

1. 研究著作發表：國際期刊論文14篇，研討會論文16篇，技術報告和其他18篇及專書著作3本
- (1) Jong-Kai Hsiao, **Ming-Fong Tai***, Chung-Yi Yang, Yung-Chiang Lee, Hsu-Yang Wang, Hon-Man Liu*, Jau-Shiung Fang and Shin-Tai Chen, **2006**: Labeling of Cultured Macrophages with Novel Magnetic Nanoparticles, *J. Magn. Magn. Mater.* **304**, e4–e6. (SCI:1.031, 2009 IF = 1.204, cited No.: 13) [Correspondence authors]
 - (2) **Ming-Fong Tai***, T. Y. Lee and Ming-Way Lee, **2006**: Structural and Magnetic Properties in Mn-doped Magnetic Semiconducting $Mg(In_{2-x}Mn_x)O_4$ System, *J. Magn. Magn. Mater.*, **304**, e176–e178. (SCI:1.031, 2009 IF = 1.204) [Correspondence author]
 - (3) Jong-Kai Hsiao, **Ming-Fong Tai**, Chung-Yi Yang, Shin-Tai Chen, Jaw-Lin Wang, Huan-Chiu Ku, and Hon-Man Liu*, **2007**: Comparison of micrometer sized and nanosized magnetic particles for cell labeling, *IEEE Transactions on Magnetics*, 43, 2421-2423. (SCI, 2009 IF = 1.061, cited No.: 6).
 - (4) Jong-Kai Hsiao, **Ming-Fong Tai**, Hung-Hao Chu, Shin-Tai Chen, Hung Li, Dar-Ming Lai, Sung-Tsang Hsieh, Jaw-Lin Wang, Hon-Man Liu*, **2007**: Magnetic Nanoparticle Labeling Mesenchymal Stem Cells without Transfection Agent: Cellular Behavior and Capability of Detection with Clinical 1.5T Magnetic Resonance at the Single Cell Level, *Magnetic Resonance in Medicine*, 58, 717–724. (SCI, 2009 IF = 3.225, [cited no: 53](#))
 - (5) M. W. Lee*, **M. F. Tai**, S. H. Chiou, **2008**: Transport and magnetic properties of Mn-doped $MgIn_{2-x}O_4$. *J. of Alloys and Compounds*, 461 (2008) 316–320. (SCI, 2009 IF = 2.135)
 - (6) J.-K. Hsiao, T.-I. Weng, **M.-F. Tai**, Y.-F. Chen, Y.-H. Wang, C.-Y. Yang, J.-L. Wang, and H.-M. Liu*, **2009 Feb**: Cellular Behavior Change of Macrophage After Exposure to Nanoparticles Cellular Behavior Change of Macrophage after Exposure to Nanoparticles, *J. Nanosci. Nanotechnol.* 9, 1388-1393. (SCI, 2009 IF = 2.467, [cited no: 3](#))
 - (7) Chung-Yi Yang, **Ming-Fong Tai**, Shin-Tai Chen, Yi-Ting Wang, Ya-Fang Chen, Jong-Kai Hsiao*, Jaw-Lin Wang and Hon-Man Liu*, **2009**: Labeling of human mesenchymal stem cell: Comparison between paramagnetic and superparamagnetic agents, *J. Appl. Phys.*, **105**, 07B314 (2009); published online 20 March 2009 (SCI, 2009 IF = 2.072, [cited no: 2](#))
 - (8) B. C. Chang, C. H. Hsu, **M. F. Tai**, Y. Y. Hsu, and H. C. Ku*, **2009**: “Anisotropic Microcrystalline Powder Alignment of the Weak-ferromagnetic Superconductor System $RuSr_2EuCu_2O_8$ (R = Pr, Nd, Sm, Eu, Gd, $Gd_{0.5}Dy_{0.5}$)”, *J. Phys.: Conf. Ser.* **150**, p.052033-p.052037 (2009). (25th Inter. Conf. on Low Temperature Physics-LT25, 6–13 Aug. 2008, Amsterdam, The Netherlands, SCI, 2009 IF = 1.964).
 - (9) H. C. Ku*, B. C. Chang, C. H. Hsu, Y. F. Chen, and **M. F. Tai**, **2009**: “Anisotropic Magnetic and Superconducting Properties of Aligned Weak-ferromagnetic Superconductor $RuSr_2GdCu_2O_8$ ”, *J. Phys.: Conf. Ser.* **150**, p.052131-p.052134 (2009). 25th Inter. Conf. on Low Temperature Physics-LT25, 6–13 Aug. 2008, Amsterdam, The Netherlands, Published online: 31 March 2009. (SCI, 2009 IF = 1.964).
 - (10) B. C. Chang, Y. B. You, T. J. Shiu, **M. F. Tai**, H. C. Ku*, Y. Y. Hsu, L. Y. Jang, J. F. Lee, Z.

Wei, K. Q. Ruan, and X. G. Li, **2009**: “Angular dependence of x-ray absorption spectrum for field-aligned iron-based superconductors”, *Phys. Rev. B* 80, P.165108-165111 (2009). (SCI, 2009 IF = 3.475, [cited no: 3](#))

(11) Chung-Yi Yang, Jong-Kai Hsiao, **Ming-Fong Tai**, Shin-Tai Chen, Hui-Ying Cheng, and Hon-Man Liu*, **2010**: “Direct labeling of hMSC with SPIO: the long-term influence on toxicity, chondrogenic differentiation capacity, and intracellular distribution”, *Molecular Imaging and Biology*, **V13, N3**, PP.443-451, DOI: 10.1007/s11307-010-0360-7, Published online: 22 June, 2010. (SCI, 2009 IF = 2.467, [cited no: 7](#))

(12) M. H. Lai¹, M. W. Lee, Gou-Jen Wang and **M. F. Tai**, **2011**: “Photovoltaic Performance of New-Structure ZnO-nanorod Dye-Sensitized Solar Cells”, *Int. J. Electrochem. Sci*, **V6**, pp.2122-2130 (2011). (SCI, 2009 IF = 3.019, 5-Year IF: 3.172, [cited no: 6](#))

(13) Chung-Yi Yang, **Ming-Fong Tai**, Chih-Peng Lin, Chen-Wen Lu, Jaw-Lin Wang, Jong-Kai Hsiao and Hon-Man Liu*, **2011**: “Mechanism of Cellular Uptake and Impact of Ferucarbotran on Macrophage Physiology”, *PLoS ONE*, **V6**, issue 9, e25524 (Sep. 2011). (SCI, 2009 IF= 4.351, [cited no: xx](#))

(14) Y. B. You, T. K. Hsiao, B. C. Chang, **M. F. Tai**, Y. Y. Hsu, H. C. Ku*, Z. Wei, K. Q. Ruan, and X. G. Li, “Anisotropic Structural and Magnetic Properties of the Field-Aligned Superconducting System $\text{SmFeAsO}_{1-x}\text{F}_x$ ($x = 0, 0.1, 0.2, 0.25$ and 0.3)”, *J. Phys.: Conf. Ser.* **V273**, 012109 (2011). (SCI, 2009 IF = 1.964)

