

## Woongmo Sung

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### ◆ Personal Data

- Date of Birth: 30<sup>th</sup> Nov, 1984, in Republic of Korea
- Nationality: Republic of Korea
- Family Status: Unmarried, Single
- Language: Korean as a First Language, Good in English
- Military Service in Republic of Korea Completed

### ◆ Education

- Ph.D., Physics, Sogang University, 2016 (GPA: 4.14/4.3); Advisor: Prof. Doseok Kim  
(Dissertation: Adsorption Characteristics of Halide Anions in Langmuir Monolayer/water Interface)
- M.S., Physics, Sogang University, 2011 (GPA: 4.15/4.3); Advisor: Prof. Doseok Kim  
(Dissertation: Interfacial Structure of Water and Lipid Monolayer Probed by Sum-frequency Generation Spectroscopy)
- B.S., Physics, Sogang University, 2009 (GPA: 3.65/4.3); Graduated with Magna Cum Laude

### ◆ Appointments

- Postdoctoral Researcher, Soft Matter Optical Spectroscopy Laboratory, Sogang University, Korea  
(Feb, 2016-Mar 2017); Supervisor: Prof. Doseok Kim
- Postdoctoral Researcher, Molecular Spectroscopy Laboratory, RIKEN, Japan (Apr-Sep, 2017)  
; Supervisor: Prof. Tahei Tahara
- JSPS Fellowship Visiting Researcher, Molecular Spectroscopy Laboratory, RIKEN, Japan  
(Sep, 2017-Sep, 2019); Supervisor: Prof. Tahei Tahara
- Postdoctoral Researcher, Molecular Spectroscopy Laboratory, RIKEN, Japan  
(Sep, 2019-2022); Supervisor: Prof. Tahei Tahara
- Research Scientist, Molecular Spectroscopy Laboratory, RIKEN, Japan (Sep, 2022-present)  
; Supervisor: Prof. Tahei Tahara

### ◆ Awards

- Global Ph. D. Fellowship, Republic of Korea (ID: NRF-2011-0031045, 2011-2013).
- JSPS Postdoctoral Researcher Fellowship for Research in Japan, Japan (ID: P17036, 2017-2019).

### ◆ Features

- Skilled experimentalist having experience in construction of nonlinear optical spectroscopy setups.
- Deep understanding in structures and dynamics of aqueous interfaces.
- Experience in using LabVIEW® and Igor Pro® for automatizing setup, MatLab® and Origin® for modeling and data analysis.
- Experimental techniques: Femtosecond laser based nonlinear optical spectroscopy (Sum-frequency and second-harmonic generation spectroscopy), Surface pressure-area ( $\pi$ -A) isotherm measurement, ATR FT-IR spectroscopy.
- Highly self-motivated Ph.D., amicable personality and good interpersonal skills.

### ◆ Research Interest:

- Structure and dynamics of interfacial and confined molecules.
- Developing nonlinear optical spectroscopy technique.
- Time-resolved spectroscopy using femtosecond laser and frequency-tunable optical parametric devices.

### ◆ Publication List:

#### (First Author)

- 1) W. Sung, C. Müller, S. Hietzschold, R. Lovrinčić, N. P. Gallop, A. A. Bakulin, S. Nihonyanagi, T. Tahara, "Preferred orientations of organic cations at lead-halide perovskite interfaces revealed using vibrational sum-frequency spectroscopy," Mater. Horiz. 7, 1348 (2020).
- 2) W. Sung, S. Krem, D. Kim, "Binding of trivalent ions on fatty acid Langmuir monolayer: Fe<sup>3+</sup> versus La<sup>3+</sup>," J. Chem. Phys. 149, 163304 (2018).
- 3) W. Sung, Z. Avazbaeva, D. Kim, "Salt promotes protonation of amine groups at air/water interface," J. Phys. Chem. Lett. 8, 3601 (2017).
- 4) W. Sung, D. Kim, "Observation of isolated ionic liquid cations and water molecules in an inert solvent," Phys. Chem. Chem. Phys. 18, 27529 (2016).
- 5) W. Sung, W. Wang, J. Lee, D. Vaknin, D. Kim, "Specificity and Variation of Length Scale over Which Monovalent Halide Ions Neutralize a Charged Interface," J. Phys. Chem. C 119, 7130 (2015).

