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KIT Energy News

에너지융합기술 혁신인재 양성사업단

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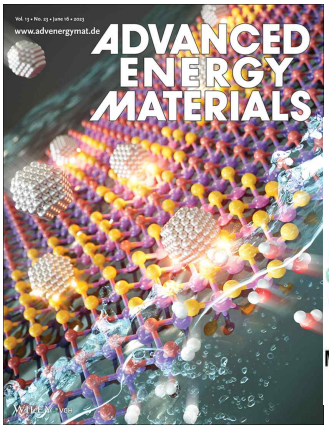
KIT Energy 소식

고가 백금 촉매 대체할 그린수소 생산비 절감 차세대 촉매 개발

- 2차원 소재 구조제어 통해 촉매 활성도 1000배 향상 확인



한국연구재단은 인하대 전기준 교수팀과 금오공대 박철민 교수팀이 수전해 반응에서 촉매로 많이 활용되는 2차원 소재 이황화몰리브덴(MoS2)의 구조를 제어할 수 있는 기술을 개발했다고 밝혔다.

수전해 과정에서 반응과 효율 등을 증가시키기 위해 촉매를 사용하는데, 반응성이 가장 높은 귀금속의 경우 값이 비싸 경제성을 보완할 수 있는 연구가 활발히 진행되고 있다.

그 중 우수한 촉매 후보군으로 각광 받는 2차원 소재의 경우, 다층보다 단일 원자층에서 높은 효율을 갖는데, 단일층 내에서도 구조적으로 다른 2개 상(Phase)에 따라 성능 차이를 보인다.

하지만 고품질의 균일한 단일층을 합성하면서도 존재하는 2개의 구조가 다른 상을 제어하는 데 한계가 있었다.

연구팀은 화학기상증착법(CVD)을 통해 균일한 단일 원자층의 이황화몰리브덴을 제작, 여기에 극미량(<1%)의 팔라듐 금속을 삽입해 원자층에 존재하는 2개의 상을 조절하는 데 성공했다.

합성된 이황화몰리브덴은 기존 합성연구의 결과와 비교해 높은 순도 및 수전해 효율을 보였다.

구조적 상변이 비율을 최대 86%까지 제어했는데 이는 세계 최고 기술 수준을 달성한 수치다. 또한 수소 발생 효율 측면에서 최고 수준의 백금 촉매와 유사한 수치를 보였고, 특히 기존 백금 촉매 대비 1000배 이상 높은 촉매 질량 활성 수치를 확인했다.

연구팀은 “수전해 반응 촉매, 반도체, 광소자 및 전자소자 등 다양한 연구 및 산업 방면에서 상의 구조적인 제어를 통해 각 분야에 적합한 정도의 상 비율을 조절할 수 있어 전략적 응용이 가능할 것”이라고 기대했다.

과학기술정보통신부와 한국연구재단이 추진하는 중견연구사업의 지원으로 수행된 이번 연구 성과는 에너지 분야 국제학술지 ‘어드벤스드 에너지 메터리얼즈’(Advanced Energy Materials)에 4월 25일 게재됐다.

2023.06.13.

