



Hector Mario Henao Zapata

Ingeniero de Minas y Metalurgia (Universidad Nacional - Colombia)

Master of Engineering (Tohoku University, Japón)

Doctor of Engineering (Tohoku University, Japón)

Área de especialización: Investigación y desarrollo de una manera económica y ambientalmente sostenible de procesos Pirometalúrgicos de metales no ferrosos y termodinámica de aleaciones metálicas.

Asignaturas dictadas: Pirometalurgia

- Conocimiento especializado en físico-química de materiales tanto en investigación fundamental como aplicada.
- Educador en Australia y conferencista en eventos internacionales.
- Más de 60 publicaciones y reportes de investigaciones para la industria sobre procesos metalúrgicos de Cu, Ni, Pb, Zn, As, In, Ge, metales preciosos, hierro fundido y aleaciones metálicas para soldadura de materiales electrónicos.
- Experto en paquetes de programas de simulación de procesos termodinámicos y cinética como FactSage, Thermo-Calc y DICTRA.
- Ganador del premio internacional, "International Award-winner, TMS Extraction & Processing Science Award 2010".

Empleo, Industrial y Educativas Credenciales

2014. Universidad Tecnica Federico Santa Maria (Chile)-Académico Tiempo Completo-Ingeniería Metalúrgica y de Materiales.

2006-2012. Universidad de Queensland (UQ-Australia) - "Senior Research Fellow"-PYROSEARCH-Facultad de Ingeniería Química

2012-2013. Universidad de Queensland (UQ-Australia)- "Senior Research Fellow"-Centro de investigación para la fabricación de materiales electrónicos (CMEM-NS)-Facultad de Minas, Mecánica y Materiales-Departamento de materiales

2003-2006. Universidad de Tohoku, Japón - Research Associate-Graduate School of Engineering

2000-2003. PhD en Metalurgia-Graduate School of Engineering – Universidad Tohoku, Japón
Tesis "Fase de equilibrio entre Ni-S/Ni-Fe y escoria relacionado a la fundición de níquel"

1998-2000. M.Sc., metalurgia Graduate School of Engineering – Universidad Tohoku, Japón
Tesis "Distribución de elementos menores entre aleaciones de Fe-Ni aleación y escorias con base de MgO"

1993-1998. Industria – INGEOMINAS, Colombia - Coordinador del proyecto

1990-1993. Industria – EREESA, Colombia - ingeniero metalúrgico

1983-1989. Licenciado en ingeniería metalúrgica y minera – Universidad Nacional-Colombia
Tesis " Producción de sulfato de manganeso a partir de una mena de manganeso"

Investigaciones

Proyectos como Research Fellow (investigador asociado): Australia Research Council (ARC-Linkage Project)

Nombre del proyecto: "Fundamental Experimental and Modelling Studies of Slag/Matte/Metal/Gas Systems In Support Of Sustainable Copper smelting And Converting Technologies".

Proyecto patrocinado por Rio Tinto / KUCC, Xstrata Cu (Mount Isa operación), BHP Billiton (Olympic Dam operación), Xstrata Technology, Outotec Oy

Proyectos industriales patrocinados por las partes interesadas de Japón, México y Chile

Nombre del proyecto: -"Investigation of Phase Equilibria of Cu smelting slags. CODELCO Chile". (December 2006 – July 2007)

Nombre del proyecto:-"Investigation of Phase Equilibria of Cu smelting slags of interest to Sumitomo Metal Mining Co., Ltd., Japan" (October 2010 – April 2011)

Nombre del proyecto:-"Research on phases and partitioning of silver and major elements in granulated lead blast furnace slag at CIDT Peñoles". PEÑOLES R&D Centre-PeñolesAddress: Prol. Comonfort s/n Antigua Aduana Col.