2.近五年內學術著作目錄：2006-2011 年

國際期刊論文 14 篇，研討會論文 16 篇，技術報告和其他 12 篇及專書著作 3 本。

(1)國際期刊論文：

1. Jong-Kai Hsiao, **Ming-Fong Tai***, Chung-Yi Yang, Yung-Chiang Lee, Hsu-Yang Wang, Hon-Man Liu*, Jau-Shiung Fang and Shin-Tai Chen, **2006**: Labeling of Cultured Macrophages with Novel Magnetic Nanoparticles, *J. Magn. Magn. Mater.* **304**, e4–e6. (SCI:1.031, 2009 IF = 1.204, cited No.: 13) [Correspondence authors]
2. **Ming-Fong Tai***, T. Y. Lee and Ming-Way Lee, **2006**: Structural and Magnetic Properties in Mn-doped Magnetic Semiconducting $\text{Mg}(\text{In}_{2-x}\text{Mn}_x)\text{O}_4$ System, *J. Magn. Magn. Mater.*, **304**, e176–e178. (SCI:1.031, 2009 IF = 1.204) [Correspondence author]
3. Jong-Kai Hsiao, **Ming-Fong Tai**, Chung-Yi Yang, Shin-Tai Chen, Jaw-Lin Wang, Huan-Chiu Ku, and Hon-Man Liu*, **2007**: Comparison of micrometer sized and nanosized magnetic particles for cell labeling, *IEEE Transactions on Magnetics*, 43, 2421-2423. (SCI, 2009 IF = 1.061, cited No.: 6).
4. Jong-Kai Hsiao, **Ming-Fong Tai**, Hung-Hao Chu, Shin-Tai Chen, Hung Li, Dar-Ming Lai, Sung-Tsang Hsieh, Jaw-Lin Wang, Hon-Man Liu*, **2007**: Magnetic Nanoparticle Labeling Mesenchymal Stem Cells without Transfection Agent: Cellular Behavior and Capability of Detection with Clinical 1.5T Magnetic Resonance at the Single Cell Level, *Magnetic*

Resonance in Medicine, 58, 717–724. (SCI, 2009 IF = 3.225, cited no: 53)

5. M. W. Lee*, M. F. Tai, S. H. Chiou, 2008: Transport and magnetic properties of Mn-doped $\text{MgIn}_{2-x}\text{O}_4$. *J. of Alloys and Compounds*, 461 (2008) 316–320. (SCI, 2009 IF = 2.135)
6. J.-K. Hsiao, T.-I. Weng, M.-F. Tai, Y.-F. Chen, Y.-H. Wang, C.-Y. Yang, J.-L. Wang, and H.-M. Liu*, 2009 Feb: Cellular Behavior Change of Macrophage After Exposure to Nanoparticles Cellular Behavior Change of Macrophage after Exposure to Nanoparticles, *J. Nanosci. Nanotechnol.* 9, 1388-1393. (SCI, 2009 IF = 2.467, cited no: 3)
7. Chung-Yi Yang, Ming-Fong Tai, Shin-Tai Chen, Yi-Ting Wang, Ya-Fang Chen, Jong-Kai Hsiao*, Jaw-Lin Wang and Hon-Man Liu*, 2009: Labeling of human mesenchymal stem cell: Comparison between paramagnetic and superparamagnetic agents, *J. Appl. Phys.*, **105**, 07B314 (2009); published online 20 March 2009 (SCI, 2009 IF = 2.072, cited no: 2)
8. B. C. Chang, C. H. Hsu, M. F. Tai, Y. Y. Hsu, and H. C. Ku*, 2009: “Anisotropic Microcrystalline Powder Alignment of the Weak-ferromagnetic Superconductor System $\text{RuSr}_2\text{EuCu}_2\text{O}_8$ (R = Pr, Nd, Sm, Eu, Gd, $\text{Gd}_{0.5}\text{Dy}_{0.5}$)”, *J. Phys.: Conf. Ser.* **150**, p.052033-p.052037 (2009). (25th Inter. Conf. on Low Temperature Physics-LT25, 6–13 Aug. 2008, Amsterdam, The Netherlands, SCI, 2009 IF = 1.964).
9. H. C. Ku*, B. C. Chang, C. H. Hsu, Y. F. Chen, and M. F. Tai, 2009: “Anisotropic Magnetic and Superconducting Properties of Aligned Weak-ferromagnetic Superconductor $\text{RuSr}_2\text{GdCu}_2\text{O}_8$ ”, *J. Phys.: Conf. Ser.* 150, p.052131-p.052134 (2009). 25th Inter. Conf. on Low Temperature Physics-LT25, 6–13 Aug. 2008, Amsterdam, The Netherlands, Published online: 31 March 2009. (SCI, 2009 IF = 1.964).
10. B. C. Chang, Y. B. You, T. J. Shiu, M. F. Tai, H. C. Ku*, Y. Y. Hsu, L. Y. Jang, J. F. Lee, Z. Wei, K. Q. Ruan, and X. G. Li, 2009: “Angular dependence of x-ray absorption spectrum for field-aligned iron-based superconductors”, *Phys. Rev. B* 80, P.165108-165111 (2009). (SCI, 2009 IF = 3.475, cited no: 3)
11. Chung-Yi Yang, Jong-Kai Hsiao, Ming-Fong Tai, Shin-Tai Chen, Hui-Ying Cheng, and Hon-Man Liu*, 2010: “Direct labeling of hMSC with SPIO: the long-term influence on toxicity, chondrogenic differentiation capacity, and intracellular distribution”, *Molecular Imaging and Biology*, V13, N3, PP.443-451, DOI: 10.1007/s11307-010-0360-7, Published online: 22 June, 2010. (SCI, 2009 IF = 2.467, cited no: 7)
12. M. H. Lai¹, M. W. Lee, Gou-Jen Wang and M. F. Tai, 2011: “Photovoltaic Performance of New-Structure ZnO-nanorod Dye-Sensitized Solar Cells “, *Int. J. Electrochem. Sci*, **V6**, pp.2122-2130 (2011). (SCI, 2009 IF = 3.019, 5-Year IF: 3.172, cited no: 6)
13. Chung-Yi Yang, Ming-Fong Tai, Chih-Peng Lin, Chen-Wen Lu, Jaw-Lin Wang, Jong-Kai Hsiao and Hon-Man Liu*, 2011: ”Mechanism of Cellular Uptake and Impact of Ferucarbotran on Macrophage Physiology”, *PLoS ONE*, **V6**, issue 9, e25524 (Sep. 2011). (SCI, 2009 IF= 4.351, cited no: xx)
14. Y. B. You, T. K. Hsiao, B. C. Chang, M. F. Tai, Y. Y. Hsu, H. C. Ku*, Z. Wei, K. Q. Ruan, and X. G. Li, “Anisotropic Structural and Magnetic Properties of the Filed-Aligned Superconducting System $\text{SmFeAsO}_{1-x}\text{F}_x$ (x = 0, 0.1, 0.2, 0.25 and 0.3)”, *J. Phys.: Conf. Ser.*