◈ 관련 기사 ◈

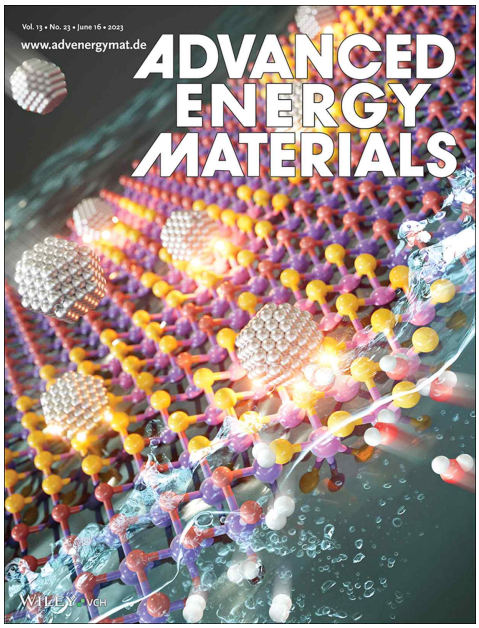
해럴드경제	“고가 백금촉매 완벽대체” 그린수소 값싸게 만든다	http://news.heraldcorp.com/view.php?ud=20230613000459
News1	국내 연구진, 그린 수소 생산 차세대 촉매 개발	https://www.news1.kr/articles/5075164
아이뉴스24	그린 수소 생산…차세대 촉매 나왔다	https://www.inews24.com/view/1602170
아시아경제	"백금 말고 이황화몰리브덴"…그린수소 생산비 대폭 낮춘다	https://view.asiae.co.kr/article/2023061316064652087
전국매일신문	한국연구재단, 그린 수소 생산 차세대 촉매 개발	http://www.jeonmae.co.kr/news/articleView.html?idxno=963449
충청뉴스	한국연구재단, 그린 수소 생산 위한 차세대 촉매 소개	http://www.ccnnews.co.kr/news/articleView.html?idxno=297896
조선비즈	[과학게시판] 그린 수소 백금 촉매 대체할 차세대 촉매 개발 外	https://biz.chosun.com/science-chosun/technology/2023/06/14/6QNNBGSOIZGS7KER4G747GQPI4/

에너지변환

Advanced Energy Materials
Volume 13, June 2023, p2300183 (Impact Factor : 27.8)

Pd Sulfidation-Induced 1T-Phase Tuning in Monolayer MoS_2 for Hydrogen Evolution Reaction

Hien Duy Mai, Sangmin Jeong, Gi-Nam Bae, Ngoc Minh Tran, Jong-Sang Youn, Cheol-Min Park,* and Ki-Joon Jeon*



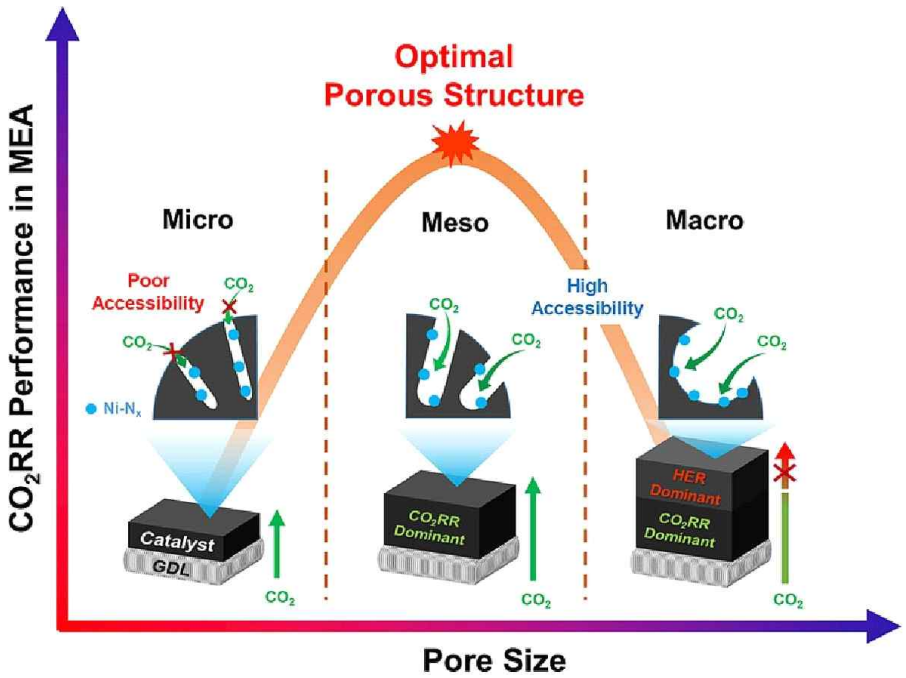
For single-atom-layer hydrogen evolution reaction catalysts, enrichment of the 1T-phase in monolayer molybdenum disulfide is important to achieve ideal metal utilization efficiency and exposure of active surface atoms. Herein, it is discovered that the 1T-phase degree in monolayer MoS_2 can be enhanced through sulfidation of the Pd species deposited on MoS_2 (Pd_xS_y/1T-MoS_2). Raman and X-ray photoelectron spectroscopy reveal that the sulfidation-assisted phase transition results in considerably greater proportions of 1T-phase fraction (up to 86%) without using alkali-metal-based approaches. Observations of S-atom displacement/translation at the atomic level contribute to the understanding of the phase transformation of MoS_2. The maximized surface atom activation and metal utilization efficiency in Pd_xS_y/1T-MoS_2 lead to unprecedentedly high mass activity (-3444 A mg_{Pd}^{-1}) and turnover frequency (1892 s^{-1}), three orders of magnitude higher than those of commercial Pt/C 10 wt% (3.6 A mg_{Pt}^{-1} and 3.6 s^{-1}). The sulfidation-assisted 1T-phase enrichment has major implications for the designs of efficient electrocatalysts through MoS_2 phase engineering.