- 6) W. Sung, D. Vaknin, D. Kim, "Different Adsorption Behavior of Rare Earth and Metallic Ion Complexes on Langmuir Monolayers Probed by Sum-Frequency Generation Spectroscopy," J. Opt. Soc. Korea, 17, 10 (2013).
- 7) W. Sung, D. Kim, Y.R. Shen, "Sum-frequency vibrational spectroscopic studies of Langmuir monolayers," Curr.Appl. Phys., 13, 619 (2013).
- 8) W. Sung, S. Seok, D. Kim, C. S. Tian, Y. R. Shen, "Sum-Frequency Spectroscopy Study of Langmuir Monolayers of Lipids Having Oppositely Charged Headgroups," Langmuir 26, 18266 (2010).

### **(Participating Author)**

- 1) S. Krem, M. Lee, S. Sam, W. Sung, D. Kim, "Structure of Electric Double Layer under Cationic Langmuir Monolayer: Charge Condensation Effect," J. Phys. Chem. Lett. 12, 3417 (2021).
- 2) M.M. Sartin, W. Sung, S. Nihonyanagi, T. Tahara, "Molecular mechanism of charge inversion revealed by polar orientation of interfacial water molecules: A heterodyne-detected vibrational sum frequency generation study," J. Chem. Phys. 149, 024703 (2018).
- 3) Z. Avazbaeva, W. Sung, J. Lee, M. D. Phan, K. Shin, D. Vaknin, D. Kim, "Origin of the Instability of Octadecylamine Langmuir Monolayer at Low pH," Langmuir 31, 13753 (2015).
- 4) J. Lee, W. Sung, D. Kim, "Two-dimensional correlation analysis of sum-frequency vibrational spectra of Langmuir monolayers," J. Opt. Soc. Korea 18, 558 (2014).
- 5) S. Cha, M. Ao, W. Sung, B. Moon, B. Ahlström, P. Johansson, Y. Ouchi, D. Kim "Structures of ionic liquid–water mixtures investigated by IR and NMR spectroscopy," Phys. Chem. Chem. Phys. 20, 9591 (2014).
- 6) W. Wang, W. Sung, M. Ao, N. A. Anderson, D. Vaknin, D. Kim, "Halide Ions Effects on the Surface Excess of a Long Chain Ionic Liquid," J. Phys. Chem. B, 117, 13884 (2013).
- 7) S. Chae, H. Min, J. Lee, B. Hwang, W. Sung, W. Jang, Y. Yoo, J. Oh, J. Park, D. Kang, D. Kim, Y. Kim, H. Baik, "Fabrication of a Multidomain and Ultrafast-Switching Liquid Crystal Alignment Layer Using Contact Printing with a Poly(dimethylsiloxane) Stamp," Adv. Mater. 25, 1408 (2013).
- 8) Y. Jeon, D. Vaknin, W. Bu, J. Sung, Y. Ouchi, W. Sung, D. Kim, "Surface Nanocrystallization of an Ionic Liquid," Phys. Rev. Lett. 108, 055502 (2012).

### **◆ Oral presentations in International Conferences**

- W. Sung, K. Inoue, S. Nihonyanagi, T. Tahara, "Vibrational relaxation of water at the air/H<sub>2</sub>O interface revealed by time-resolved heterodyne-detected vibrational sum-frequency generation in the OH stretch hot-band region", The 22nd International Conference on Ultrafast Phenomena (2020).
- W. Sung, Z. Avazbaeva, J. Lee, D. Kim, "Protonation of octadecylamine Langmuir monolayer by adsorption of halide", American Physical Society March Meeting (2016).

- W. Sung, D. Kim, "Investigation on imidazolium ionic liquids and water molecules by matrix isolation infrared spectroscopy", The International Chemical Congress of Pacific Basin Societies (2015).
- W. Sung, J. Lee, D. Kim, "Ionic liquid and water molecules diluted in hydrophobic solvent matrix investigated by infrared absorption spectroscopy", American Physical Society March Meeting (2015).
- W. Sung, W. Wang, J. Lee, D. Vaknin, D. Kim, "Depth profile of halide anions under highly charged biological membrane", American Physical Society March Meeting (2015).
- W. Sung, D. Vaknin, D. Kim, "Different adsorption behavior of rare earth and metallic ion complex on Langmuir monolayers probed by sum-frequency generation spectroscopy", 14<sup>th</sup> International Conference on Organized Molecular films (2012).
- W. Sung, S. Seok, D. Kim, "Interfacial water structure change of Langmuir monolayer effected by oppositely charged head group and counterion adsorption", 13<sup>th</sup> International Conference on Organized Molecular films (2010).
- W. Sung, S. Seok, D. Kim, "Lipid/water system with varying charge densities at the interface monitored by sum-frequency vibrational spectroscopy", American Physical Society March Meeting (2010).
- W. Sung, S. Seok, D. Kim, "Sum-frequency spectra of Langmuir monolayers of lipid molecules having different headgroups", 8<sup>th</sup> Conference on Lasers and Electro-Optics/Pacific Rim (2009).

