# Cellulose Nanocrystal (CNC)-Stabilized Ferrofluids: Effective Stabilization Condition for Optimized Magnetic and Self-Heating Performance

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This study presents the development of biocompatible and eco-friendly ferrofluids (bio-FFs) by stabilizing magnetite nanoparticles (MNPs) on cellulose nanocrystals (CNCs) derived from bacterial cellulose with the ultimate aim of utilizing the structural anisotropy of CNCS along with the magnetic anisotropy. The nano-scale stabilization of CNCs unravels the optimized magnetic saturation (22 emu/g), self-heating efficiency (90 °C in 900 seconds), excellent biocompatibility, and tunable flow behavior, making them suitable for biomedical applications. The bio-FFs exhibit reproducible cyclic heating performance and stability under varying environmental (pH and humidity) conditions, highlighting their potential for hyperthermia, targeted drug delivery, and environmental remediation.

*Keywords: Magnetic nanofluids; Bacterial cellulose; Sustainable stabilization; Magnetic anisotropy; Structural anisotropy.*

## 1. Introduction

Ferrofluids (magnetic nanofluids) have significant potential for applications ranging from nanomedicine to environmental solutions, where stabilizing MNPs without harsh chemicals is crucial [1]. Optimized stabilization at the nanoscale can enhance their magnetic response, flow behavior, and self-heating performance, which can be effectively leveraged in hyperthermia treatment and targeted drug delivery. In this work, we fabricated the bio-FFs by stabilizing MNPs on CNCs, which serve as nanoscale biocompatible stabilizers due to their high aspect ratio, anisotropic morphology, and thermochemical stability (Figure 1).

## 2. Results and discussion

The bio-FFs with tailored rheo-magneto-thermal response have been fabricated by anchoring the MNPs ($Fe_3O_4$) on three different concentrations of CNCs that have been derived from bacterial cellulose (BC) via standard acid treatment.

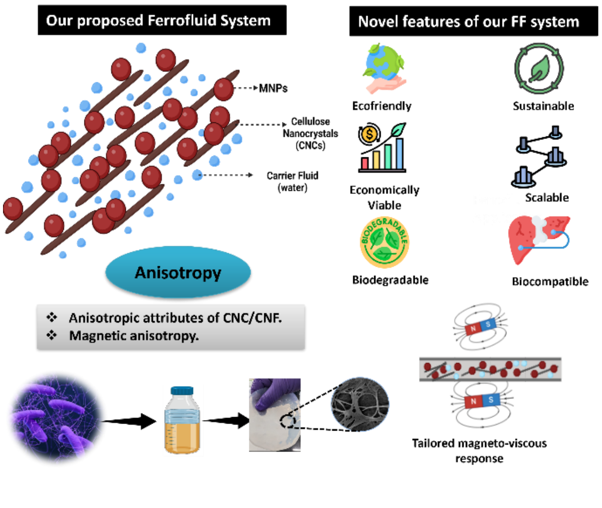


Figure 1: Schematic representation of MNP's stabilization on CNC and novel features of synthesized bio-FFs.

The extensive investigation of the structural, morphological, magnetic, induction heating, rheological, and maneuvering aspects of these bio-FFs has revealed the pronounced role of CNC concentration. As a result, we achieved optimized magnetic properties with saturation magnetization values up to 22 emu/g (Figure 2a), tunable flow behavior (Figure 2b), self-heating performance of up to 90 °C in 900 seconds (Figure 2c), and excellent biocompatibility (even at 10 mg/mL of bio-FF) at a specific CNC concentration, attributed to the efficient stabilization of MNPs. Moreover, the reproducibility of cyclic heating performance, along with stable magnetic properties under varying pH, temperature, and humidity conditions, underscores the potential of these sustainable bio-FFs with adjustable rheo-magneto-thermal characteristics for diverse biomedical applications.

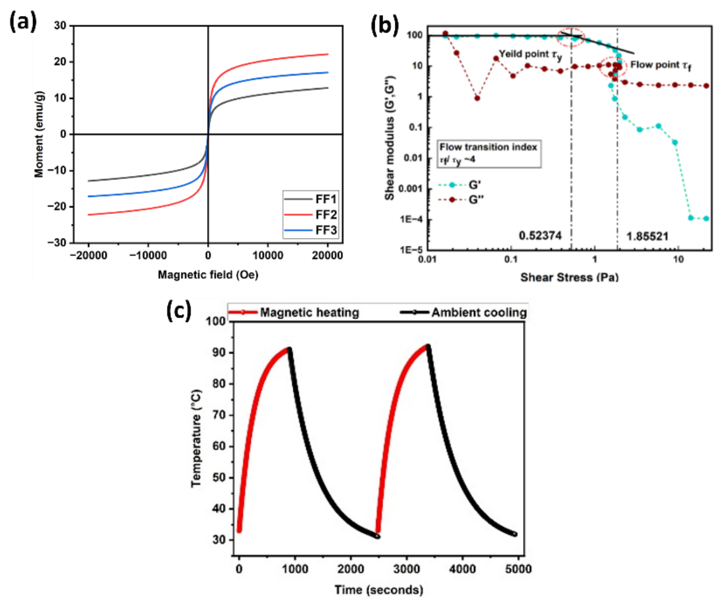


Figure 1: (a) Room temperature M-H curves of bio-FFs, (b) Rheological properties of FF2, (3) Self-heating attributes of FF2.

## References

[1] Xu et al., Chem. Eng. J. 443 (2022), 136252.