Nombre del proyecto:-"Construction of the Operating Phase Diagram for a Flash Smelter Furnace. Tamano Smelter, Japan" (June 2007 – November 2007)

Publicaciones

45 publicaciones relacionadas con el procesamiento de minerales y fundición de Cu , Ni, Pb , Zn , As y metales preciosos.

Publicaciones en Revistas Científicas Internacionales

- (1) **Hector M. Henao**, Chisato Masuda, Kazuhiro Nogita, Tin recovery from wave solder dross, Submitted to International Journal of Mineral Processing (January 2014)
- (2) **Hector M. Henao**, Akira Sugiyama and Kazuhiro Nogita, Comparison of solidification behavior between in-situ observation and simulation of Fe-C-Si system, submitted to Journal of Metals and Alloys (January 2014)
- (3) **Hector M. Henao**, Microstructure Control of Sn-Cu-Ni alloys for Pb-free solder applications, to be submitted to Journal of Metals and alloys (in preparation 2014)
- (4) Johto Hannu, **Hector M. Henao**, Evgueni Jak, Pekka Taskinen Experimental study on the phase diagram of the Fe-O-S system Hannu, Metallurgical and Materials Transactions B (2013)
- (5) X. Xu, **H. M. Henao**, P. C. Hayes and E. Jak, Experimental Study Of Phase Equilibria In The "SnO"-SiO₂-"FeO" System At Silica Saturation, And Fixed Oxygen Partial Pressures At 1473 K , International Journal of Materials Research, approved
- (6) Taufiq Hidayat, **Hector Henao Zapata**, Peter Hayes, and Evgueni Jak, "Phase Equilibria Studies of the Cu-Fe-O-Si System in Equilibrium with Air and with Metallic Copper", Metallurgical and Materials Transactions B, 43B (2012) 1034-1045