(2)研討會論文

1. **Ming-Fong Tai**, Jong-Kai Hsiao, Yi-Fong Chou, Kuo-Chih Wang, Bor-Zin La, Shin-Tai Chen, **2006**: “Syntheses of Fe-Ni Magnetic Nanoparticles and Their Applications on Biologic Labeling”, 中國顆粒學會2006年會暨海峽兩岸顆粒技術研討會論文集(Proceedings of 2006 Annual Conference of Chinese Society of Particuology cum Symposium on Particle Technology across Taiwan Straits), pp308-310. Beijing, China, Aug. 18-21, 2006. [Correspondence author, **Peer reviewed**]
2. **戴明鳳***、邱立翰、劉彥君、吳月娥, **2008**: 主流科技之簡易 DIY 實驗融入物理基礎教學和科普教育的效益. 2008 年海峽兩岸物理基礎課程教學研討會, 中國上海市, 2008 年 5 月 23-25 日。華東理工大學學報自然科學版增刊, 2008 年 5 月出刊, 第 100-105 頁。
3. Y. J. Wu, M. Chen, C. L. Huang, **M. F. Tai**, L. H. Chiou and H. S. Koo*, **2008**: Characteristic observation and analysis of ZnO doped with carbon nanotubes in dye-sensitized solar cells. IUMRS-ICEM 2008, Sydney, Australia, Jul. 28-Aug. 1, 2008.
4. **Ming-Fong Tai***, Ching Cheng, Jauyn Grace Lin, Li-Ling Tsai, Mon-Shu Ho, Fu-Jen Kao, Maw-Kuen Wu and J. Raynien Kwo, **2008**: **The Status of the Women Physicists and Working Group Activities in China-Taiwan**. The 3rd IUPAP International Conference on Women in Physics (ICWIP2008) in Seoul, Korea, October 8-10 2008. [Correspondence author]
5. **戴明鳳**, 邱立翰, **2008**: 染料敏化太陽電池 DIY 實作之科普教育成效研究, 2008 年物理教學與示範研討會, 台灣彰化, 國立彰化師範大學物理系, 2008 年 8 月 21-20 日, 論文全文將刊載於「物理教育學刊」。
6. Chung-Yi Yang, **Ming-Fong Tai**, Shin-Tai Chen, Jong-Kai Hsiao, Yi-Ting Wang, Ya-Fang Chen, Jaw-Lin Wang and Hon-Man Liu, **2008**: Comparison of stem cells labeling using paramagnetic and superparamagnetic MRI contrast agents, submitted to *J. Appl. Phys.*, Abstract Designation: BS-02, Presentation format: Poster, Proceedings Journal: JAP, Submitted to the 53rd Magnetism and Magnetic Materials Conference (MMM2008), Nov. 10-14, 2008, Austin, Texas, USA.
7. B. C. Chang, C. H. Hsu, **M. F. Tai**, Y. Y. Hsu, and H. C. Ku*, **2009**: “Anisotropic Microcrystalline Powder Alignment of the Weak-ferromagnetic Superconductor System $\text{RuSr}_2\text{EuCu}_2\text{O}_8$ (R = Pr, Nd, Sm, Eu, Gd, $\text{Gd}_{0.5}\text{Dy}_{0.5}$)”, *J. Phys.: Conf. Ser.* **V150**, pp.052033-052037 (2009). (SCI).
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9. **戴明鳳**, **2009**: ”染料敏化奈米材料太陽電池之簡易自製實驗融入科普活動的實施成效”, 第二屆海峽兩岸科普研討會, 於 2009 年 8 月 27~29 日在福建省漳州市。
10. 林志明, 謝宜庭, 陳宏志, **戴明鳳***, 劉心華, 2010: ”Gd 取代型鈮鐵石榴石陶鐵磁性材料研製”, 第 19 屆國防科技學術研討會論文集, 發表於 99 年度國防科技學術合作計畫成果發表會, 2010 年 11 月於台灣桃園縣龍潭可望園區舉辦。
11. 周文采, **戴明鳳***, 張似璫, 顏麗娜, 邱絹琇, 2010: ”核能與輻射教育推廣及其成效探討

(1/2) ”，99 年度原能會與國科會科技學術合作研究計畫(MF)成果發表會於 100 年 12 月 7 日(二)於台灣桃園縣龍潭核能研究所舉行。

12. 謝宜庭，林志明，**戴明鳳***，劉心孳，2010：”高性能氮化鐵吸波材料研製”，第 19 屆國防科技學術研討會論文集，發表於 99 年度國防科技學術合作計畫成果發表會，2010 年 11 月於台灣桃園縣龍潭可望園區舉辦。
13. 林志明，林振榮，謝宜庭，陳宏志，鐘仕堯，**戴明鳳***，劉心孳，2011：”摻銻二氧化錫粉體製程及特性研究”，第 20 屆國防科技學術研討會論文集，發表於 100 年度國防科技學術合作計畫成果發表會，2011 年 11 月 17 日於台灣桃園縣龍潭可望園區舉辦。
14. 鐘仕堯，謝宜庭，陳宏志，謝文凱、林志明，江慧真，**戴明鳳***，劉心孳，2011：”低紅外發射率奈米鋁摻雜氧化鋅研製及特性評估”，第 20 屆國防科技學術研討會論文集，發表於 100 年度國防科技學術合作計畫成果發表會，2011 年 11 月 17 日於台灣桃園縣龍潭可望園區舉辦。
15. **戴明鳳***，周文采，張似璫，吳易翰，顏麗娜，邱絹琇，彭志煒，2011：”核能與輻射教育推廣及其成效探討(2/2) ”，100 年度原能會與國科會科技學術合作研究計畫(MF)成果發表會於 100 年 12 月 16 日(五)於台灣桃園縣龍潭核能研究所舉行。
16. 李敏，**戴明鳳***，張似璫，顏麗娜，彭志煒，2011：”核電知識深耕推廣計 ”，100 年度原能會與國科會科技學術合作研究計畫(MF)成果發表會於 100 年 12 月 16 日(五)於台灣桃園縣龍潭核能研究所舉行。

(3)技術報告及其他著作(Technical Reports and Other Publications)

