

Research Activities of KRISS 2016 – 2020

- Acoustic gas thermometry in the temperature range from – 40 °C and 120 °C, report being prepared
- Microwave resonance measurement techniques in acoustic gas thermometry
- Gas metrology for thermometry applications including argon isotopes for primary thermometry, oxygen purity and neon isotopes for ITS-90
- Thermocouple thermometry: Ni freezing/melting cell, mini multi-fixed-point cell, inhomogeneity of type B thermocouples
- Humidity sensors for upper-air measurement (low temperature, low DP and low pressure)
- Metrology for meteorology: radiosonde calibrations, solar irradiation correction, novel techniques for humidity measurements
- Radiation thermometry: spectral responsivity measurement
- Thermophysical quantities: high-temperature guarded hot plate, large-area heat flow meter, laser flash method, transient hot wire method, gas calorimetry

Comparisons Piloted/Copiloted 2016 – 2020

- APMP.T-K9 (SPRT calibration from Ar TP to Zn FP): Co-pilot (Pilot: NIM). Measurement in progress
- APMP.T-K4.2 (SPRT calibration at Al): Pilot. Measurement in progress
- APMP.T-S10 (Thermal Conductivity): Pilot. Circulation of artifact just started after approval of the protocol
- APMP.T-S17 (Air thermometer): Pilot. Circulation of artifact delayed due to the COVID19 situation
- APMP.T-S6 (IPRT, from -50 °C to 400 °C): Co-pilot (Pilot:NMIM). Final report published
- APMP.T-S7 (Pt/Pd thermocouple at Co-C eutectic): Pilot. Final report published

International leadership

- Dr. Inseok Yang is now Chair of the APMP TCT (Technical Committee Thermometry) (Dec. 2018 – Dec. 2021)

KRISS Publication in thermometry 2016 – 2020

Primary Thermometry

Yang, I., Underwood, R., & de Podesta, M. (2018). Investigating the adequacy of a low-cost vector network analyser for microwave measurements in quasispherical resonators. *Measurement Science and Technology*, 29(7), 075013. doi:10.1088/1361-6501/aac47b [Collaboration with NPL]

Feng, X. J., Zhang, J. T., Moldover, M. R., Yang, I., Plimmer, M. D., & Lin, H. (2017). Determination of the molar mass of argon from high-precision acoustic comparisons. *Metrologia*, 54(3), 339-347. doi:10.1088/1681-7575/aa68c7 [Collaboration with NIM, NIST, and LNE]

Key/Supplementary Comparison Report

Ali, N. M., Othman, H., Ho, M.-K., Yang, I., Gabi, V., Zhang, Z., . . . Ragay, M. (2017). Final report on APMP supplementary comparison of industrial platinum resistance thermometer for range -50 °C to 400 °C. (APMP.T-S6). *Metrologia*, 54(1A), 03001. doi:10.1088/0026-1394/54/1A/03001

Kim, Y. G., Wei, Z., Ogura, H., Jahan, F., & Singh, Y. P. (2016). Final report of APMP.T-S7: APMP regional comparison of Co-C eutectic melting point using Pt/Pd thermocouples. *Metrologia*, 53(1A), 03003-03003. doi:10.1088/0026-1394/53/1a/03003

Realization of ITS-90

Steur, P. P. M., Yang, I., Giraudi, D., & Pavese, F. (2020). Amount concentration of Ar in O₂ obtained by means of thermal analysis of certified mixtures at the α - β transition of O₂, and preliminary confirmation of a new finding. *The Journal of Chemical Thermodynamics*, 141, 105934. doi:https://doi.org/10.1016/j.jct.2019.105934 [Collaboration with INRiM]

Steur, P. P. M., Yang, I., & Pavese, F. (2020). The Effect of Argon Content on the β - γ Transition of Oxygen. *International Journal of Thermophysics*, 41(1), 7. doi:10.1007/s10765-019-2582-5 [Collaboration with INRiM]

Steur, P. P. M., Yang, I., Kim Jin, S., Nakano, T., Nagao, K., & Pavese, F. (2019). An inter-comparison of isotopic composition of neon via chemical assays and thermal analyses (IUPAC Technical Report). In *Pure and Applied Chemistry* (Vol. 91, pp. 1869). [Collaboration with INRiM]

Park, S. N., & Yang, I. (2018). Calibration interval of standard platinum resistance thermometers in a range between 0 °C and 419 °C. *Journal of Physics: Conference Series*, 1065(12), 122016. doi:10.1088/1742-6596/1065/12/122016

Yang, I., Lee, J. B., Moon, D. M., & Kim, J. S. (2017). Preparation of primary reference material of argon in oxygen by the gravimetric method for application to thermometry. *Metrologia*, 54(2), 184. doi:10.1088/1681-7575/aa5894

Steur, P. P. M., Yang, I., & Pavese, F. (2017). Evidence for Argon Content in Pure Oxygen from Thermal Data. *International Journal of Thermophysics*, 38(2), 20. doi:10.1007/s10765-016-2160-z [Collaboration with INRiM]