에너지변환

Chemical Engineering Journal
Volume 464, May 15, 2023, p142593 (Impact Factor : 15.1)

Deciphering mass transport behavior in membrane electrode assembly by manipulating porous structures of atomically dispersed Metal-Nx catalysts for High-Efficiency electrochemical CO_2 conversion

Seunghyun Lee, Ye Eun Jeon, Seonggyu Lee, Wonhee Lee, Seongbeen Kim, Jaeryung Choi, Jinkyu Park, Jeong Woo Han, You Na Ko, Young Eun Kim, Jinwon Park, Jungbae Kim*, Ki Tae Park*, Jinwoo Lee*



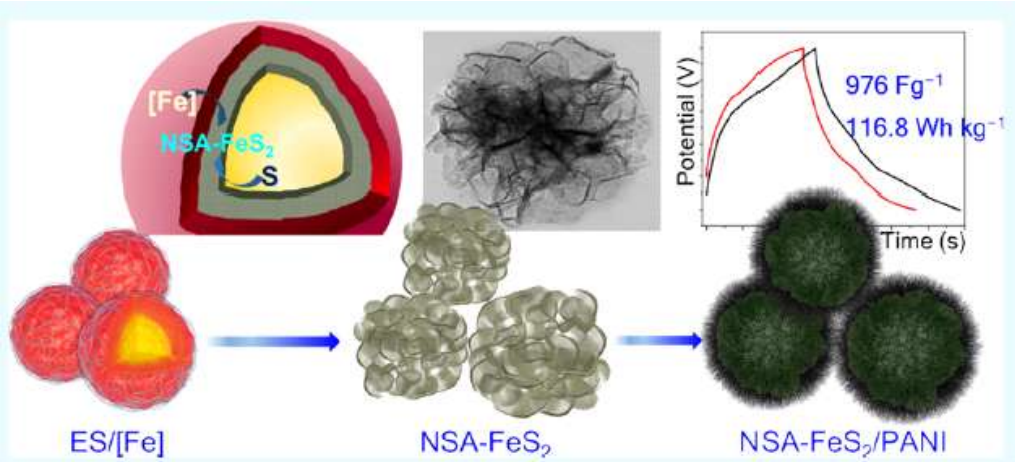
The introduction of a porous structure is a promising approach to promote the electrochemical reaction of catalysts, which can maximize the utilization of catalytic active sites and enhance mass transport. To fully understand the role of the porous structure, parallel studies on both half-cell and full-cell environments must be performed; however, few studies have reported electrochemical CO2 conversion in a full-cell operation. In this work, we fabricated four types of porous Nisingle bondNsingle bondC model catalysts designed to systematically investigate the relationship between porous structures and catalytic performances in a membrane electrode assembly (MEA) based catholyte-free CO2 electrolyzer. The performance degradation of the microporous catalyst in the MEA resulted from low CO2 accessibility due to small openings (<2 nm), and the absence of meso- or macropores that can facilitate mass transport in the catalyst layer. A thick catalyst layer developed a region in which H2 evolution was dominant; the formation of this region degraded the CO2 reduction efficiency in the MEA based on the macroporous catalyst. Consequently, mesoporous Ni-Nx catalysts with small, uniform particles exhibited the highest efficiency in MEAs, because their appropriate pore size and catalyst layer thickness facilitated mass transport. The optimized catalyst achieved industry-relevant performance for CO production (265 mA cm−2 at 2.3 V) with a state-of-the-art energy efficiency of 55 % and excellent long-term stability in a full cell.