1. **戴明鳳**，2007：『過去與現代女性科學家所面臨的困境—從女性諾貝爾科學獎得獎主及與諾貝爾科學獎擦身而過的女性科學家談起』，物理雙月刊，第 29 卷第 2 期，p546-562, 2007 年 4 月出刊。
2. **戴明鳳**，2007：『氣候變遷與能源科技』，物理雙月刊，第 29 卷第 3 期，主編，2007 年 6 月出刊。
3. **戴明鳳**，2007：『女性科學家的現況和困境』，知識通訊評論，第 62 期，第 63-64 頁(來鴻論壇)，2007 年 12 月出刊。
4. **戴明鳳**，2008：『2007 物理與化學女性學者聯合研討會』會議紀錄和與會者感言，物理雙月刊，女性專欄，第 30 期第 1 卷，p791, 2008 年 2 月出刊，中華民國物理學會出版。
5. **戴明鳳**，2008：『女性學者面臨各種抉擇之間的得與失』，台灣女科技人電子報第 007 期 科技人論壇，2008 年 7 月 10 日出刊。
6. **邱韻如**、**戴明鳳**，『緣起不減—兩岸大學物理基礎課程教學之成長—「2008 年海峽兩岸物理基礎課程教學研討會暨參訪活動」與交流之見聞』，物理雙月刊，第 30 卷第 5 期，p542-558, 2008 年 10 月出刊。
7. **戴明鳳**，2009：中山科學研究院第四研究所委託計畫「 $(Y_{1-x}Gd_x)FeO_3$ 系列微波陶鐵磁材料研製與其磁性特性分析」研究報告，2009 年 12 月。
8. **戴明鳳**，2010：台灣女科技人電子報第 036 期主編，<http://www2.tku.edu.tw/~tfst/038.htm>，2010 年 12 月 10 日出刊。

9. 戴明鳳，2010：「亞太物理學會聯合會第二屆女物理工作者研討會會議報告」，台灣女科技人電子報第 036 期(<http://www2.tku.edu.tw/~tfst/036.htm>)，2010 年 12 月 10 日出刊。
10. 戴明鳳，2010：「我認識的國科會自然處研究員何怡帆小姐」，台灣女科技人電子報第 036 期(<http://www2.tku.edu.tw/~tfst/036.htm>)，2010 年 12 月 10 日出刊。
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12. 戴明鳳，2010：中山科學研究院第四研究所委託計畫「Gd 取代型釷鐵石榴石陶鐵磁性材料研製」研究報告(國防部研究勞務採購委託案# XD99087P)，2010 年 12 月。
13. 戴明鳳，2010：中山科學研究院第四研究所委託計畫「奈米吸收劑開發及毫米波吸波應用研究」整合型計畫暨子計畫二：「高性能氮化鐵吸波材料研製」研究成果報告(99 年度國防學術合作案# XD99081-P499)，2010 年 12 月。
14. 戴明鳳，2011：台灣女科技人電子報第 038 期主編，<http://www2.tku.edu.tw/~tfst/038.htm>，2011 年 2 月 10 日出刊。
15. 戴明鳳，2011：台灣女科技人電子報第 042 期主編，<http://www2.tku.edu.tw/~tfst/042.htm>，2011 年 6 月 10 日出刊。
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17. 戴明鳳，2011：中山科學研究院第四研究所委託計畫「低紅外發射率銻錫摻雜氧化物 ATO 粉體研製及特性評估」研究報告(100 年度國防學術合作案# XD00025P)，2010 年 12 月。
18. 戴明鳳，2011：中山科學研究院電子所委託計畫「釷釷鐵石榴石陶鐵磁圓錠與低損耗溫度穩定 X 頻微波循環器基板委製」計畫研究報告，2010 年 12 月。

(4) 專書

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3. 戴明鳳(主編)、林志明、林智遠編撰，高中「基礎物理(二)A」教科書，全華科技圖書公司印行，約 250 頁，2011 年 6 月初版。

3. 近五年之研究內容與主要研究成果說明

近五年主要集中在下列幾個系列材料的研製和其特性與應用的探討：

- A. 生醫用之磁性奈/微米膠珠材料與其應用
- B. $\text{RuSr}_2\text{RCu}_2\text{O}_8$ 與 $\text{SmFeAsO}_{1-x}\text{F}_x$ 磁性超導系列
- C. 其他氧化物材料： $\text{Mg}(\text{In},\text{Mn})_2\text{O}_4$ 和 ZnO 奈米柱及其在染料敏化太陽電池的應用
- D. 磁性微波陶瓷材料
- E. ZnO 奈米柱材料

A. 生醫用之磁性奈/微米膠珠材料與其應用：與台大醫院影像檢測團隊合作，已完成下列成果：

1. 鐵基之磁性奈米粒研發：以各種化學法研製分散性佳、粒徑分佈均勻、穩定度佳的奈米級氧化鐵粒和鐵鎳合金奈米微粒。經由選擇不同的溶劑、不同的介面活性劑、控制反應液的酸鹼度、熱迴流溫度和時間可獲得不同粒徑大小的奈米磁粒。研發可快速、方便、量產的便利製程。
2. 磁性奈/微米級膠珠研發：生醫用磁性材料需具備高生物相容性、無生物毒性、超順磁性等特性，故無機磁性奈米粒須披覆可生物相容之高分子聚合物，形成奈/次微米級膠珠，才能用於生醫實驗。已成功掌握表面包覆聚乙烯亞胺(Polyethyleneimine, PEI)或葡聚糖(Dextran, 聚合葡萄糖)等生物相容之高分子聚合物，並形成磁性膠珠的製備流程。
3. 磁性膠珠在基因轉植之定向導引和增強效應研究：與美國加州 Jerry L. Pettis VA Medical Center 的骨骼疾病研究中心(Musculoskeletal Disease Center; MDC) Shin-Tai Chen 研究員合作完成「磁性奈米微粒對反轉錄濾過性病毒之基因轉錄效應之增強影響」的應用研究。先製備具超順磁性或具超軟鐵磁性(即矯頑力 $H_c = 0$)之含鐵氧化物奈米粒，並於奈米粒表面經修飾製程，包覆上可與生物相容之 PEI 分子(同時作為磁粒子的分散劑)，形成磁性膠珠。再使膠珠與奈米級的反轉錄濾過性病毒載體(retroviral vectors, 約 80-200 nm 大小)結合，形成具磁性的奈米級或微米級病毒載體，稱為磁病毒載體(magnetic viral vectors)。藉由外加磁場的導引作用，將反轉錄病毒載體所攜帶的正常基因或作為疾病治療用的基因載入特定範圍的生物細胞內(如我們使用 HT108 人類細胞)，使之達成高效率基因轉錄或基因改造的目的。實驗結果證實以磁力導引奈米磁病毒載體，可高效率地完成特定標的之基因轉錄功能，並可增強轉錄效率且提高基因表現的成果，進而可降低病毒載體的使用劑量。部分實驗並已在大老鼠體內證實其可行性，實驗結果顯示奈米磁粒在人體細胞和大老鼠的腿骨內沒有觀測到明顯的生物毒性反應。與未含磁粒子的對照控制組比較，確實具有較高的基因表現效率和生物活性。我們證實了磁性奈米粒的定向導引功能，此研究成果對基因藥物傳輸提供了很廣大的應用空間，此結果亦可應用於一般藥物的定點傳輸。
4. 證實表面包覆 PEI 分子之鐵鎳磁性合金奈米粒應用於磁共振造影(Magnetic resonance image, MRI)檢測和細胞標式(cell labeling)的可行性：與台大醫院醫學影像科部門廖漢文主任醫師和蕭仲凱主治醫師合作，進行磁性奈米粒對 MRI 造影術的顯影提昇應用的評估研究，已獲得正面之定性和定量的實驗結果。亦實驗證實我們自製的磁性奈米粒