Secondary Thermometry

Kim, Y.-G., & Kim, S. (2020). Melting and freezing behavior of pure Ni cells in alumina crucibles with different internal structures. *Metrologia*, 57(3), 035011. doi:10.1088/1681-7575/ab7d56

Pearce, J. V., Edler, F., Elliott, C. J., Greenen, A., Harris, P. M., Izquierdo, C. G., . . . Veltcheva, R. I. (2018). A systematic investigation of the thermoelectric stability of Pt-Rh thermocouples between 1300 °C and 1500 °C. *Metrologia*, 55(4), 558-567. doi:10.1088/1681-7575/aacbf7 [Collaboration with NPL, and others]

Jeon, H.-G., Song, J. Y., O, B., & Kim, Y.-G. (2018). Measurement of electrical resistance of thermoelectric materials with a temperature gradient using instant load-voltage analysis. *Measurement Science and Technology*, 29(9), 095601. doi:10.1088/1361-6501/aaced1

Ragay-Enot, M., Lee, Y. H., & Kim, Y.-G. (2017). Fabrication of a mini multi-fixed-point cell for the calibration of industrial platinum resistance thermometers. *Measurement Science and Technology*, 28(7), 075007. doi:10.1088/1361-6501/aa7274

Kim, Y.-G., Lee, Y. H., & Joung, W. (2017). Temperature dependence of the thermoelectric inhomogeneity for type B thermocouples from 180 °C to 960 °C. *Measurement Science and Technology*, 28(5), 055006. doi:10.1088/1361-6501/aa6366

Kim, Y.-G., Yang, I., & Joung, W. (2016). High Temperature Long-Term Stability of an (Al–Ag–Cu) Three-in-One Multicell. *International Journal of Thermophysics*, 37(1), 1-9. doi:10.1007/s10765-015-2020-2

Humidity & Moisture

Lee, S.-W., Choi, B. I., Kim, J. C., Woo, S.-B., & Kim, Y.-G. (2020). Reducing individual difference and temperature dependency of QCM humidity sensors based on graphene oxides through normalization of frequency shifts. *Sensors and Actuators B: Chemical*, 313, 128043. doi:10.1016/j.snb.2020.128043

Park, E. U., Choi, B. I., Kim, J. C., Woo, S.-B., Kim, Y.-G., Choi, Y., & Lee, S.-W. (2018). Correlation between the sensitivity and the hysteresis of humidity sensors based on graphene oxides. *Sensors and Actuators B: Chemical*, 258, 255-262. doi:10.1016/j.snb.2017.11.104

Pálková, Z., Rudolfová, M., Georgin, E., Ben Ayoub, M. W., Fernicola, V., Beltramino, G., . . . Heinonen, M. (2017). Effect of Handling, Packing and Transportation on the Moisture of Timber Wood. *International Journal of Thermophysics*, 38(10), 153. doi:10.1007/s10765-017-2292-9 [Collaboration with CMI and others]

Heinonen, M., Bell, S., Choi, B. I., Cortellessa, G., Fernicola, V., Georgin, E., . . . Strnad, R. (2017). New Primary Standards for Establishing SI Traceability for Moisture Measurements in Solid Materials. *International Journal of Thermophysics*, 39(1), 20. doi:10.1007/s10765-017-2340-5 [Collaboration with MIKES and others]

Lee, S.-W., Choi, B. I., Kim, J. C., Woo, S.-B., Kim, Y.-G., Kwon, S., . . . Seo, Y.-S. (2016). Sorption/desorption hysteresis of thin-film humidity sensors based on graphene oxide and its derivative. *Sensors and Actuators B: Chemical*, 237, 575-580. doi:10.1016/j.snb.2016.06.113

Metrology for Meteorology

Lee, S.-W., Yang, I., Choi, B. I., Kim, S., Woo, S.-B., Kang, W., . . . Kim, Y.-G. (2020). Development of upper air simulator for the calibration of solar radiation effects on radiosonde temperature sensors. *Meteorological Applications*, 27(1), e1855. doi:10.1002/met.1855

Lee, S.-W., Choi, B. I., Woo, S.-B., Kim, J. C., & Kim, Y.-G. (2019). Calibration of a radiosonde humidity sensor at low temperature and low pressure. *Metrologia*, 56(5), 055008. doi:10.1088/1681-7575/ab336f

Lee, S.-W., Choi, B. I., Kim, J. C., Woo, S.-B., Kim, Y.-G., Yoo, J., & Seo, Y.-S. (2019). Reduction and compensation of humidity measurement errors at cold temperatures using dual QCM humidity sensors based on graphene oxides. *Sensors and Actuators B: Chemical*, 284, 386-394. doi:https://doi.org/10.1016/j.snb.2018.12.154

Lee, S.-W., Choi, B. I., Woo, S.-B., Kim, J. C., & Kim, Y.-G. (2019). Development of a low-temperature low-pressure humidity chamber for calibration of radiosonde humidity sensors. *Metrologia*, 56(2), 025009. doi:10.1088/1681-7575/ab0cc0

