSe$ with consecutive layer stacking is an A-B-C stacking which breaks the mirror-plane symmetry of monolayer InSe. However, the mirror-plane symmetry of the monolayer InSe causes the band-edge optical response vanishing, which would be expected to affect optical selection rules and spin-orbit coupling in few-layer InSe. To investigate optical properties of InSe, we have begun to numerically study the Landau level spectra with and without spin-orbit coupling. Within the tight-binding model, the atomic hoppings, spin-orbit coupling, and magnetic field are all taken into account without using approximations. Both Landau energies and Landau wave functions can be simultaneously resolved. In particular, wave functions in terms of sublattices provide an intuitive way to define the quantum state of individual Landau levels. Such an explicit level characterization also plays a crucial role in determining the transition rules in magneto-optical spectra. In our current progresses, we have calculated Landau levels which can be classified into specific groups based on their orbital and spin. These properties make the InSe quite different from the transition metal chalcogenide materials, such as MoS_2 [1], and allow electronics and optoelectronic applications such as transistors, photodetectors and electroluminescent devices.



(Yi-Hua Wang and Hong-Yi Chen, *in progress*, 2017)

Although InSe has a lot of potentials in the applications, there are many fundamental issues that remain elusive. In particular, the mass of the electron, hole and exciton are largely unknown in 2D InSe. Moreover, the electronic band structure is needed to deepen the understanding for the fundamental research and applications. In this project, I would therefore intend to continue our study of the electronic properties of 2D metal chalcogenide materials based on the spin-orbit coupling and electron-electron interactions. The onsite spin-orbit coupling effectively removes the spin degeneracy in the valence band edges around the K points and causes these spin-polarized states having quite different behaviors. Since the electrons can be excited by linearly and circularly polarized light, in magneto-optical spectra, selection rules can be effectively determined as well. Particularly, absorption lines can be used to provide a direct evidence of the spin-orbit coupling.

Furthermore, the luminescence experiments have shown cold and hot luminescence peaks. The cold luminescence, called A-peak, is attributed to a low energy transition between bands dominated by s and p_z orbitals. Combined with the mirror reflection symmetry ($z \rightarrow -z$) of the conduction and valence bands, the transition is caused by the electric dipole coupled to out-of-plane polarized photons. The hot luminescence, called B-peak, involves holes in the valence band contributed by the p_x and p_y orbitals. This transition is strongly coupled to the in-plane polarized photons. These experimentally observed transitions should be understood through the band structure parameters and selection rules of the 2D InSe.

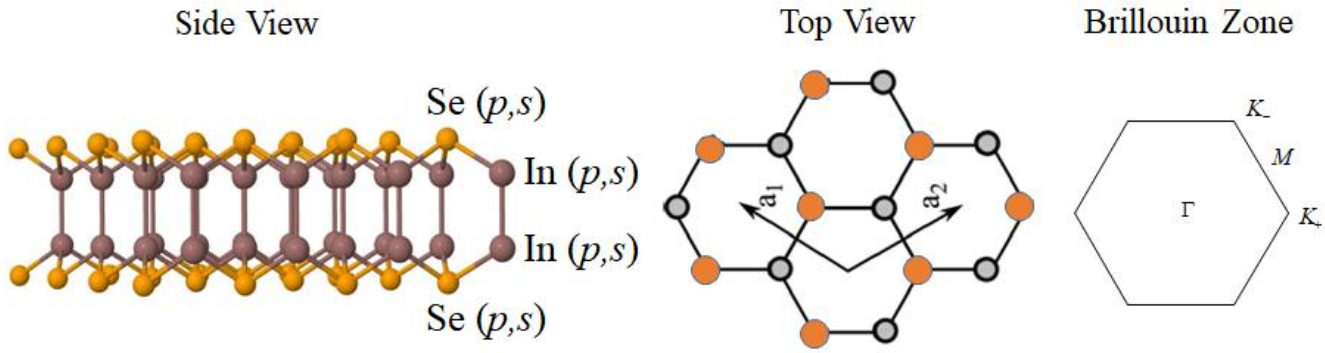
The monolayer GeSe, a family of 2D metal chalcogenide, the highest valence band shows an inverted "Mexican hat" band structure. Near the band edge, the constant energy contours form a ring in k-space and van Hove singularity in the density of states. A large density of states of a system should make instabilities and transitions to different phase such as magnetism. For GeSe, there is a Stoner-type magnetic instability as increasing the hole doping. As changing the doping level, the magnetic moment is also varied leading the monolayer GeSe to a half-metallic ferromagnetic ground state [5]. In this project, we also are interesting the similar phenomena could be happened in the 2D InSe. From the experimental results, InSe and GeSe are found to have similar band structure and atomic structure. We, nevertheless, are confidently to believe that InSe will experience the same phase transition as the increasing the hole doping. We would study the magnetic moment as a function of hole-doping and investigate different phases in 2D InSe.