- (7) Taufiq Hidayat, **Hector Henao Zapata**, Peter Hayes, and Evgueni Jak, "Phase Equilibria Studies of Cu-O-Si Systems in Equilibrium with Air and with Metallic Copper, and Cu-Me-O-Si Systems (Me = Ca, Mg, Al, and Fe) in Equilibrium with Metallic Copper", *Metallurgical and Materials Transactions B*, 43B (2012) 1290-1299
- (8) Hiroyuki Ohno, **Hector M. Henao** and Kimio Itagaki, "Effect of Al₂O₃ or MgO on Liquidus Line in the FeOX Corner of FeOX-SiO₂-CaO System at 1523 K under Various Oxygen Partial Pressures", *High Temperature Processes*, 30B (2011) 333-338
- (9) **Hector M. Henao**, Claudio Pizarro, Jonkion Font, Alex Moyano, Peter C. Hayes, and Evgueni Jak, "Phase Equilibria of "Cu₂O"-FeO"-CaO-MgO-Al₂O₃ Slags at PO₂ of 10^{-8.5} atm in Equilibrium with Metallic Copper for a Copper Slag Cleaning Production", *Metallurgical and Materials Transactions B*, 41B, (2010) 1186-1193
- (10) **H. M. Henao**, C. Nexhip, D. P. George-Kennedy, P. C. Hayes, E. Jak, "Investigation of Liquidus Temperatures and Phase Equilibria of Copper Smelting Slags in the FeO-Fe₂O₃-SiO₂-CaO-MgO-Al₂O₃ System at PO₂ 10⁻⁸ atm", *Metallurgical and Materials Transactions B*, 41B (2010) 767-779.
- (11) Stanko Nikolic, **Hector Henao**, Peter C. Hayes and Evgueni Jak, "Phase Equilibria in Ferrous Calcium Silicate Slags Part II, "Evaluation of Experimental Data and Computer Thermodynamic Models", *Metallurgical and Materials Transactions B*, 39B (2008) 190-199
- (12) **Hector M. Henao** and Kimio Itagaki, "Activity and Activity Coefficient of Iron Oxides in the Liquid FeO-Fe₂O₃-CaO-SiO₂ Slag Systems at Intermediate Oxygen Partial Pressures", *Metallurgical and Materials Transactions B*, 38B (2007) 769-780
- (13) **Hector M. Henao** and Kimio Itagaki, High Temperature Phase Relations in FeOX (X=1 and 1.33)-CaO-SiO₂ Systems under Various Oxygen Partial Pressure, *Materials Transactions, JIM*. Vol. 46, No. 4(2005) 812-819.
- (14) L. Voisin, **Hector M. Henao**, Mitsuhisa Hino and K. Itagaki: Phase Relations, Activities and Minor Elements Distribution in Fe-Pb-As and Fe-Pb-Sb Systems Saturated with Carbon at 1473 K. *Mater. Trans. JIM* Vol. 46, No. 12 (2005), 3030-3036.
- (15) L. Voisin, **Hector M. Henao** and K. Itagaki: Phase Relations and Distribution of Some Minor Elements in Fe-Cu-Sb System Saturated with Carbon at 1473 K. *Mater. Trans. JIM*, Vol. 46, No. 1 (2005) 74-79.
- (16) **Hector M. Henao** and Kimio Itagaki: Phase Equilibrium and Distribution of Minor Elements between Ni-S Melt and Al₂O₃-CaO-MgO Based slag at 1873 K, *Metall. Trans. B*. Vol. 35B (2004) 1041-1049.
- (17) L. Voisin, **Hector M. Henao** and K. Itagaki: Phase Relations and Distribution of Some Minor Elements in Fe-Cu-As System Saturated with Carbon at 1473 K. *Mater. Trans. JIM*, Vol. 45, No. 9 (2004) 2851-2856.
- (18) **Hector M. Henao**, Mitsuhisa Hino and Kimio Itagaki: Phase Equilibrium between Ni-S Melt and CaO-Al₂O₃ Based slag in CO-CO₂-SO₂ gas mixtures at 1773 K, *Mater. Trans. JIM*, Vol. 43(2002) 2873-2879.
- (19) **Hector M. Henao**, Mitsuhisa Hino and Kimio Itagaki: Phase Equilibrium between Ni-S Melt and FeOX-SiO₂ or FeOX-CaO Based Slag under Controlled Partial Pressures, *Mater. Trans. JIM*, Vol. 43, No. 9 (2002) 2219-222.
- (20) **Hector M. Henao**, Mitsuhisa Hino and Kimio Itagaki: Phase Equilibrium between Ni-S Melt and CaO-Al₂O₃ Based slag in CO-CO₂-SO₂ gas mixtures at 1773 K, *Mater. Trans. JIM*, Vol. 43, No. 11 (2002) 2873-2879.
- (21) **Hector M. Henao**, Mitsuhisa Hino and Kimio Itagaki: Distribution of Ni, Cr, Mn, Co and Cu Between Fe-Ni Alloy and FeOX-MgO-SiO₂ Base Slags, *Mater. Trans. JIM*, Vol. 42, No. 9 (2001) 1959-1966.
- (22) L. Voisin, **Hector M. Henao** and K. Itagaki: Phase Relations and Distribution of Some Minor Elements in Fe-Cu-As System Saturated with Carbon at 1473 K. *Mater. Trans. JIM*, Vol. 45, No. 9 (2004) 2851-2856.
- (23) L. Voisin, **Hector M. Henao** and K. Itagaki: Phase Relations and Distribution of Some Minor Elements in Fe-Cu-Sb System Saturated with Carbon at 1473 K. *Mater. Trans. JIM*, Vol. 46, No. 1 (2005) 74-79.

- (24) L. Voisin, Hector M. Henao, Mitsuhisa Hino and K. Itagaki: Phase Relations, Activities and Minor Elements Distribution in Fe-Pb-As and Fe-Pb-Sb Systems Saturated with Carbon at 1473 K. Mater. Trans. JIM Vol. 46, No. 12 (2005), 3030-3036.