에너지저장

ACS Applied Materials & Interfaces
Volume 15, May 2023, p26967−26976 (Impact Factor : 9.5)

Fabrication of Assembled FeS2 Nanosheet and Application for High-Performance Supercapacitor Electrodes

Farkhod Azimov, Jinseok Lee, Subin Park, and Hyun Min Jung*



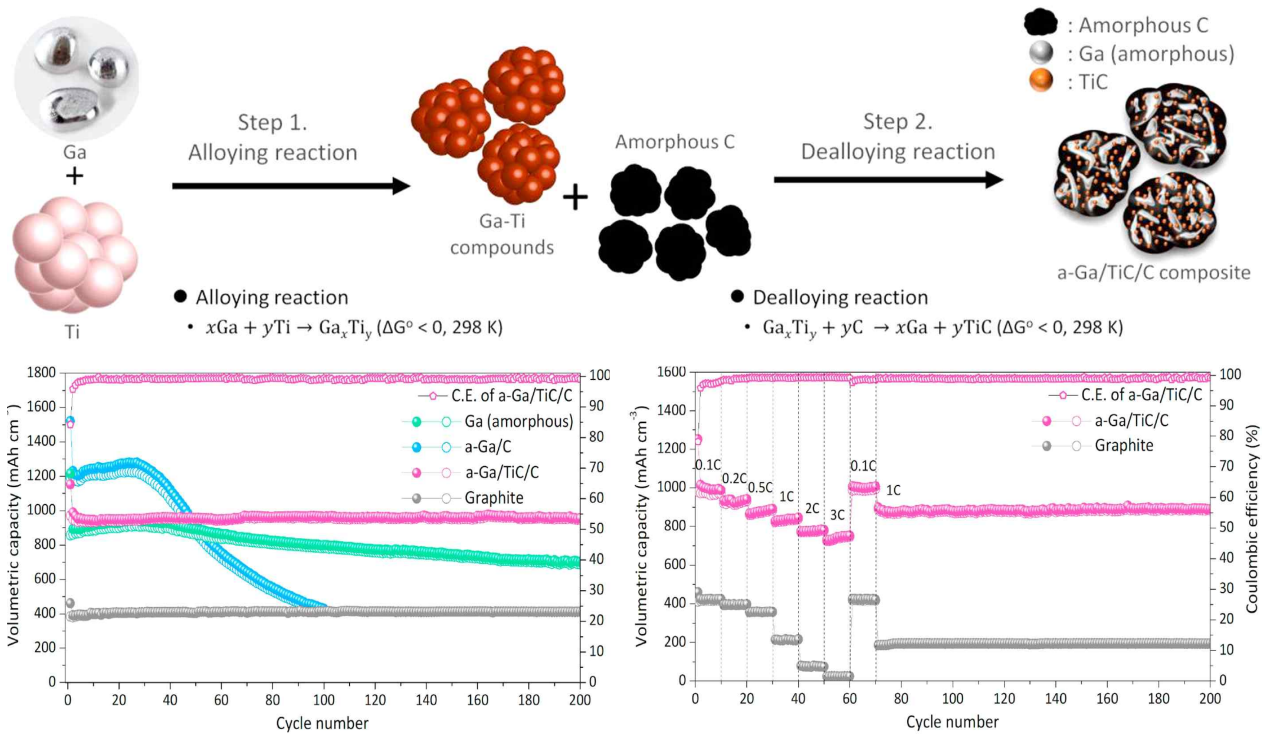
To overcome the low-energy-density limitation of supercapacitors, we aimed to achieve a material with a high specific capacitance by manipulating the nanostructure of FeS2, which comprises the most abundant and affordable elements. In this study, nanosheet-assembled FeS2 (NSA-FeS2) was fabricated using a novel method. Sub-micron droplets of sulfur particles stabilized with polyvinylpyrrolidone were formed in silicone oil medium, and Fe(CO)5 was absorbed and reacted on the surface to form coreshell particles, ES/[Fe], with a sulfur core and an iron-containing outer shell. The high temperature treatment of ES/[Fe] produced NSA-FeS2, in which pyrite FeS2 nanosheets grew and were partially interconnected. In a three-electrode system, the as-prepared NSA-FeS2 and NSA-FeS2/polyaniline (PANI) composites exhibited specific capacitances of 763 and 976 F/g, respectively, at a current density of 0.5 A/g, with corresponding capacitance retentions of 93 and 96% after 3000 charge−discharge cycles. The capacitance retention of the NSA-FeS2/PANI composites was 49% when the current density was increased from 0.5 to 5 A/g. Notably, the obtained specific capacitances exhibited the highest values in pure FeS2 and FeS2-based composites, indicating the significant potential for the utilization of iron sulfide in pseudocapacitive electrode materials.