#### ◆ Award in Conference

- Poster Presentation Award in 6<sup>th</sup> International Congress on Ionic Liquids (2015), Title: "Investigation on imidazolium ionic liquid molecules by matrix-isolation infrared spectroscopy"

#### ◆ Research Experiences

##### 1) Sogang University, Republic of Korea

##### M.S., 2009-2011

- Studying Microscopic structure of monolayers on air/water interface

As the mean nearest neighbor distance of lipid molecule is 7-10 Å, structure of monolayer depends strongly on lateral interaction. In this research, I applied pressure-area ( $\pi$ -A) isotherm and vibrational sum-frequency generation (VSFG) spectroscopy on composite monolayer of positively- and negatively charged lipid molecules in 1:1 ratio of mixing. In comparison to monolayers consisting only of positive or negatively charged lipid molecules, this composite monolayer shows spectral signature of liquid-condensed phase even in absence of surface pressure. From many of previous studies using  $\pi$ -A isotherm, it was usually known that zero surface pressure of Langmuir monolayer indicates liquid-expanded or gaseous phase where amphiphilic molecules are denatured. However, VSFG experiment clearly demonstrated that composite monolayer can exist as 'condensed phase island' on air/water interface due to the strong coulomb attraction.

## Ph.D., 2011-2016

- Construction of phase sensitive broadband VSFG setup

In conventional VSFG spectroscopy using picosecond Nd:YAG laser as a light source. Bandwidth of infrared pulse generated from optical parametric device is limited to few  $\text{cm}^{-1}$ . For this reason, it requires  $\sim 1$  hour scanning time for measuring interface in the  $1000 \text{ cm}^{-1}$  scanning window. To improve the condition of VSFG setup, I built broadband VSFG (BB-VSFG) system using a femtosecond Ti:Sapphire laser and home-built optical parametric amplification device. By using 40 fs 800 nm pump laser pulse, the measured infrared beam bandwidth was  $\sim 400 \text{ cm}^{-1}$  in FWHM, and reasonable VSFG spectra of lipid monolayer/water could be obtained in 3 minutes acquisition of signal on the CCD camera. By introducing a local oscillator pulse for heterodyne-detection in this BB-VSFG setup, it was able to measure electric field of SF signal directly. From this phase sensitive detection, orientation of interfacial water under charged surface was investigated.

- Research on ion specificity at membrane/water interface

According to classical Poisson-Boltzmann theory, depth profile of ion concentration near charged surface is uniquely determined for given bulk concentration, valency, temperature, and surface charge density. However, even these conditions are held, precipitation of charge colloid particle, polymer appear differently for ion species. In this research, I performed VSFG spectroscopy and X-ray fluorescence measurement on positively charged lipid monolayer/water interface with insertion of NaCl and NaI salts. It turned out that  $\text{I}^-$  anion has greater surface affinity than  $\text{Cl}^-$ . In microscopic picture,  $\text{I}^-$  anions are directly bound to charged monolayer whereas  $\text{Cl}^-$  shows more diffused depth profile in 6-8 nm from interface. This result shows similarity with recent spectroscopy and MD simulation works on anion excess at charge neutral air/water interface.

## Postdoctoral Researcher, 2016-2017

- Research on protonation behavior of amine groups in condensed monolayer

Amine is one of most abundant functional group in biological system. It was well-known that protonation of alkylamine group is proceeded below pH 10 in bulk phase. However, protonation in condensed amine film has not been fully investigated. In this research, I performed phase sensitive BB-VSFG experiment on octadecylamine (ODA) Langmuir monolayer in conjunction with surface pressure-area ( $\pi$ -A) isotherm, and the result was compared with previous measurements on cationic lipid (DPTAP) Langmuir monolayer. In the case of ODA monolayer on pure water, both SF intensity of water OH band and surface pressure are significantly smaller than those of DPTAP monolayer implying that only small portion of protonated amine group ( $-\text{NH}_3^+$ ) exist in the monolayer. In the presence of sodium halides (NaCl and NaI) in the solution, it was found that sign of  $\text{Im}\chi^{(2)}$  of water OH band remained same as ODA monolayer on pure water, but there was a substantial increment in the SF amplitude implying that more protonated amine groups exist when the ions enter in subsurface.