---

1. Yen-Hung Ho, Yi-Hua Wang, and Hong-Yi Chen, Phys. Rev. B 89, 155316 (2014).
2. D. A. Bandurin, A. V. Tyurnina, L. Y. Geliang, A. Mishchenko, V. Zolyomi, S. V. Morozov, R. K. Kumar, R. V. Gorbachev, Z. R. Kudrynskyi, S. Pezzini, Z. D. Kovalyuk, U. Zeilter, K. S. Novoselov, A. Patane, L. Eaves, I. I. Grigorieva, V. I. Falko, A. K. Geim, and Y. Gao, Nature Nanotechnology 12, 223 (2017).
3. S. J. Magorrian, V. Zolyomi, and V. I. Falko, Phys. Rev. B 94, 245431 (2016).
4. G. W. Mudd, M. R. Molas, X. Chen, V. Zolyomi, K. Nogajewski, Z. R. Kudrynskyi, Z. D. Kovalyuk, G. Yusa, O. Makarovsky, L. Eaves, M. Potemski, V. I. Falko, and Patane, Scientific Report 6, 39619 (2016).
5. T. Cao, Z. Li, and S. G. Louie, Phys. Rev. Lett. 114, 236602 (2015).

C. 研究方法

We use a tight-binding model where the basis is from the s and p orbitals of In and Se atoms to describe the mono-layer InSe.



The Hamiltonian up to next-nearest neighbor hoppings takes the form

$$\hat{H} = \begin{pmatrix} a_{s,s} & a_{s,p_x} & a_{s,p_y} & a_{s,p_z} & b_{s,s} & b_{s,p_x} & b_{s,p_y} & b_{s,p_z} \\ a_{p_x,s} & a_{p_x,p_x} & a_{p_x,p_y} & a_{p_x,p_z} & b_{p_x,s} & b_{p_x,p_x} & b_{p_x,p_y} & b_{p_x,p_z} \\ a_{p_y,s} & a_{p_y,p_x} & a_{p_y,p_y} & a_{p_y,p_z} & b_{p_y,s} & b_{p_y,p_x} & b_{p_y,p_y} & b_{p_y,p_z} \\ a_{p_z,s} & a_{p_z,p_x} & a_{p_z,p_y} & a_{p_z,p_z} & b_{p_z,s} & b_{p_z,p_x} & b_{p_z,p_y} & b_{p_z,p_z} \\ b^*_{s,s} & b^*_{p_x,s} & b^*_{p_y,s} & b^*_{p_z,s} & c_{s,s} & c_{s,p_x} & c_{s,p_y} & c_{s,p_z} \\ b^*_{s,p_x} & b^*_{p_x,p_x} & b^*_{p_y,p_x} & b^*_{p_z,p_x} & c_{p_x,s} & c_{p_x,p_x} & c_{p_x,p_y} & c_{p_x,p_z} \\ b^*_{s,p_y} & b^*_{p_x,p_y} & b^*_{p_y,p_y} & b^*_{p_z,p_y} & c_{p_y,s} & c_{p_y,p_x} & c_{p_y,p_y} & c_{p_y,p_z} \\ b^*_{s,p_z} & b^*_{p_x,p_z} & b^*_{p_y,p_z} & b^*_{p_z,p_z} & c_{p_z,s} & c_{p_z,p_x} & c_{p_z,p_y} & c_{p_z,p_z} \end{pmatrix}$$

where *a* is the hopping between Indium atoms, *b* is the hopping between Indium and Selenide atoms, *c* is the hopping between Selenide atoms.