Papers en preparación a pronta presentación

- (1) **H. M. Henao**, G. Richards, P. C. Hayes and E. Jak, "Indium partitioning between lead bullion and slag at selected process conditions (Partially published on Pb-Zn 2010, Vancouver).
- (2) **H. M. Henao**, G. Richards, P. C. Hayes, E. Jak, "Germanium partitioning between lead bullion and slag at selected process conditions (Partially published on Pb-Zn 2010, Vancouver)"
- (3) **H. M. Henao**, P. C. Hayes, E. Jak, "Effect MgO and Al₂O₃ on Liquidus of the "FeO"-SiO₂-CaO-MgO and "FeO"-SiO₂-CaO-Al₂O₃ System at PO₂ 10⁻⁸ atm and at 1300 oC. Part II. Effect of Al₂O₃ on Liquidus"
- (4) **H. M. Henao**, P. C. Hayes, E. Jak, "Effect MgO and Al₂O₃ on Liquidus of the "FeO"-SiO₂-CaO-MgO and "FeO"-SiO₂-CaO-Al₂O₃ System at PO₂ 10⁻⁸ atm and at 1300 oC. Part I. Effect of MgO on Liquidus"
- (5) S. Acharya, **H. Henao**, E. Jak, P.C. Hayes "Phase equilibria studies on the "SnO"-Al₂O₃-SiO₂" system at tin metal saturation".

Publicaciones varias

- (1) **H. M. Henao**, L. A. Ushkov and E. Jak, "Experimental investigation of slag liquidus and minor element partitioning between slag and matte in support of the copper Isasmelt smelting process commissioning and optimisation at Kazzinc", Molten 2012, Beijing, China, 28th to 30th May (2012)
- (2) **H. M. Henao**, P. C. Hayes and E. Jak: Phase Equilibria of "Cu₂O"-FeO-SiO₂-CaO Slags at PO₂ at 10⁻⁸ atm in Equilibrium with Metallic Copper, Molten 2012, Beijing, China, 28th to 30th May (2012)
- (3) S. Nikolic, **H. Henao**, B. Zhao, P.C. Hayes, and E. Jak: Phase equilibria in the FeO-Fe₂O₃-CaO-SiO₂ slag system, TMS, Seattle, USA, 14th-18th February 2010.
- (4) **H. M. Henao**, P. C. Hayes and E. Jak, "Sulphur Capacity of the "FeO"-CaO-SiO₂ Slag of Interest to the Copper Smelting Process", Copper 2010, 6th to 10th June (2010), Hamburg, Germany.
- (5) T. Hidayat, **H.M. Henao**, P.C. Hayes, and E. Jak, "Experimental study of phase equilibria of silicate slag systems", Copper 2010, 6th to 10th June (2010), Hamburg, Germany.
- (6) **H. Henao**, B. Zhao, P. Hayes and E. Jak, "Copper Short Course on Physicochemical Properties Of Cleaning Slags, Copper 2010, 6th to 10th June (2010), Hamburg, Germany.
- (7) **H. M. Henao**, P. C. Hayes, E. Jak and G.G. Richards, "Research on Indium and Germanium Distributions Between Lead Bullion and Slag at Selected Process Conditions", Pb-Zn 2010, 03th to 06th October (2010), Vancouver, Canada
- (8) H. M. Henao, C. Nexhip, D. P. George-Kennedy, P. Hayes, E. Jak, "Investigation of Phase Equilibria Of Copper Smelting Slags in the FeO-Fe₂O₃-SiO₂-CaO-MgO-Al₂O₃ System at Fixed Oxygen Potential: Molten 2009, VIII International Conference on Molten Slags, Fluxes and Salts, 17th to 21th January (2009), Santiago, Chile.
- (9) H. M. Henao, C. Pizarro, J. Font, A. Moyano, P. Hayes and E. Jak, "Phase Equilibria of Fayalite-Based Slags for the Slag Cleaning Process in Copper Production", Molten 2009, VIII International Conference on Molten Slags, Fluxes and Salts, 17th to 21th January (2009), Santiago, Chile.
- (10) E. Jak, S. Nikolic, B. Zaho, H. M. Henao and P. C. Hayes, "Liquidus Temperatures in Calcium Ferrite Slags Equilibrated with Molten Copper at Fixed Oxygen Partial Pressures".: The Carlos Diaz Symposium on Pyrometallurgy, TMS, Proceeding, 25th to 30th, August, (2007) 93-111, Toronto, Canada