## **2) Visiting Scientist, Sep, 2013, Ames National Laboratory, Iowa, USA**

- Monitoring structure and profile of monolayer and adsorbed ions

Density profile of ions ( $\text{Cl}^-$  and  $\text{I}^-$ ) adsorbed on cationic lipid (DPTAP) Langmuir monolayer was investigated by grazing angle X-ray fluorescence spectroscopy. In comparison to neat NaCl and NaI solutions, X-ray fluorescence from interface region (6-8 nm) was markedly enhanced due to counterion adsorption. From model fitting it was shown that total number of anion in interfacial region was almost same for  $\text{Cl}^-$  and  $\text{I}^-$ , and the profile of  $\text{I}^-$  ion is more inclined to interface. From X-ray reflectivity measurement on this system, it was found that monolayer become more staggered in vertical direction when counterions are adsorbed on.

## **3) Postdoctoral and Visiting Researcher, 2017-Present, Molecular Spectroscopy Laboratory, RIKEN, Japan**

- Investigation on vibrational dynamics of interfacial water

Air/water is a simplest yet ubiquitous interface presenting in nature. Using surface sensitive spectroscopies the structure of air/water interface has been revealed. However, the dynamics of interfacial water especially vibrational dynamics are not fully understood, and the time scale of vibrational relaxation is still under debates. In the research project, I used cutting edge interface spectroscopy technique called time-resolved and heterodyne-detected vibrational sum-frequency generation spectroscopy (TR-HD-VSFG) for determining vibrational relaxation time ( $T_1$ ) of OH stretch motion of interfacial water. The result shows  $T_1$  of 200-300 fs of hydrogen bonded OH stretch which is moderately increases with vibrational frequency. Comparing to the previous investigation on bulk water, the time scale of the interfacial  $T_1$  is similar to that of bulk for hydrogen bonded OH moieties. On the other hand I found substantially slow  $T_1$  (~1 ps) of hydrogen-bond free OH moiety which exist only at the topmost water layer of air/water interface. A Clear evidence of conversion from excited free OH stretch to excited hydrogen-bonded OH stretch was also found in the study.

- Investigation on interfacial structure of organic cations in perovskite interfaces

The structure of the interfacial layers of lead halide perovskites is expected to play a crucial role in carrier dynamics and in the performance of perovskite-based devices. However, little is known about the structure and dynamics of perovskite interfaces at the molecular level. In the study, I investigated molecular structures at perovskite interfaces by monitoring the alignment of cations in methylammonium (MA) lead bromide perovskite. For this I applied heterodyne-detected vibrational sum-frequency generation (HD-VSFG) spectroscopy in conjunction with the DFT calculations. At the interfaces contacting to air, glass, and PCBM electron transport layer, no resonant VSFG signal was found indicating a randomized arrangement of cations. On the other hand, HD-VSFG spectra of Spiro-MeOTAD/perovskite interface exhibited a clear vibrational resonance peak corresponding to the

antisymmetric bending mode of ammonium, indicating that the ammonium moiety of MA cation is preferentially oriented towards the Spiro-MeOTAD layer.

- Construction of the interferometric two-dimensional HD-VSFG setup

Two-dimensional vibrational spectroscopy such as 2D IR has been utilized for investigation on frequency-frequency correlation among vibrational dynamics, and it successfully monitors vibrational coupling, energy transfer, chemical exchange, and inhomogeneity in bulk materials. However, there are only handful reports on two-dimensional vibrational spectroscopy at interface because of challenging conditions of the experiment from smaller detection region and smaller optical response. In the project I constructed interferometer based two-dimensional HD-VSFG setup having  $\sim 10 \mu\text{J}$  of IR pulse energy which is higher than the IR pulse energy typically used in 2D IR experiment ( $\sim 1\text{-}2 \mu\text{J}$ ). By using the interferometer scheme, I can achieve both spectral and temporal resolution better than the previous hole-burning type 2D HD-VSFG setup. Using the interferometric 2D HD-VSFG, I have investigated self-assembled monolayer of octadecylsiloxane consisting of long alkyl chains. From the 2D spectra I found clear anharmonic coupling between symmetric and anti-symmetric stretch mode of terminal methyl group before vibrational relaxation.