在 MRI 的應用潛力。

長期以來生醫領域的研究人員通常僅信賴氧化鐵或含有少量磁性稀土離子之高分子聚合物的磁性材料可在人體內或細胞內的生物相容性，很少輕易嘗試氧化鐵系列以外之無機磁性物質使用於人體內。但通常包覆了高分子聚合物的氧化鐵微膠珠之磁性強度不夠高，致使磁性材料在生醫上的應用範圍受限。我們以實驗室內自製的鐵鎳磁性合金奈米膠珠進行細胞標示實驗，並經普魯士藍染色(Prussian blue staining)實驗顯示鐵鎳合金在細胞內部不會氧化，也沒有觀測到細胞對合金奈米粒明顯的排斥性和生物毒性。初步的 MRI 影像實驗結果顯示我們所製備的鐵鎳合金粒的 MR 影像對比效率與現已市售之 MR 影像對比劑(Ferucarbotran MR contrast agent)之效率相當。使得鐵鎳磁性合金奈米粒具有成為新 MR 對比劑材料的高度潛力。部分研究成果已發表於 SCI 期刊。

5. Comparison of micrometer sized and nanosized magnetic particles for cell labeling :

Magnetic resonance imaging (MRI) has been used globally as a noninvasive tool for investigating human anatomy and pathological conditions. Nanosized particles of iron oxide (NPIO) has been applied extensively as contrast medium for MRI. Recently, micrometer sized particles of iron oxide (MPIO) has also been demonstrated the feasibility for cell labeling to monitor immune response. In this study, we compared the cellular labeling efficiencies of these two kinds of magnetic particles. The NPIO exhibit stronger saturation magnetization and produce more MRI signal change. On the contrary, MPIO revealed better particle uptake ability than NPIO in incubated cells. Microscopically, both MPIO and NPIO were located in the cytoplasm but not in the cell nucleus. On MRI examination, MPIO labeled cells showed more pronounced signal change compared to NPIO labeled cells. We conclude that MPIO is more efficacious in cell labeling than NPIO. Our results give some useful information for development and improvement to facilitate its MRI applications on stem cell trafficking, evaluation of transplantation rejection and monitoring immune responses. (The results has been published: Jong-Kai Hsiao*, **Ming-Fong Tai***, Chung-Yi Yang, Shin-Tai Chen, Jaw-Lin Wang, Huan-Chiu Ku, and Hon-Man Liu*, **2007: IEEE Transactions on Magnetics**, 43, pp2421-2423.).

6. Magnetic Nanoparticle Labeling Mesenchymal Stem Cells without Transfection Agent: Cellular Behavior and Capability of Detection with Clinical 1.5T Magnetic Resonance at the Single Cell Level

(Jong-Kai Hsiao, Ming-Fong Tai, Hung-Hao Chu, Shin-Tai Chen, Hung Li, Dar-Ming Lai, Sung-Tsang Hsieh, Jaw-Lin Wang, Hon-Man Liu, *Magnetic Resonance in Medicine*, **58**, pp.717–724, **2007**.): This work was to evaluate the efficacy of labeling human mesenchymal stem cells (hMSCs) by ionic superparamagnetic iron oxide (SPIO) without a transfection agent and verifying its capability to be detected with clinical 1.5 T magnetic resonance (MR) at the single-cell level. Human hMSCs (hMSCs) were successfully labeled with Ferucarbotran, a clinically used ionic SPIO, without aid of a transfection agent. The labeling efficiency of hMSCs was determined by iron content

measurement spectrophotometrically, and the influence of labeling on cell behavior was ascertained by examination of cell viability using the trypan blue exclusion method, cell proliferation analysis using MTT (3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay, mitochondrial membrane potential (MMP) change, differentiation capacity, and reactive oxygen species (ROS) production measured by dichlorofluorescein diacetate (DCFDA) fluorescent probe. Labeled hMSCs were scanned under 1.5 T MRI with three-dimensional (3D) and twodimensional (2D) T_2 -weighted gradient echo (GRE) pulse sequences. Human hMSC labeling without transfection agent was efficient. The iron content in hMSCs was 23.4 pg Fe/cell. No significant change was found in viability, proliferation, MMP change, ROS production, or differentiation capacity. About 45.2% of the hMSCs could be detected using 1.5 T MRI at the single cell level with 3D GRE and four repetitions. Our labeling procedure is simpler, and efficacy is acceptable and comparable to other methods reported. No significant cellular behavior change was found in the labeled hMSCs. With proper MR pulse sequence, the labeled hMSCs can be detected at a single level. The results supply useful data for the future *in vivo* study on the clinical application.

7. Cellular Behavior Change of Macrophage after Exposure to Nanoparticles (J.-K. Hsiao, T.-I. Weng, **M.-F. Tai***, Y.-F. Chen, Y.-H. Wang, C.-Y. Yang, J.-L. Wang, and H.-M. Liu*, *J. Nanosci. Nanotechnol.* 9, pp.1388-1393, 2009.): Magnetic nanoparticles (MNPs) are few of the nanoparticles used clinically. When MNPs are delivered into human body, they are ingested by macrophages. We evaluated the cellular response of macrophage after MNPs loading. In face of stimulation by lipopolysaccharide, a strong stimulant derived from bacterial cell wall, MNPs loaded macrophage exhibited decreased phagocytic activity and decreased generation of cytokines such as TNF- α , IL-1 β whereas increased nitric oxide generation was noticed. Although these changes might decrease bactericidal activity, it also alleviates the risk of sepsis, a life threatening phenomenon in infection patients. The finding has significant implications on nanoparticle based targeted drug delivery.

8. Labeling of human mesenchymal stem cell: Comparison between paramagnetic and superparamagnetic agents (Chung-Yi Yang, Ming-Fong Tai*, Shin-Tai Chen, Yi-Ting Wang, Ya-Fang Chen, Jong-Kai Hsiao*, Jaw-Lin Wang and Hon-Man Liu*, 2009.; *J. Appl. Phys.*, **105**, 07B314, 2009): Paramagnetic and superparamagnetic substances are used to trace stem cell in living organisms under magnetic resonance imaging (MRI). We compared paramagnetic and superparamagnetic iron oxide (SPIO) substance for their labeling efficiency by using clinically widely used gadolinium chelates and iron oxide nanoparticles. Without the aid of transfection agent, human mesenchymal stem cells were labeled with each agent separately in different concentration and the optimized concentration was determined by maintaining same cell viability as unlabeled cells. Iron oxide nanoparticle labeling has a detecting threshold of 12 500 cells *in vitro*, while gadolinium chelates

labeling could be detected for at least 50 000 cells. In life animal study, we found there is an eightfold sensitivity in cells labeled with iron oxide superparamagnetic nanoparticles; however, the magnetic susceptibility artifact would obscure the detail of adjacent anatomical structures. We conclude that labeling stem cells with superparamagnetic substance is more efficacious. However, the cells labeled by superparamagnetic nanoparticles might interfere with the interpretation of anatomical structure. These findings would be beneficial to applications of magnetic substances toward stem cell biology and tissue engineering.

