

有機-無機ハイブリッド材料 Organic-Inorganic Hybrid Materials

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1983年早稲田大学理工学部応用化学科卒業、1988年早稲田大学大学院博士課程 応用化学専攻修了(工学博士)、1987~1990年早稲田大学助手、1989~1990年米国マサチューセッツ工科大学訪問研究員、1990~1992年早稲田大学専任講師、1992~1999年早稲田大学助教授、2000年~早稲田大学教授、2007年仏国モンペリエ第二大学招聘教授、2010年~早稲田大学材料技術研究所研究員、2012年度日本とラミックス協会学術賞、2014年度日本化学会化学教育賞、2018 年度粉体粉末冶金協会研究功績賞、2019年度日本セラミックス協会フェロ

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現在、無機化学と有機化学をシームレスに用い、無機一有機ハイブリッド材料と無機材料の作製を展開している。現在の研究活動は以下の通りである。
1.無機ナノ材料の表面修飾による無機一有機ハイブリッド材料の作製無機一有機ハイブリッド材料を遷移金属酸化物ナノシートやナノ粒子などの無機ナノ材料から作製している。有機ホスホン酸やリン酸エステルなどのリン化合物やアルコールなど種々のカップリング剤を用いた表面修飾により、有機基を無機ナノ材料の表面に固定化している。特に、バルクスケールとマイクロスケールの液一液二相系での表面修飾法を開発している。また、原子移動ラジさか重合(ATRP)法の開始基を表面に固定化し、ポリマー鎖をATRP法で生りマールの液一液二相系での表面修飾法を開発している。また、原子移動ラジさか重合とで、ポリマー鎖の固定化を行っている。これらのナノ材料を、ポリマーハイブリッド材料のナノフィラーとして用いており、得られるハイブリッド材料の光学特性や機械的性質を評価している。一方、位置選択的表面修飾により、ナノシートの2つの面が異なる性質を持つヤヌスナノシートが作製できる。2.化学的合成法による無機一有機ハイブリッド材料の作製いくのかの化学的合成ルートにより、ハイブリッド材料を合成している。一つのルートでは、層状物質の層間に分子やイオンを導入するインターカレーション反応を利用して二次元ハイブリッド材料を作製しており、カオリナイト等の層状物質のインターカレーション化学を発展させている。加えて新たな唇表面修飾技術も生み出している。もう一つのルートはブルーゲル法を利用しており、例えば有機リン化合物と金属化合物を用い、リチウムイオン伝導性などの性質を有する無機一方機パイブリッド材料を作制している。

修飾技術も生み出している。もう一つのルートはゾルーゲル法を利用しており、例えば有機リン化合物と金属化合物を用い、リチウムイオン伝導性などの性質を有する無機一有機ハイブリッド材料を作製している。

3.化学的に合成された前駆体からの無機材料の作製無機高分子を前駆体とした熱分解により非酸化物セラミックス材料を合成しており、特に高温/高圧プロセスによる、起硬材料である窒化物高圧相の作製を行っている。また、テトラクロロ鉄(III) 酸陰イオンを含む前駆体からのマヴネタイトナノ粒子の作製も行っている。さらに、前駆体から多孔質炭素材料を作製し、その応用の可能性を検討するために電気化学的性質を調査している。

We have been involved for some time in preparation of organic-inorganic hybrid materials as well as inorganic materials by seamless use of inorganic and organic chemistry. Our recent research activities can be divided into the following categories:

1. Preparation of inorganic-organic hybrid materials via surface modification of inorganic

1. Preparation of inorganic-organic hybrid materials *via* surface modification of inorganic nanomaterials.

Inorganic-organic hybrid materials have been prepared using inorganic nanomaterials, lnorganic-organic hybrid materials have been prepared using inorganic nanomaterials, typically transition metal oxide nanoparticles and nanosheets. Organic groups are immobilized on the surfaces of inorganic nanomaterials *via* surface modification with various coupling agents, including phosphorous compounds, such as organophosphonic acids and esters of phosphoric acid, and alcohols. In particular, surface modification using biphasic systems on both bulk and micro scales has been developed. Grafting of polymer chains has also been achieved *via* atom transfer radical polymerization (ATRP) using organophosphorous compounds bearing ATRP initiator groups and subsequent polymerization. These have been enployed as nanofillers for polymer-based hybrids, and the properties of the resulting polymer-based hybrids including optical and mechanical properties have been evaluated. Regioselective surface modification of nanosheets, on the other hand, can provide Janus nanosheets bearing two properties located separately, one each of the two surfaces of individual nanosheets. They can be utilized as a two-dimensional surfactant and a dual-functional material.

2. Preparation of organic-inorganic hybrid materials *via* chemical routes. One route utilizes intercalation reactions, insertion of ions and molecules in the interlayer space of layered compounds, to provide two-dimensional hybrid materials. Intercalation chemistry for some layered compounds, such as kaolinite, has been developed. New intercalative grafting reactions have also been produced. Another route involves a sol-gel process, which typically utilizes organophosphorous compounds and metal compounds, for preparing organic-inorganic hybrid materials with such functions as Li-ion conductivity.

3. Preparation of inorganic materials have been prepared from inorganic polymers

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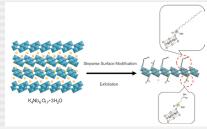


Figure 1 Janus nanosheets

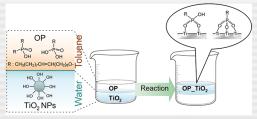


Figure 2 Surface modification of titanium dioxide nanoparticles in a liquid-liquid biphasic system.