에너지저장

Materials Today Energy
Volume 35, July 2023, p101327 (Impact Factor : 9.3)

Optimized Ga-based nanocomposite for superior Li-ion battery anodes

Jeong-Myeong Yoon, Young-Han Lee, Cheol-Min Park*



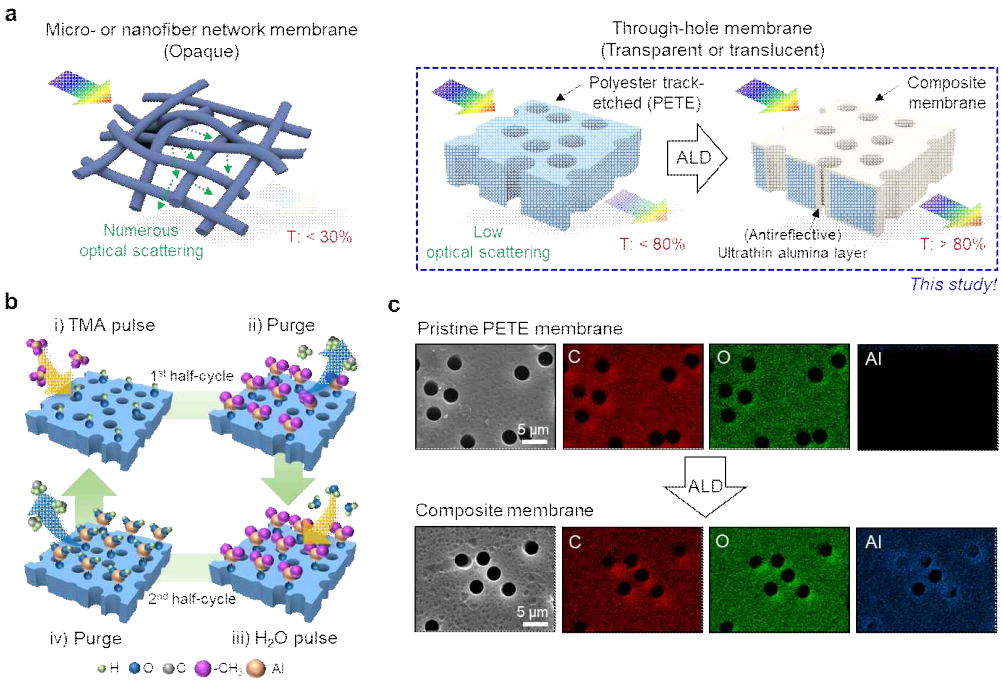
Among the various liquid metals, Ga has unique properties, such as a low melting temperature, fluidity, and non-toxicity. In addition, Ga can alloy with Li to form a Li_2Ga phase, which can be applied to high-capacity anodes for Li-ion batteries (LIBs). However, Ga-based materials readily melt and agglomerate during lithiation/delithiation owing to their low melting temperature and high surface energy, resulting in poor cycling stability. In this study, two structural types of Ga, crystalline and amorphous, were selected and electrochemically investigated as LIB anodes. Subsequently, to address the melting and agglomeration issues of the Ga anode, an optimized Ga-based nanocomposite was developed using a novel synthetic concept, namely a solid-state alloying-dealloying process. This process involves an alloying reaction of Ga and Ti to form various Ga-Ti compounds, such as Ga_3Ti, Ga_2Ti, and Ga_3Ti_2, and a dealloying reaction with amorphous C to form a nanocomposite comprising evenly dispersed amorphous Ga and Li-inactive TiC in the amorphous C matrix. The Li-inactive TiC and amorphous C matrix in the nanocomposite effectively confined amorphous Ga, thereby preventing the problems caused by its melting and agglomeration during cycling. In addition, an interesting transformation behavior of amorphous Ga into electrochemically stabilized Ga nanocrystallites (approximately 2-3 nm) was demonstrated during cycling, contributing to the high electrochemical performance. The Ga-based nanocomposite exhibited a superior electrochemical performance. This study proposes a better understanding of high-performance Ga-based anodes for LIBs as well as an effective fabrication method for high-performance nanocomposites by solid-state alloying-dealloying.