- 9. Direct labeling of hMSC with SPIO: the long-term influence on toxicity, chondrogenic differentiation capacity, and intracellular distribution:** Chung-Yi Yang, Jong-Kai Hsiao, **Ming-Fong Tai**, Shin-Tai Chen, Hui-Ying Cheng, and Hon-Man Liu, **2010:**”, *Molecular Imaging and Biology*, V13, N3, PP.443-451, 2010): This study was to evaluate the long-term cellular toxicity, labeling efficiency, chondrogenic differentiation capacity, and intracellular distribution following direct SPIO nanoparticle labeling of *hMSCs* in the absence of transfection agents. The *hMSCs* were incubated with a SPIO, Ferucarbotran, at concentrations of 0, 1, 10, and 100 µg Fe/ml for 24 or 72 h. The cell granularity and size change, reactive oxygen species generation, and mitochondria membrane potential were measured by flow cytometry. The differentiation capacity of the cells into chondrocytes was determined by Alcian blue and Safranin-O staining, immunocytochemical analysis, and reverse transcription polymerase chain reaction. Results: The intracellular distribution of the internalized particles was visualized via confocal microscopy. No significant difference was found in the toxicity of labeled cells relative to controls. Successful chondrogenesis of Ferucarbotran-labeled *hMSCs* was confirmed. The intracellular SPIO nanoparticles were located within the lysosomes. Conclusions: In conclusion, we have demonstrated the feasibility of direct labeling with Ferucarbotran without impairment of cellular function, toxicity, or inhibition of differentiation capacity. Furthermore, lysosomal metabolism takes place after intracellular uptake of Ferucarbotran.
- 10. Mechanism of Cellular Uptake and Impact of Ferucarbotran on Macrophage Physiology** (Chung-Yi Yang, Ming-Fong Tai, Chih-Peng Lin, Chen-Wen Lu, Jaw-Lin Wang, Jong-Kai Hsiao and Hon-Man Liu, **PLoS ONE**, **V6**, issue 9, e25524, 2011): SPIO nanoparticles are contrast agents used for magnetic resonance imaging. Ferucarbotran is a clinically approved SPIO-coated carboxydextran with a diameter of about 45–60 nm. We investigated the mechanism of cellular uptake of Ferucarbotran with a cell model using the murine macrophage cell line Raw 264.7. We observed a dose-dependent uptake of these SPIO particles by spectrophotometer analysis and also a dose-dependent increase in the granularity of the macrophages as determined by flow cytometry. There was a linear correlation between the side scattering mean value and iron content (P,0.001, R2 = 0. 8048). For evaluation of the endocytotic pathway of these ingested SPIO particles, different

inhibitors of the endocytotic pathways were employed. There was a significant decrease of side scattering counts in the cells and a less significant change in signal intensity based on magnetic resonance in the phenylarsine oxide-treated macrophages. After labeling with SPIO particles, the macrophages showed an increase in the production of reactive oxygen species at 2, 24, and 48 h; a decrease in mitochondrial membrane potential at 24 h; and an increase in cell proliferation at 24 h. We concluded that Ferucarbotran was internalized into macrophages via the clathrin mediated pathway and can change the cellular behavior of these cells after labeling.

B. $\text{RuSr}_2\text{RCu}_2\text{O}_8$ 與 $\text{SmFeAsO}_{1-x}\text{F}_x$ 磁性超導系列

- 1. Anisotropic Magnetic & Superconducting Properties of Aligned Weak-ferromagnetic Superconductor $\text{RuSr}_2\text{GdCu}_2\text{O}_8$** (H. C. Ku*, B. C. Chang, C. H. Hsu, Y. F. Chen, and M. F. Tai, *J. Phys.: Conf. Ser.* **150**, pp.052131-052134, 2009): The $\text{RuSr}_2\text{GdCu}_2\text{O}_8$ Ru-1212 cuprate is a weak-ferromagnetic superconductor with a magnetic ordering of Ru moments at $T_N(\text{Ru}) = 131$ K, a superconducting transition in the CuO_2 layers at $T_c = 56$ K, and a low temperature Gd antiferromagnetic ordering at $T_N(\text{Gd}) = 2.5$ K. The c -axis aligned powder can be achieved at room temperature using the field-rotation method where the tetragonal c -axis is perpendicular to the aligned magnetic field B_a and along the rotation axis. The anisotropic temperature dependence of magnetic susceptibility for the aligned powder down to 2 K indicates weak anisotropy with $\chi_c > \chi_{ab}$ at room temperature due to strong anisotropic Gd contribution and $\chi_c < \chi_{ab}$ below 185 K where strong Ru anisotropic short-range exchange interaction overtakes the Gd contribution. Anisotropic diamagnetic superconducting intragrain shielding signal of aligned microcrystalline powder-in-epoxy below vortex lattice melting temperature at 39 K in 1-G field is much weaker than the intergrain polycrystalline bulk sample signal due to the small grain size ($d \sim 1\text{-}10 \mu\text{m}$), long penetration depth ($\lambda_{ab} \sim 0.6 \mu\text{m}$, $\lambda_c \sim 2 \mu\text{m}$) and the two-dimensional (2D) character of CuO_2 layers.
- 2. Anisotropic Microcrystalline Powder Alignment of the Weak-ferromagnetic Superconductor System $\text{RuSr}_2\text{RCu}_2\text{O}_8$ (R = Pr, Nd, Sm, Eu, Gd, $\text{Gd}_{0.5}\text{Dy}_{0.5}$)** (B. C. Chang, C. H. Hsu, M. F. Tai, Y. Y. Hsu, and H. C. Ku, *J. Phys.: Conf. Ser.* **150**, p.052033-p.052037, 2009): The powder alignment method is used to investigate the anisotropic physical properties of the weak-ferromagnetic superconductor system $\text{RuSr}_2\text{RCu}_2\text{O}_8$. Due to weak magnetic anisotropy of this tetragonal system, partially c -axis aligned microcrystalline powder (diameter $\sim 1\text{-}10 \mu\text{m}$) in epoxy can be obtained only for R = Eu and Gd through the field-rotation powder alignment method where c -axis is perpendicular to the aligned magnetic field $B_a = 0.9$ T and parallel to the rotation axis. For smaller rare earth compound R = $\text{Gd}_{0.5}\text{Dy}_{0.5}$, powder alignment can be achieved using the simple field powder alignment method where c -axis is partially aligned along the aligned

magnetic field. No powder alignment can be achieved for larger rare earths $R = \text{Pr}, \text{Nd}$ or Sm due to the lack of magnetic anisotropy in these compounds. We have discussed the aligned mechanism of powder at room temperature using the spin-orbital-related anisotropic paramagnetic susceptibility and the low temperature anisotropic physical properties of $\text{RuSr}_2\text{RCu}_2\text{O}_8$.

