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Master of Science HES-SO in Life Sciences

Formulation of nanoparticle containing functional inks for modern printing techniques

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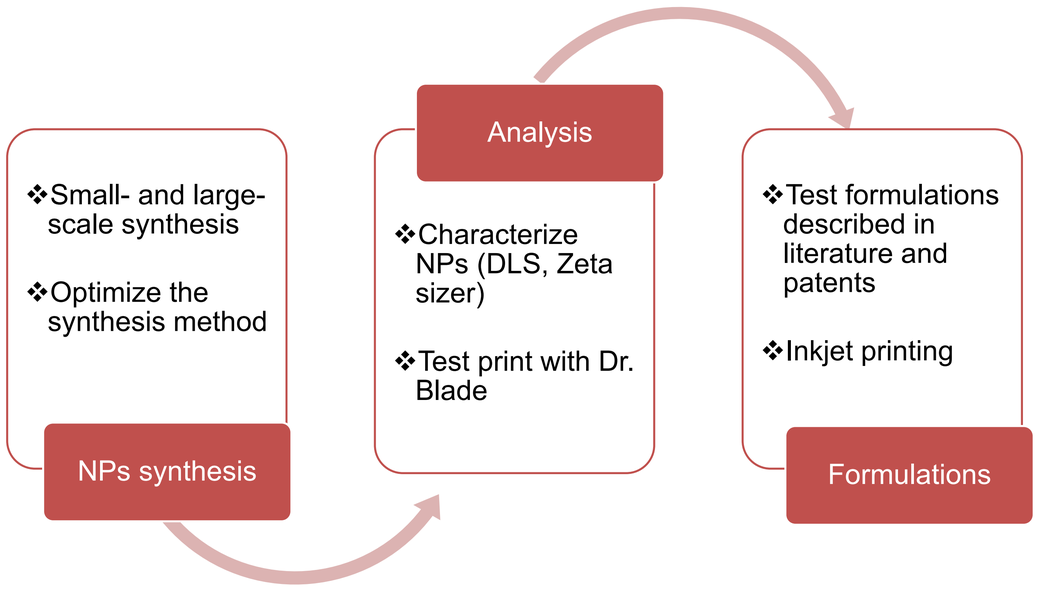
DESCRIPTION

Functional inks containing nanoparticles (NPs) have a wide range of applications in the electronics and decoration industries, stimulated by the affordable availability of these nanoparticles and skills in large-scale synthesis. Several sectors are currently in transition to Industry 4.0, characterized by a shift from analog to digital production methods. In the case of the packaging industry, for example, the most widespread process is hot stamping (Fig.1) to introduce metallic-type decorative elements. But inkjet printing, a non-impact digital technique, offers advantages such as low costs, high quality, high productivity and precise control of the volume of ink deposited. Inks must meet strict physico-chemical properties (surface tension, viscosity, adhesion to substrate, etc.) to obtain optimum reliability and performance from the printing system, as well as the best resolution.

Fig.1 : Hot stamping technique on the left and inkjet printing on the right

OBJECTIVES

The aim of this work was to formulate a stable, low-toxicity aqueous ink based on metal nanoparticles to enable inkjet printing with a specific rendering. To achieve this goal, several objectives have been set and summarized in the diagram below.



RESULTS

Synthesis

The optimization of the synthesis scale-up (Fig.2) was mainly based on the safety of the purification process, by adjusting the centrifuging temperature and the quantity of water to reduce the potentially explosive atmosphere. It was found that adding water to the purification process, regardless of the centrifuging temperature, did not achieve the desired visual effect, despite an increase in reaction yield. To combine safety and optimum visual effect, a centrifugation temperature of 10°C and 100% MeOH were chosen, but still exceeded the LEL by 0.6%.

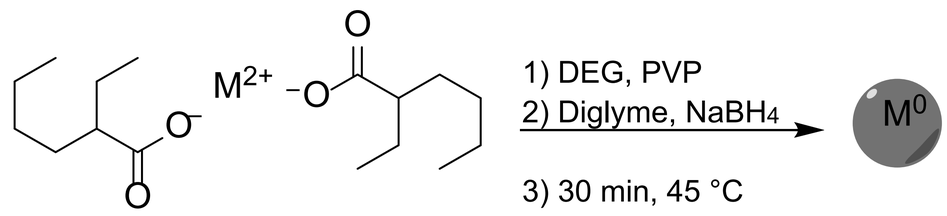


Fig. 2 : Reaction of reduction to form NPs

This synthesis allows to produce ~15 g of NPs, with a yield of 61 ± 10 % and a mean hydrodynamic nanoparticle diameter of 20.95 ± 3.95 nm.

Formulation

The formulation of a mainly aqueous, non-toxic ink was studied. It was noted that the addition of organic solvents tends to impair the visual appearance and reduce the abrasion resistance of the deposition on the substrate. It was essential to formulate an aqueous ink based on several components, namely humectants to increase viscosity and surfactants to adapt the ink's surface tension and enable good adhesion with the substrate. The final formulation was produced by comparing its properties with those of a commercial Epson ink for inkjet printing (Table 2). The ink produced in the laboratory could be printed with an inkjet printer, providing the desired visual effect and optimum print quality without satellites. But it fades when the finger is wiped directly after printing.

Table 2 : Physical characteristics of inks

Properties	Ink Epson 111	Ink laboratory
Hydrodynamic particle diameter [nm]	19.22 ± 3.56	16.39 ± 2.96
Dynamic viscosity [mPa*s]	3.220 ± 0.060	2.032 ± 0.024
Static surface tension [mN/m]	27.35 ± 0.10	30.87 ± 0.04
Density [g/ml]	1.038	1.059

The formulated ink is stable for up to 12h in the printer, after which creaming is observed and nanoparticles tend to sediment. The ink must therefore be removed from the printer after each use and stored under argon gas on a stirring plate to preserve its properties.

CONCLUSION

In conclusion, the synthesis of metal nanoparticles was optimized by focusing primarily on the visual aspect of NP deposition in aqueous media, rather than on the yield of the synthesis. Scale-up of the synthesis proved reproducible, but the safety aspect of the purification step still needs to be improved. Consideration could be given to purging the centrifuge with argon or using a continuous flow to eliminate the risk of explosion. As far as formulation is concerned, printing results are in line with expectations, with exceptional quality. To overcome problems of deposit abrasion after printing, a surface treatment or protective coating could be applied.

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