- (11) Hector M. Henao and Kimio Itagaki: Activity and Activity Coefficient of Iron Oxides in the Liquid FeOx-CaO-SiO₂ Slag Systems at Intermediate Oxygen Partial Pressures, Proceedings of the Sohn International Symposium, TMS, Aug. 27-31, 2006, San Diego, USA
- (12) Hector M. Henao, Katsunori Yamaguchi and Shigeru Ueda: Distribution of Precious Metals (Au, Pt, Pd, Rh and Ru) between Copper Matte and Iron- Silicate Slag at 1573 K ,Proceedings of the Sohn International Symposium, TMS, Aug. 27-31, 2006, San Diego, USA.
- (13) Hector M. Henao, Hiroyuki Ohno and Kimio Itagaki: Effect of Al₂O₃ or MgO Addition on Liquidus of FeOx Corner in FeOx-SiO₂-CaO Slag at 1250 and 1300 oC, Proceedings of the Sohn International Symposium, TMS, Aug. 27-31, 2006, San Diego, USA.
- (14) L. Voisin, Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Phase Relations and Distribution of Precious Metals in Pb-Fe-As and Pb-Fe-Sb Systems Saturated with Carbon, Proceedings of the The Lead and Zinc 05 International Symposium, Oct. 17-19, 2005, Kyoto, Japan.
- (15) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Effect of Al₂O₃ and MgO Addition on Liquidus of FeOx Corner in FeOx-SiO₂-CaO Slag at 1573 K, Materials and Resources, Spring Symposium, 2005, Tokyo, Japan.
- (16) Hector M. Henao, Florian Kongoli, Kimio Itagaki: Experimental Investigation of Phase Relations in the FeOx-CaO-SiO₂ Base Slags at Different Oxygen Partial Pressures, Proceeding of REWAS` 2004 Global Symposium on Recycling, Waste Treatment and Clean Technology, September, 2004, Madrid, Spain, pp. 2589-2599.
- (17) Leandro Voisin, Hector M. Henao and Kimio Itagaki: Phase Relations and Distribution of Some Minor Elements in Fe-Cu-As and Fe-Cu-Sb Systems Saturated with Carbon at 1473 K. Proceeding of REWAS` 2004 Global Symposium on Recycling, Waste Treatment and Clean Technology, September, 2004, Madrid, Spain, pp. 2569-2579.
- (18) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Phase Relations in the FeOx-CaO-SiO₂ Slag under Different Partial Pressure, Materials and Resources, Autumn Symposium, 2004, Morioka, Japan.
- (19) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Phase Equilibrium and Distribution of Minor Elements between Al₂O₃-CaO-MgO Based Slags and Ni-S Melt, Materials and Resources, Autumn Symposium, 2003, Ube, Japan.
- (20) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Distribution of Minor Elements between Ni-S Melt and Al₂O₃-CaO-MgO Slag at 1873 K, Proceedings of Yazawa International Symposium on Metallurgical and Materials Processing, TMS, March, 2003, San Diego, USA, pp.329-340.
- (21) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Phase Equilibrium between Ni-S Melt and Slags under Controlled Partial Pressures, Proceedings of the Third International Sulfide Smelting Symposium, TMS, Feb.2002, Seattle, USA, pp.523-531.
- (22) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Phase Equilibrium between Ni-S and Slag under Controlled Partial Pressure of SO₂, Materials and Resources, Materials and Resources, Autumn Symposium, 2001, Japan, Sapporo
- (23) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Equilibrium Between Nickel Alloy Containing Minor Elements and FeOx-MgO-SiO₂ Slags, Proceedings of the Second International Conference on Processing Materials for Properties, TMS-MMIJ, Nov., 2000 San Francisco, USA, pp.857-862.
- (24) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Effect of Al₂O₃ or CaO addition on the Distribution of Chromium and Copper between FeOx-MgO-SiO₂., Materials and Resources, Spring Symposium, 2000. Tokyo, Japan.
- (25) Hector M. Henao, Mitsuhsa Hino and Kimio Itagaki: Distribution of Cr between Ni Alloy and FeOx-MgO-SiO₂ Base Slags. Materials and Resources, Spring Symposium, 1999, Tokyo, Japan.
- (26) Recovery of Precious Metals From Vein-Type Complex ores (International Seminar on the Improvement of Recovery of precious Metals and Pollution Control) INGEOMINAS-Cali, Colombia. Feb. 1996.