3. **Angular dependence of x-ray absorption spectrum for field-aligned iron-based superconductors** (B. C. Chang, Y. B. You, T. J. Shiu, **M. F. Tai**, H. C. Ku*, Y. Y. Hsu, L. Y. Jang, J. F. Lee, Z. Wei, K. Q. Ruan, and X. G. Li, *Phys. Rev. B* 80, P.165108-165111, 2009): Anisotropic Fe K-edge and As K-edge X-ray absorption near edge spectrum (XANES) measurements on superconducting ($T_c = 52$ K) $(\text{Sm}_{0.95}\text{La}_{0.05})\text{FeAs}(\text{O}_{0.85}\text{F}_{0.15})$ field-aligned microcrystalline powder are presented. The angular dependence of Fe pre-edge peak (dipole transition of Fe-1s electrons to Fe-3d/As-4p hybrid bands) relative to the tetragonal ab -plane of aligned powder indicates larger density of state (DOS) along the c -axis, and is consistent with the LDA band structure calculation. The anisotropic Fe K-edge spectra exhibit a chemical shift to lower energy compared to FeO which are closely related to the itinerant character of Fe^{2+} -3d⁶ orbitals. The anisotropic As K-edge spectra are more or less the mirror images of Fe K-edge due to the symmetrical Fe-As hybridization in the FeAs layer. Angular dependence of As main peak (dipole transition of As-1s electrons to higher energy hybrid bands) was observed suggesting character of As-4d e_g orbitals.
4. **Anisotropic Structural & Magnetic Properties of the Filed-Aligned Superconducting System $\text{SmFeAsO}_{1-x}\text{F}_x$ ($x = 0, 0.1, 0.2, 0.25$ and 0.3)** (Y. B. You, T. K. Hsiao, B. C. Chang, **M. F. Tai**, Y. Y. Hsu, H. C. Ku*, Z. Wei, K. Q. Ruan, and X. G. Li, *J. Phys.: Conf. Ser.* **V273**, 012109, 2011):

Anisotropic structural and magnetic properties of the field-aligned superconducting system $\text{SmFeAsO}_{1-x}\text{F}_x$ ($x = 0, 0.1, 0.2, 0.25$ and 0.3) are reported. Due to the Fe spin-orbital related anisotropic exchange coupling, all the tetragonal microcrystalline powders in epoxy were aligned at room temperature using the field-rotation method where the tetragonal ab -plane is parallel to the magnetic alignment field B_a of 0.9 T and the c -axis parallels to the rotating axis. Anisotropic magnetic properties are studied through low temperature magnetic measurements along the c -axis and paralleled to the ab -plane of aligned samples in both zero-field-cooled (ZFC) and field-cooled (FC) modes. The under-doped compound ($x = 0.1$) is not superconducting with an antiferromagnetic Néel temperature $T_N \sim 40$ K, while the two optimum-doped compounds ($x = 0.2$ and 0.25) show high superconducting transition temperatures T_c of 49K and 50K, respectively. The variation of anisotropic structural and magnetic properties for this system are discussed and compared with the previously reported 52 K anisotropic superconductor $\text{Sm}_{0.95}\text{La}_{0.05}\text{FeAsO}_{0.85}\text{F}_{0.15}$.

C. 其他氧化物材料:

1. **Transport and magnetic properties of Mn-doped $\text{MgIn}_{2-x}\text{O}_4$** (M. W. Lee*, **M. F. Tai**, S.

H. Chiou, **2008**: *J. of Alloys and Compounds*, 461 (2008) 316–320.): Transport and magnetization of $\text{Mg}(\text{In}_{2-x}\text{Mn}_x)\text{O}_4$ polycrystalline pellets ($0 < x < 0.55$) have been measured from 2 to 300 K. The doping MgIn_2O_4 with Mn results in an increase in electrical resistivity and a decrease in electron concentration. The electrical resistivity increases with decreasing temperature throughout the temperature range and variable-range hopping is observed at low temperatures. The diamagnetic pure MgIn_2O_4 changes to paramagnetic after doping. The paramagnetism of the doped samples obeys the Curie–Weiss law. The magnetic-field dependence of the magnetization of the doped samples can be well described by the Brillouin function.

2. Photovoltaic Performance of New-Structure ZnO-nanorod Dye-Sensitized Solar Cells

(M. H. Lai¹, M. W. Lee, Gou-Jen Wang and M. F. Tai, **2011**., *Int. J. Electrochem. Sci*, **V6**, pp.2122-2130, 2011): Currently, the photoelectrode of nanorod-based dye-sensitized solar cells (DSSCs) consists of nanorods grown on a transparent conducting layer (TCO) substrate. This work presents a new structure for nanorod DSSCs. ZnO nanorods and a ZnO film were cogrown using a one-step chemical-vapor deposition method. The ZnO film functioned as the TCO of the DSSC. The ZnO nanorod/ZnO film structure was sensitized with D149 or N719 dye and assembled into a DSSC. Two notable features in this new DSSC structure are: (1) the junction between the TCO film and the nanorods is completely eliminated; (2) the TCO and the photoelectrode are made of the same material. Testing showed that under AM1.5 illumination, a short current density of 15.7 mA/cm^2 and a power conversion efficiency η of 1.82% can be achieved. The η is more than two times higher than the η reported earlier for ZnO-nanorod DSSCs with the same structure.

3. Growth of ZnO nanorods on ordinary glass substrate using chemical vapor deposition without catalyst:

ZnO has some special optical properties, such as high UV emission and field emission. Previous works mainly investigated the growth technologies of ZnO nanorods on silicon substrates. In this study, we have developed a rather simple and economic chemical vapor deposition technique to successfully grow well-aligned ZnO nanorods on ordinary glass without using catalyst. We heated Zn powder at 600°C and glass substrate temperatures at 450°C under a flowing Ar gas (~ 2 torr). The distance between Zn metallic powder and glass substrate was set to ~ 2 cm. Our experimental results showed that the morphologies of our ZnO nanorods are controlled by the process parameters of both reaction time (20-40 min) and the Ar flowing rate (50-500 sccm). X-ray diffraction patterns show only a rather sharp diffraction peak of (0002) plane. The result indicated that our ZnO nanorods have hexagonal structure and exhibit a perfect orientation. The scanning electron images of our ZnO nanorods showed a well-aligned configuration with an aspect-ratio of 60 when the growing times of ~ 30 min and a Ar flowing rate of ~ 400 sccm. Room-temperature photoluminescence measurements appear that ZnO nanorods exhibit strong ultraviolet (UV) emission at 385nm and reduce the

emission of green light.

