論文 / 著書情報
Article / Book Information

題目(和文)	フォトレドックス触媒作用による窒素及び酸素含有反応性ラジカル種の発生とその合成化学的利用
Title(English)	Generation of reactive nitrogen- and oxygen-containing radical species by photoredox catalysis and their synthetic applications
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10531号, 授与年月日:2017年3月26日, 学位の種別:課程博士, 審査員:穐田 宗隆,吉沢 道人,小坂田 耕太郎,中村 浩之,稲木 信介
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10531号, Conferred date:2017/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	化学環境学　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Incorporation of nitrogen- and oxygen-containing functional groups via radical species generated by the action of photoredox catalysis has been developed. Nitrogen- and oxygen-containing compounds are ubiquitous in natural compounds, bioactive compounds, drugs and so on. Therefore, introduction of *N*- and *O*-containing functional groups to molecules has been regarded highly important. The author focuses on radical reactions because of its unique reactivities such as a wide range of functional group tolerance and the regioselectivity on addition to multiple bonds. Visible-light-promoted photoredox catalysis has attracted increasing attention as a powerful synthetic tool in the field of organic synthesis, because photoredox catalysis is a green chemical process thanks to many favorable aspects as exemplified by visible light (sunlight) driven, atom-economic and redox neutral reactions. The single electron transfer processes involved therein can be applied to generation of radicals via the photoredox process. This process has advantages over the conventional radical systems that frequently use an excess amount of redox reagents or special equipments. For the use of photoredox catalysis as a green radical generating method it is essential to design appropriate precursors. In the present study, the author has developed new radical precursors containing heteroatoms and used them for selective reactions.

Oxidation chemistry of amines and ethers has been studied extensively and established. 1e-Redox processes by photoredox catalysis are expected to trigger the interconversion of amines and ethers but *N*-protected amines and ethers are difficult to be oxidized by photoredox catalysis due to its high oxidation potentials. Organotrifluoroborates serve as radical precursors upon 1e-oxidation. This inspired the author to incorporate the trifluoroborate groups at the carbon atom adjacent to the nitrogen atoms of amines and the oxygen atoms of ethers. He examined the photocatalytic reaction of potassium Boc-protedted aminomethyltrifluoroborate or 4-methoxyphenoxymethyltrifluoroborate with electron-deficient olefins in the presence of the Ir photocatalyst in acetone/MeOH under visible light irradiation (blue LEDs: λ_{max} = 425 nm). As a result, hydroamino- or hydroalkoxy-methylation of the olefins proceeded in good yields with high tolerance with a wide variety of functional groups, and the present methods are regarded as *indirect* introduction of heteroatom-functional groups to olefins. Furthermore, the hydro-aminomethylation provides us with a new strategy for the synthesis of biologically active γ-aminobutyric acid (GABA) derivatives.

Intermolecular radical amination and oxygenation are difficult due to the propensity of nitrogen- and oxygen-centered radicals undergoing hydrogen-abstraction. The synthetic utilities of these radicals remain unexplored because of lack of effective radical precursors and reaction systems. The author developed stable and easy-to-use pyridinium reagents such as *N*-Ts protected aminopyridinium tetrafluoroborate and 3,5-bis(trifluoromethyl)benzoyloxylutidinium triflate salts as nitrogen- and oxygen-centered radical precursors. First of all, he succeeded in synthesis of *N*-Ts protected aminopyridinium tetrafluoroborate and established aminohydroxylation of olefins with the aminopyridinium salt in the presence of *fac*-[Ir(ppy)$_3$] catalyst (ppy: 2-pyridylphenyl) under visible light irradiation. The resultant vicinal aminoalcohol skeletons are ubiquitous in biologically active natural compounds and drugs. The aminating reagents serve as excellent *N*-centered radical precursors by the action of the photoredox catalysis. Furthermore, aminohydroxylation of olefins with iminopyridinium ylide by dual catalysis of Lewis acid and photoredox catalysis was developed. The dual catalytic system enables synthesis of various *N*-protected aminoalcohols such as trifluoroacetoxy, Boc (*tert*-butoxycarbonyl), troc (2,2,2-trichloroethoxycarbonyl) and alloc (allyloxycarbonyl) derivatives, which could not be accessible by the aminopyridinium system mentioned above.

The successful generation of nitrogen-centered radical from amionopydinium salts encouraged the author to examine the generation of oxgen-centered radicals from pyridinium analogues and to develop an effective method for radical C-O bond formation. He established aroyloxylation of arenes with *N*-aroyloxylutidinium salts via the aroyloxy radicals by the action of photoredox catalysis under visible light irradiation. Although carboxy radicals are apt to decarboxylation to give the corresponding carbon-centered radicals or abstract a hydrogen atom from substrates nearby to give the carboxylic acids, electron-withdrawing groups on the benzoyl moiety of the aroyloxylutidinium salts increased the electrophilicity of the aroyloxy radical to increase the yields of the substituted oxygenated products. The present amination and oxygenation are regarded as a direct introduction of nitrogen- and oxygen-atoms.

The author has developed new methods for introduction of nitrogen- and oxygen-functionalities to alkenes or arenes via carbon-, nitrogen-, and oxygen-centered radical intermediates generated by the photoredox catalysis. Organotrifluoroborates and amino- and carboxy-pyridinium salts undergo 1e-oxidation and 1e-reduction via reductive and ocidative quenching cycle, respectively, to generate the corresponding carbon-, nitrogen-, and oxygen-centered radicals, which undergo hydro-aminomethylation of olefins (Chapter 2), hydro-alkoxymethylation of olefins (Chapter 2), aminohydroxylation of olefins (Chapter 3), and aroyloxylation of arenes (Chapter 4).