Spin-orbit coupling is able to generate additional transitions which accompanied by the electron spin-flip. The selection rules are different from the selection rules for transitions in the absence of the spin-orbit coupling. In the tight-binding model, the general spin-orbit interaction is difficult to blend in the Hamiltonian. The exfoliation of InSe is demonstrated in encapsulated ($\mathrm{InSe/hBN}$) and texturized ($\mathrm{InSe/SiO_2}$). The texturized InSe has been shown to enhancing the optical emission which could be interpreted by a spin-orbit coupling. However, for the encapsulated InSe, the optical properties are still unknown. Here, we would adapt the Rashba spin-orbit coupling to investigate the influence of the spin-orbit coupling.

We will calculate the magneto-optical spectra to study the electronic band structure and the spin-orbit coupling. First, we implement the exact diagonalization for a full matrix. After we diagonalize the Hamiltonian matrix, we select few low energy states to calculate the magneto-optical spectra. As we shown in the introduction, the size of a unit cell is corresponding to the applied field at $98\ \mathrm{T}$. To reduce the applied field, the lattice should be increased as a square law. In order to accelerate our results, we would exploit the GPGPU method.

The results will be submitted to the SCI journals. For the participants, such as students and postdocs, they

can learn the physics of the spin-orbit coupling, and the GPGPU calculations.

D. 結果與討論（含結論與建議）

Although the tight-binding method is elegant to study the band structure and the accompanied optical properties, the spin-orbit coupling is difficult to be integrated into the Hamiltonian. Even more, the transport properties based on the Landauer formalism is also difficult to implement with different shape of the potentials. Therefore, the $\vec{k}\cdot\vec{p}$ approximation [3] is a good candidate as

$$\widehat{H}=\begin{pmatrix} E_c & E_z d_z & \alpha_1\vec{A} & 0 \\ E_z d_z & E_v & 0 & \alpha_2\vec{A} \\ \alpha_1\vec{A} & 0 & E_{v_1} & 0 \\ 0 & \alpha_2\vec{A} & 0 & E_{v_2} \end{pmatrix}, \qquad \alpha_{1(2)}=\frac{\hbar e}{cm}\beta_{1(2)}$$

where h_c, h_v, h_{v_1}, and h_{v_2} are for the bands c, v, v_1 and v_2. The bottom of the conduction band can be approximated by a quadratic term

$$E_c=\frac{\hbar^2 k^2}{2m_c}\ .$$

The highest valence band is fitted around the Γ point as,

$$E_v(k)=E_v+E_2k^2+E_4k^4\ .$$

The bands v_1 and v_2 are double degenerate at the Γ point described as

$$E_{v_{1(2)}}=\frac{\hbar^2k^2}{2m_{1(2)}}+\frac{\hbar^2\left(k_x^2-k_y^2\right)}{2m'_{1(2)}}\sigma_z+\frac{2\hbar^2k_xk_y}{2m'_{1(2)}}\sigma_x, \qquad \begin{cases} m_1=0.31, m'_1=0.45 \\ m_2=0.30, m'_2=0.45 \end{cases}$$