환경에너지

Journal of Hazardous Materials
volume 452, June 2023, p131241 (Impact Factor : 13.6)

Through-hole composite membrane with an ultrathin oxide shell for highly robust and transparent air filters

Taehyun Ryu, Junyong Ahn, Junyong Park*



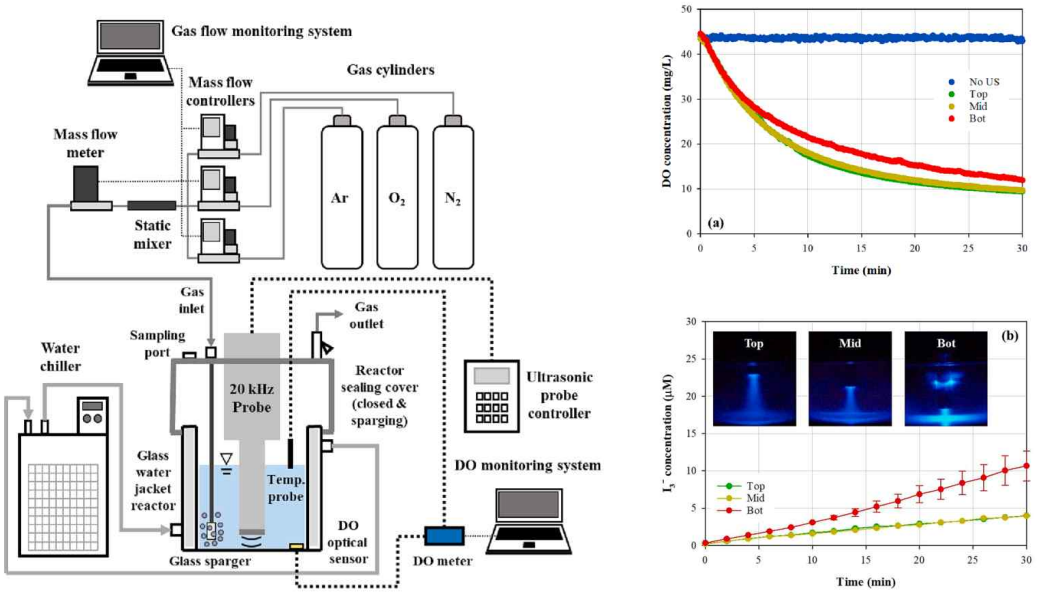
Exploring pore structures that are optically transparent and have high filtration efficiency for ultrafine dust is very important for realizing passive window filters for indoor air purification. Herein, a polyester track-etched (PETE) membrane with vertically perforated micropores is investigated as a cost-effective candidate for transparent window filters. The pore size, which governs transparency and filtration efficiency, can be precisely tuned by conformally depositing an ultrathin oxide layer on the PETE membrane via atomic layer deposition. The maximum visible light transmittance (~81.2 %) was achieved with an alumina layer of approximately 55 nm, and the resulting composite membrane exhibited competitive filtration efficiency compared to commercial products. The chemically inert alumina layer also increased resistance to various external stimuli and enabled simple cleaning of the contaminated membrane surface with a solvent. The membrane installed on an insect screen effectively maintained its filtration performance (~85 % for PM2.5) even after 10 reuse cycles under extremely harsh conditions (PM2.5 concentration: ~5000 μg cm−3). The proposed through-hole composite membrane can expand the choice of aesthetic window filters to situations that require high outside visibility and daylighting.