D. 磁性微波陶瓷材料：有 YIG 微波陶瓷和 Fe_xN 吸波兩系列磁性材料研發與其特性研究

1. $(\text{Y}_{3-x}\text{Gd}_x)\text{Fe}_5\text{O}_{12}$ 和 $\text{Y}_3(\text{Al}_{5-y}\text{Fe}_y)\text{O}_{12}$ 系列石榴石(Garnet, YIG)系列材料:

本系列材料具 $\text{Y}_3\text{Fe}_5\text{O}_{12}$ 母化合物之立方晶格結構，空間群為 $Ia3d$ ，因具有下列等特性：(1)高的金屬離子取代性，(2)在微波頻率範圍的介電損耗低、(3)可透過金屬離子的摻雜效應調變其飽和磁化強度 M_s 值，且(4)具窄的鐵磁共振線寬 ΔH 和自旋波線寬(自旋波損耗的參量) ΔH_K 等，故使之擁有寬廣且優異的微波與磁性調變特性，因而成為高功率低頻段微波元件製作的關鍵性材料。但因其燒結溫度高、溫度穩定性較差，且應用於較低微波頻段時，其飽和磁化強度 M_s 值稍顯過高。故我們有系統研製以不同元素取代 Gd 和 Fe 元素而得之 $\text{YFe}_5\text{O}_{12}$ 系列樣本，探討其物理和微波性質，使其也能應用於低頻微波波段元件的製作。我們製備之材料的微波特性，優於目前市售之微波循環器內所使用的商品化 YIG 微波鐵氧體材料。本研究目前完成了下列不同元素摻雜之石榴石系列的陶鐵磁材料研製：

- (1) Gd 離子-摻雜 $(\text{Y}_{3-x}\text{Gd}_x)\text{Fe}_5\text{O}_{12}$ 系列 ($x = 0 - 3$)
- (2) Al-摻雜 $\text{Y}_3(\text{Al}_y\text{Fe}_{5-y})\text{O}_{12}$ 系列 ($y = 0 - 2.5$)
- (3) Ca, Sn-摻雜 $(\text{Y}_{3-3x-z}\text{Gd}_{3x}\text{Ca}_z)(\text{Fe}_{5-5y-z-5e}\text{Al}_{5y}\text{Sn}_z)\text{O}_{12}$ 系列

測量結果證實我們所研製的材料經由適當的成分控制和樣品製備條件控制，能成功地製備用於磁性微波元件所需的磁性材料規格，如下所列：

- (1) 參考市售之 Trans-Tech G-250 陶鐵磁性材料之規格
- (2) 介電常數(Dielectric constant)： $\epsilon_r \sim 13.0 \pm 3$
- (3) 飽和磁化強度(Saturation magnetization)： $4\pi M_s = 250 \text{ G} \pm 50 \text{ G}$
- (4) 正切損耗(Loss tangent)： $\tan\delta < 0.005$
- (5) 藍道 g-因數(Landé g-factor)： $g \sim 2.0 \pm 0.2 @ 10 \text{ GHz}$

X 光繞射實驗證實所有樣本形成立方結構的石榴石化合物，材料的晶格參數經數據計算得約為 1.24 nm 左右。室溫直流磁滯曲線實驗結果顯示所有樣本呈現優異的軟磁性，矯頑力介於 1.7 G ~ 333.1 G，殘餘磁化強度介於 0 ~ 3 emu/g。室溫的飽和磁化強度($4\pi M_s$)隨釷含量(x)增加，呈現非常線性的遞減變化： $4\pi M_s(x) = a + \alpha x$ ， $a = 1636.9 \pm 8.2 \text{ G}$ ， $\alpha = -529.0 \pm 4.2 \text{ G/Gd}$ 。隨釷含量增加， $4\pi M_s$ 從 1122 G (當 $x = 1$)遞減至 50 G (當 $x = 0$)。在外加磁場 $H = 1\text{T}$ 時，溫度範圍 2K~350K 內，所有 $x > 0.5$ 之摻雜樣本的 $M_s(T)$ 呈現 N 型的曲線變化，曲線中可獲得有一磁性抵消點溫度 T_d ，此溫度點則隨著 Gd 的取代量增加，從 63.9 K ($x = 1.0$)線性地增加至 292.9 K ($x = 3.0$)。

本研究中除深入探討晶格結構和磁性特性，並進一步探討這些特性對其微波應用的影響。實驗結果顯示在 $f = 0.01 \sim 1.8 \text{ GHz}$ 波段，此系列材料之介電常數實部值 ϵ' 隨 Gd 含量不同，分別介於 5 ~ 14 之間。在 $f = 0.01 \sim 0.30 \text{ GHz}$ 較低頻段時，介電耗損 $\epsilon'' \sim 10^{-3}$ ；但當微波頻率提高到 0.3 ~ 1.8 GHz 時， ϵ'' 雖漸增至 3×10^{-2} ，但卻比市售的商品材料低。 $x = 1.6$ 樣品和市售微波元件所使用之 YIG 材料的電子自旋共振(ESR)實

驗測得兩材料的蘭德常數(Landé g-factor)都接近 2，顯示材料中的磁性自旋主要來自自由電子的自旋貢獻。

此外，也利用固態粉末反應法法製備鋁摻雜之 $Y_3(Al_{5-y}Fe_y)O_{12}$ 石榴石(Al-doped YIG)微波陶鐵磁材料。X光粉末繞射實驗證實我們的樣品具有和母化合物 $Y_3Fe_5O_{12}$ 相同的立方晶格結構和空間群為 $Ia3d$ 。研究中，我們以震盪樣品磁化儀(VSM)量測材料的室溫直流磁性性質，以高解析度場發射電子微探儀(FE-EPMA)分析材料的成分；並以HP-4291B阻抗分析儀測量材料在微波波段的介電常數隨頻率的變化曲線。FE-EPMA 半定量成分分析證實樣本內含有Al、Fe 和 Y等成分。磁性測量結果發現Al的摻雜量太高，會使材料的矯頑力變大，飽和磁化強度下降，且不再呈現軟磁性質，使之不適合作為微波循環器所需的陶鐵磁材料。高頻阻抗測量結果顯示，此系列材料之介電常數的實部值介於5~14之間。電磁波頻率在10 ~ 300 MHz時，介電耗損(loss tangent)僅約為 10^{-2} ；但當微波頻率為0.3 ~ 1.8 GHz時，則逐漸增高至0.2。

2. 高性能奈/微米氮化鐵 Fe_xN 微波吸波材料研製：

奈/微米氮化鐵材料因同時具有好的微波吸波特性、寬的吸收頻帶、抗環境腐蝕、耐磨損、耐高溫、與紅外光吸收材料相容性佳等等特色。此外，用於作吸波塗層時，具層薄質輕的效益、並具降低塗敷工藝難度、延長老化壽限、生命週期長等優勢，使其具有成為高效能微波吸收材料的高度潛力。過去雖有不少研究團隊從事Fe-N薄膜的研究開發，但 Fe_xN 系列的粉體研究團隊和成果卻相當有限，故近一年來，我們進行了此磁性氮化鐵材料的製程與特性研究的評估，完成了下列幾項成果：

- (1) 建立研製氮化鐵所需之前驅物奈/微米鐵粉和氧化鐵的合成技術：已完成粒徑低於 20 nm 的氧化鐵奈米粒的研製和其基本物性測量。
- (2) 完成氮化鐵吸波微粒之乾式製程系統及試製製程的建立。
- (3) 完成高磁性氮化鐵吸波劑小批量生產製程技術。