Lee, S.-W., Park, E. U., Choi, B. I., Kim, J. C., Woo, S.-B., Park, S., . . . Kim, Y.-G. (2018). Correction of solar irradiation effects on air temperature measurement using a dual-thermistor radiosonde at low temperature and low pressure. *Meteorological Applications*, 25(2), 283-291. doi:10.1002/met.1690

Lee, S.-W., Park, E. U., Choi, B. I., Kim, J. C., Woo, S.-B., Kang, W., . . . Kim, Y.-G. (2018). Compensation of solar radiation and ventilation effects on the temperature measurement of radiosondes using dual thermistors. *Meteorological Applications*, 25(2), 209-216. doi:10.1002/met.1683

Lee, S.-W., Park, E. U., Choi, B. I., Kim, J. C., Woo, S.-B., Park, S., . . . Kim, Y.-G. (2018). Dual temperature sensors with different emissivities in radiosondes for the compensation of solar irradiation effects with varying air pressure. *Meteorological Applications*, 25(1), 49-55. doi:10.1002/met.1668

Lee, S.-W., Choi, B. I., Kim, J. C., Woo, S.-B., Park, S., Yang, S. G., & Kim, Y.-G. (2016). Importance of air pressure in the compensation for the solar radiation effect on temperature sensors of radiosondes. *Meteorological Applications*, 23(4), 691-697. doi:10.1002/met.1592

Lee, S.-W., Kim, J. C., Choi, B. I., Woo, S.-B., So, J. W., Yang, S. G., & Kim, Y.-G. (2016). Development of a double cap on the humidity sensor in radiosondes for improving ventilation. *Meteorological Applications*, 23(1), 35-39. doi:10.1002/met.1517

Radiation thermometry

Sasajima, N., Lu, X., Khlevnoy, B., Grigoryeva, I., Yoo, Y. S., Otryaskin, D., . . . Yamada, Y. (2019). Performance of WC–C peritectic and Ru–C eutectic fixed points. *Metrologia*, 56(5), 055010. doi:10.1088/1681-7575/ab3707 [Collaboration with NMIJ, NIM and VNIIOFI]

Yoo, Y. S., Kim, G. J., Park, S., Lee, D.-H., & Kim, B.-H. (2016). Spectral responsivity calibration of the reference radiation thermometer at KRISS by using a super-continuum laser-based high-accuracy monochromatic source. *Metrologia*, 53(6), 1354-1364. doi:10.1088/0026-1394/53/6/1354

Thermophysical Quantities

Yang, I., Kim, D., Lee, S., & Jang, H. (2019). Construction and calibration of a large-area heat flow meter apparatus. *Energy and Buildings*, 203, 109445. doi:10.1016/j.enbuild.2019.109445

Kim, D., Jung, W., & Lee, S. (2019). Thermophysical properties of Inconel alloy 740 modified with titanium and aluminium. *International Journal of Nanotechnology*, 16(4/5), 273-280. doi:10.1504/IJNT.2019.104472

Lee, J., Kim, D., & Yoon, Y.-J. (2019). Specific heat measurements of CNT nanofluids. *International Journal of Nanotechnology*, 16(4/5), 273-280. doi:10.1504/IJNT.2019.104474

Yang, I., Kim, D., & Lee, S. (2018). Construction and preliminary testing of a guarded hot plate apparatus for thermal conductivity measurements at high temperatures. *International Journal of Heat and Mass Transfer*, 122, 1343-1352. doi:10.1016/j.ijheatmasstransfer.2018.02.072

Yoo, D., Lee, J., Lee, B., Kwon, S., & Koo, J. (2018). Further elucidation of nanofluid thermal conductivity measurement using a transient hot-wire method apparatus. *Heat and Mass Transfer*, 54(2), 415-424. doi:10.1007/s00231-017-2144-y

Lee, S., & Kim, D. (2017). The evaluation of cross-plane/in-plane thermal diffusivity using laser flash apparatus. *Thermochimica Acta*, 653, 126-132. doi:10.1016/j.tca.2017.04.011

Kim, D., Lee, J., & Kwon, S. (2017). Temperature and Heat Flow Rate Calibration of a Calvet Calorimeter from 0 °C to 190 °C. *International Journal of Thermophysics*, 38(12), 178. doi:10.1007/s10765-017-2311-x

Lee, J., Kwon, S., Joung, W., & Kim, D. (2017). Measurement of the Calorific Value of Methane by Calorimetry Using Metal Burner. *International Journal of Thermophysics*, 38(11), 171. doi:10.1007/s10765-017-2306-7

Kwon, S., Lee, J., & Kim, D. H. (2016). Reliability of thermal conductivity measurement of liquids by using transient hot-wire, photon-correlation spectroscopy and the laser flash method. *Journal of the Korean Physical Society*, 68(10), 1145-1155. doi:10.3938/jkps.68.1145

Lee, S., & Kim, D. (2016). Thermal diffusivity of silicon carbide as a reference material for laser flash apparatus. *High Temperatures – High Pressures*, 45(5/6), 345-355