환경에너지

Ultrasonics Sonochemistry
Volume 97, July 2023, 106452 (Impact Factor : 8.4)

Effect of dissolved gases on sonochemical oxidation in a 20 kHz probe system: Continuous monitoring of dissolved oxygen concentration and sonochemical oxidation activity

Jongbok Choi, Younggyu Son*



Dissolved gases have a substantial influence on acoustic cavitation and sonochemical oxidation reactions. Little research on the changes in dissolved gases and the resultant changes in sonochemical oxidation has been reported, and most studies have focused only on the initial dissolved gas conditions. In this study, the dissolved oxygen (DO) concentration was measured continuously during ultrasonic irradiation using an optical sensor in different gas modes (saturation/open, saturation/closed, and sparging/closed modes). Simultaneously, the resulting changes in sonochemical oxidation were quantified using KI dosimetry. In the saturation/open mode using five gas conditions of Ar and O_2, the DO concentration decreased rapidly when O_2 was present because of active gas exchange with the atmosphere, and the DO concentration increased when 100% Ar was used. As a result, the order of the zero-order reaction constant for the first 10 min (k_{0-10}) decreased in the order Ar:O_2 (75:25) > 100% Ar ≈ Ar:O_2 (50:50) > Ar:O_2 (25:75) > 100% O_2, whereas that during the last 10 min (k_{20-30}) when the DO concentration was relatively stable, decreased in the order 100% Ar > Ar:O_2 (75:25) > Ar:O_2 (50:50) ≈ Ar:O_2 (20:75) > 100% O_2. In the saturation/closed mode, the DO concentration decreased to approximately 70–80% of the initial level because of ultrasonic degassing, and there was no influence of gases other than Ar and O_2. Consequently, k_{0-10} and k_{20-30} decreased in the order Ar:O_2 (75:25) > Ar:O_2 (50:50) > Ar:O_2 (25:75) > 100% Ar > 100% O_2. In the sparging/closed mode, the DO concentration was maintained at approximately 90% of the initial level because of the more active gas adsorption induced by gas sparging, and the values of k_{0-10} and k_{20-30} were almost the same as those in the saturation/closed mode. In the saturation/open and sparging/closed modes, the Ar:O_2 (75:25) condition was most favorable for enhancing sonochemical oxidation. However, a comparison of k_{0-10} and k_{20-30} indicated that there would be an optimal dissolved gas condition that was different from the initial gas condition. In addition, the mass-transfer and ultrasonic-degassing coefficients were calculated using changes in the DO concentration in the three modes.