

Gels Serving as Carriers for Functional Fillers and Facilitating Novel Composite Paper Production

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Functional fillers can facilitate the development of novel composite paper products for specific end uses. But using functional components as fillers by direct addition to the fiber suspension may fall short of the desired goals. The functional filler may fail to be efficiently retained. Gels can serve as carriers of functional paper fillers by coupling with them during *in-situ* synthesis and the gelation process. This strategy is favorable for the effective utilization of functional paper fillers, without hampering the intrinsic properties of paper. Additional merits of this strategy include versatility and compatibility with existing paper-making processes.

Keywords: Gel; Filler composites; In situ synthesis; Composite paper

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Functional Fillers and Functional Composite Paper

Fillers have become the second most important component, by mass, of the paper stock. The addition of this component can reduce the production costs while enhancing many properties such as brightness and printability. Moreover, functional fillers can facilitate the development of functional paper for specific end uses. For example, metal-organic frameworks (MOFs) have promising potential in environmental remediation. The combination of MOFs and cellulose-based paper can take advantage of the low-cost, renewable, and highly industrialized matrix.

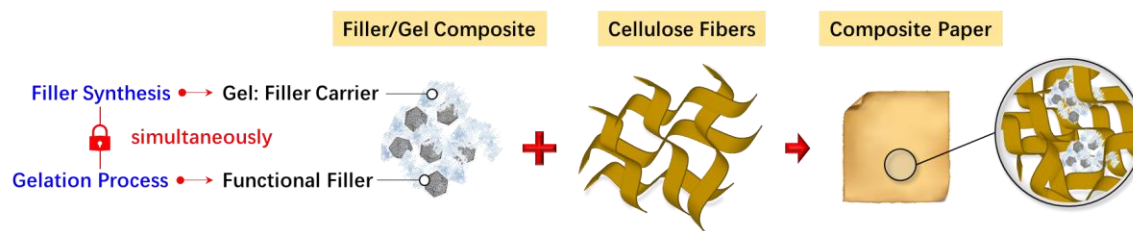
Incorporation of Functional Fillers: Challenges

Using functional components as fillers for paper products ought to be a facile practice. However, conventional filling methods sometimes fail to achieve desirable results. Why can't functional components, taking MOFs crystals as an example, be directly used as fillers? The challenges can be demonstrated in the following aspects. First, the functionality of fillers could be compromised during the papermaking process, due to the vigorous hydrodynamic shear and the chemical environment. Secondly, functional fillers would significantly impact some basic properties of paper (such as uniformity and strength). Thirdly, the size of functional fillers could be smaller than conventional fillers, which leads to lower efficiency of filler retention.

Gels as Carriers of Functional Fillers

Among various innovations related to fillers for paper, the design of filler composites has aroused general attention both industrially and academically. Here we would like to discuss a strategy utilizing gels as the carriers of functional paper fillers. For instance, chitosan gel, when serving as a carrier of MOFs, can protect the functional

fillers from being damaged or washed away. It also can protect the composite paper from mechanical deterioration. Such results originate from the natural compatibility and affinity between chitosan and cellulosic fibers. To carry out this strategy, the critical point is to couple the synthesis of functional fillers with the gelation process. The filler/gel composites are then added to the pulp and transformed together into the composite paper. The *in-situ* synthesis is of vital importance, which distinguishes this strategy from other filler modification methods, since it guarantees the uniform distribution of fillers and the strong filler-gel affinity.



Potential Merits and Challenges of Gel as Filler Carriers

Gels, as carriers for fillers, show many desirable features while facing some challenges.

- **Compatibility with existing papermaking processes:** Since the gel carriers are added directly to the pulp, this strategy is compatible with the existing paper-making procedures. Hence, continuous production capability can be realized. These features make commercial-scale production more likely.
- **Adaptability and Versatility:** Different filler/gel composites can be obtained by using different metal ions and ligand molecules. Another contribution of this strategy is to fabricate composite paper with different kinds of functional fillers. Composite gels with different kind of functional fillers can be integrated into one paper product, which may be challenging otherwise.
- **Coupling of synthesis and gelation:** For different functional fillers, it may be important to choose the suitable polymer to serve as the gel carrier. Thus, the coupling of functional fillers synthesis with gelation process is an ongoing exploration.

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