Reportes Industriales

Los objetivos de estos trabajos fueron mejorar la operación de los smelters en términos de recuperación de metales valiosos y preservación de la integridad de los refractarios de los hornos. Los parámetros evaluados incluyen composición de la escoria y temperatura del proceso.

- (1) Investigation of Phase Equilibria and Viscosities of Smelting Slag for a Flash Smelting Furnace. Technical Services (Smelter) Kennecott Utah Copper LLC, PO Box 6001, Magna, Utah, 84044-6001.
- (2) The Effect of As, SiO₂ and SO₂ on the Stability of Accretions Forming above Slag Surface in the Flash Converting Furnace. Technical Services (Smelter) Kennecott Utah Copper LLC, PO Box 6001, Magna, Utah, 84044-6001.
- (3) Structural Analysis of Complex Accretions in the Flash Converter. Technical Services (Smelter) Kennecott Utah Copper LLC, PO Box 6001, Magna, Utah, 84044-6001.
- (4) Investigation of Phase Equilibria of Cu smelting slags. CODELCO Chile.
- (5) Construction of the Operating Phase Diagram for a Flash Smelter Furnace. Tamano Smelter, Japan.
- (6) Research on Indium and Germanium Distributions Between Lead Bullion and Slag at Selected Process Conditions. Teck Cominco Research, Teck Cominco Trail Metallurgical Operations
- (7) Research of Ni sulphide smelting Isasmelt slag and matte phase equilibria. X'strata Technology.
- (8) Analysis of Iron Content in Blister Copper from Equilibrium Experiments. Olympic Dam, BHP Billiton.
- (9) Research on phases and chemical partitioning in the Electric Furnace at Olympic Dam, BHP Billiton December 2009 – March 2010
- (10) Investigation of Phase Equilibria of Cu smelting slags of interest to Sumitomo Metal Mining Co., Ltd., Japan (October 2010 – April 2011)
- (11) Experimental investigation of liquidus and minor elements partitioning between slag, matte and gas in support of the Cu Isasmelt smelting process at Kazzinc, Kazzinc Ltd, 1, Promyshlennaya Street, Ust-Kamenogorsk, 070002, East Kazakhstan Oblast, Republic of Kazakhstan, August 2011.
- (12) Research on phases and partitioning of silver and major elements in granulated lead blast furnace slag at CIDT Peñoles. PEÑOLES R&D Centre-PeñolesAddress: Prol. Comonfort s/n Antigua Aduana Col. Luis Echeverria
- (13) Research on phases and partitioning of major elements in granulated and pot Flash Smelting Slag at Kennecott Utah Copper (KUC LLC) February – August 2011.