The mirror reflection symmetry ($z\to -z$) of the conduction and valence band allows for

$$\frac{\hbar e}{cm}\beta_{1(2)}\vec{A}\times\vec{s}$$

spin-flip (due to the atomic spin-orbit coupling) interband transition coupled with x, y-polarized photons. The Hamiltonian should become

$$\widehat{H}=\begin{pmatrix} E_c\mathbf{I}_2 & E_z d_z & \alpha_1\mathbf{1}_s\otimes\mathbf{A} & \lambda_{c,v_2}\mathbf{s} \\ E_z d_z & E_v\mathbf{I}_2 & \lambda_{c,v_1}\mathbf{s} & \alpha_2\mathbf{1}_s\otimes\mathbf{A} \\ \alpha_1\mathbf{1}_s\otimes\mathbf{A}^\dagger & \lambda_{c,v_1}\mathbf{s} & E_{v_1}\mathbf{1}_s\otimes\mathbf{1}_p+\lambda_{v_1}s_z\otimes\sigma_y & 0 \\ \lambda_{c,v_2}\mathbf{s}^\dagger & \alpha_2\mathbf{1}_s\otimes\mathbf{A}^\dagger & 0 & E_{v_2}\mathbf{1}_s\otimes\mathbf{1}_p+\lambda_{v_2}s_z\otimes\sigma_y \end{pmatrix}$$

where $\mathbf{s}^\dagger=\left(s_x, s_y\right)$.

The results will be submitted to the SCI journals. For the participants, such as students and postdocs, they can

learn the physics of the spin-orbit coupling, and the high performance calculations.

附件一

科技部補助專題研究計畫成果報告

（□期中進度報告/□期末報告）

（計畫名稱）

計畫類別：□個別型計畫　□整合型計畫

計畫編號：MOST　－　－　－　－　－

執行期間：　年　月　日至　年　月　日

執行機構及系所：

計畫主持人：

共同主持人：

計畫參與人員：

本計畫除繳交成果報告外，另含下列出國報告，共 ___ 份：

□執行國際合作與移地研究心得報告

□出席國際學術會議心得報告

□出國參訪及考察心得報告

本研究具有政策應用參考價值：　□否　□是，建議提供機關_____

(勾選「是」者，請列舉建議可提供施政參考之業務主管機關)

本研究具影響公共利益之重大發現：□否　□是

中　華　民　國　年　月　日

附件二

科技部補助計畫衍生研發成果推廣資料表

日期：　年　月　日

<table>
<tr><td>科技部補助計畫</td><td colspan="3">計畫名稱：
計畫主持人：
計畫編號：　　領域：</td></tr>
<tr><td rowspan="2">研發成果名稱</td><td colspan="3">（中文）</td></tr>
<tr><td colspan="3">（英文）</td></tr>
<tr><td>成果歸屬機構</td><td></td><td>發明人
(創作人)</td><td></td></tr>
<tr><td rowspan="2">技術說明</td><td colspan="3">（中文）

（200-500 字）</td></tr>
<tr><td colspan="3">（英文）</td></tr>
<tr><td>產業別</td><td colspan="3"></td></tr>
<tr><td>技術/產品應用範圍</td><td colspan="3"></td></tr>
<tr><td>技術移轉可行性及預期效益</td><td colspan="3"></td></tr>
</table>

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

附件三

科技部補助專題研究計畫成果彙整表

計畫主持人：	計畫編號：
計畫名稱：	

成果項目			量化	單位	質化 （說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）
國內	學術性論文	期刊論文		篇	請附期刊資訊。
		研討會論文			
		專書		本	請附專書資訊。
		專書論文		章	請附專書論文資訊。
		技術報告		篇	
		其他		篇	
國外	學術性論文	期刊論文		篇	請附期刊資訊。
		研討會論文			
		專書		本	請附專書資訊。
		專書論文		章	請附專書論文資訊。
		技術報告		篇	
		其他		篇	
參與計畫人力	本國籍	大專生		人次	請填寫依「科技部補助專題研究計畫約用研究人力注意事項」所實際約用專任、兼任人員。
		碩士生			
		博士生			
		專任人員(博士級)			
		專任人員(非博士級)			
	非本國籍	大專生			
		碩士生			
		博士生			
		專任人員(博士級)			
		專任人員(非博士級)			
其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)					

附件四

科技部補助專題研究計畫執行國際合作與移地研究心得報告

日期：　年　月　日

計畫編號	MOST　—　—　—　—　—		
計畫名稱			
出國人員 姓名		服務機構 及職稱	
出國時間	年　月　日至 年　月　日	出國地點	
出國研究 目的	□實驗 □田野調查 □採集樣本 □國際合作研究 □使用國外研究設施		

一、執行國際合作與移地研究過程

二、研究成果

三、建議

四、本次出國若屬國際合作研究，雙方合作性質係屬：(可複選)

□分工收集研究資料
□交換分析實驗或調查結果
□共同執行理論建立模式並驗証
□共同執行歸納與比較分析
□元件或產品分工研發
□其他 (請填寫) _____

五、其他

附件五

科技部補助專題研究計畫出席國際學術會議心得報告

日期：　年　月　日

計畫編號	MOST　—　—　—　—　—		
計畫名稱			
出國人員 姓名		服務機構 及職稱	
會議時間	年　月　日至 年　月　日	會議地點	
會議名稱	(中文) (英文)		
發表題目	(中文) (英文)		

一、參加會議經過

二、與會心得

三、發表論文全文或摘要

四、建議

五、攜回資料名稱及內容

六、其他

附件六

科技部補助專題研究計畫執行出國參訪及考察心得報告

日期：　年　月　日

計畫編號	MOST　—　—　—　—　—		
計畫名稱			
出國人員 姓名		服務機構 及職稱	
出國時間	年　月　日至 年　月　日	出國地點	

一、參訪及考察過程

二、心得

三、建議

四、其他

附件七

科技部補助專題研究計畫國外學者來臺訪問成果報告

日期：　年　月　日

計畫編號	MOST　—　—　—　—　—		
計畫名稱			
邀訪學者 姓名		服務機構 及職稱	
國籍		來臺時間	年　月　日至　年　月　日
來訪目的 (可複選)	□技術指導 □實驗設備設立 □計畫諮詢/顧問 □學術演講 □國際會議主講員 □其他		

一、訪問過程

二、對本項專題計畫產生之影響、貢獻或主要成果

三、建議

四、其他

附件八

科技部補助研究計畫涉及臨床試驗之性別分析報告

日期：　年　月　日

計畫編號	MOST　-　-　-　-　-		
研究人員姓名			
任職機關系所		職稱	
計畫名稱			

說明：

本年度專題研究計畫涉及臨床試驗且進行性別分析，請於計畫成果報告(期中進度報告/期末報告)時一併繳交「性別分析報告」。

項次	項目	說明	備註
1	本計畫之研究結果已進行性別分析。		
2	本計畫之收案件數及其性別比例。		
3	本計畫研究結果之性別差異說明。 如無性別差異，亦請說明。		

107年度專題研究計畫成果彙整表

計畫主持人：陳鴻宜	**計畫編號：**107-2112-M-003-002-
計畫名稱：二維硒化鋼的自旋軌道耦合及參雜的研究	

成果項目			量化	單位	質化 （說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）
國內	學術性論文	期刊論文	0	篇	
		研討會論文	0		
		專書	0	本	
		專書論文	0	章	
		技術報告	0	篇	
		其他	0	篇	
國外	學術性論文	期刊論文	2	篇	Physica C 546, 61 (2018) RSC Adcances 9, 41703 (2019)
		研討會論文	0		
		專書	1	本	"On the Properties of Novel Superconductors", Chapter 5, IntechOpen (2019) ISBN 978-1-78984-065-0
		專書論文	0	章	
		技術報告	0	篇	
		其他	0	篇	
參與計畫人力	本國籍	大專生	0	人次	
		碩士生	0		
		博士生	0		
		博士級研究人員	0		
		專任人員	0		
	非本國籍	大專生	0		
		碩士生	0		
		博士生	0		
		博士級研究人員	0		
		專任人員	0		

其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）	