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# “Fablab ready” 3D printed piezoelectric composites

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**Abstract** — In this communication, we report the manufacturing process of green piezoelectric samples that can easily be produced in any *Fablab*. The method combines conventional 3D printing of a polymer matrix with liquid phase epitaxial grown of a piezoelectric salt. Piezoelectric resonators enhancing high coupling factors were successfully fabricated using this process. These composite transducers composed of Polylactic acid (PLA) and Rochelle Salt (RS) (or other piezoelectric salt) are promising for low energy budget or eco-friendly applications.

## I. INTRODUCTION

Additive manufacturing enables the development of low-cost environmental sensing systems for smart packaging [1]. However, for widespread deployment of IoT, the development of eco-friendly disposable smart labels is necessary [2]. Previous works on green piezoelectric devices have shown the impregnation of biodegradable Rochelle salt (RS) crystals into cellulose sheets or naturally orientated capillaries of wood [3,4], which produced eco-friendly composite bulk devices. Here we propose an additive manufacturing process combining conventional PLA 3D printing and liquid phase epitaxy. The obtained devices can be used as disposable harvester or resonators with quite high quality factors and low energy budget.

## II. METHOD

The piezoelectric samples were produced with the following method. First, disk shaped PLA matrices (Figure 1) were printed by using Ultimaker 3D printer (V1.1). PLA filament was also provided by the same company. In parallel, some RS crystal seeds were grown in order to get large single crystals (at least 2 cm wide). The crystal growth was done in an over saturated solution at room temperature (around 21°C) by mixing deionized water and RS powder provided by APC pure. Then a RS seed was attached a PLA matrix on one side and deeped into over saturated solution at 10°C in order to initiate the liquid phase crystal epitaxy through the PLA disk as shown in Fig.1. Once the PLA sample was completely embedded into the growing RS crystal (after 36 to 48 hours), it was removed from the solution. Then the exceeded RS from PLA matrix was removed by carefully cutting the RS crystal close to both sides of PLA disk and polished by sand paper until the PLA matrix surfaces appear again. Finally, electrodes were placed on the sample. Two aluminum disks (10 μm thin) were cut into commercial aluminum foil and stuck on both sides of the disk with Bare conductive ink (commercial name: “electric paint”). As previously mentioned, this manufacturing process is simple and feasible in any *Fablab* without any sophisticated equipment. Both energy and financial budgets of such a process are low compared to standard piezoelectric ceramic or even organic samples in terms of costs and complexity. Then electrical characterizations were performed in order to get the resonance

behavior of the manufactured piezoelectric disk samples. We have measured the impedance spectrum of the devices using E4980A, Keysight impedance analyser.

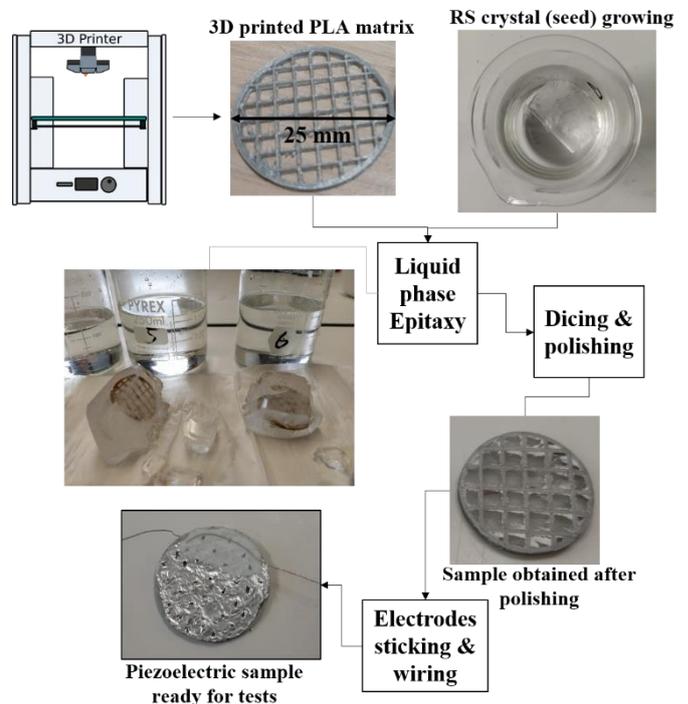


FIGURE 1. Illustration of the manufacturing process flow of the RS/PLA piezoelectric samples (diameter 25 mm, thickness: 2.5 mm).

## III. RESULTS

All samples emitted audible acoustic waves when driven electrically from 1 to 15 kHz. Moreover, the clear electromechanical coupling modes were observed in the admittance spectra of all manufactured samples. In particular, some RS based disks showed admittance spectra with well-identified resonant frequencies in ambient condition (Fig. 2).

In order to evaluate performance and reproducibility of our process we calculated the resonant frequency ( $f_r$  [Hz]), quality ( $Q$ ) and coupling factors ( $k_p$ ). RS/PLA composite disks exhibit high resonant frequencies and  $Q$  factors. First resonant mode is around 47 kHz, and average quality factor is close to 80 (Fig.3). Therefore, these devices exhibit better performances compared to the ones obtained in previous works [3,4]. Coupling factors, close to 0.2, are encouraging in order to target energy harvesting in the future. Nevertheless, the standard deviations of these sets of parameters are still quite high. This indicates that our manufacturing process can still be improved in order to get better reproducibility.

factors ( $k_p$ ) extracted from conductance and susceptance spectra of RS/PLA pseudo composite samples.

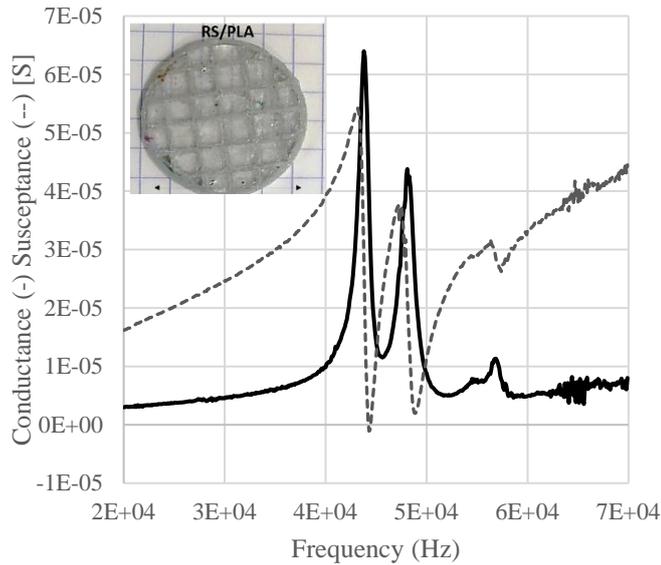


FIGURE 2. Conductance and susceptance spectra of 2.5 mm thick RS/PLA manufactured sample.

#### IV. CONCLUSION

In conclusion, we have successfully manufactured RS/PLA composite piezoelectric transducers using 3D printing of a PLA matrix on which the RS piezoelectric crystals were grown by liquid phase epitaxy. The piezoelectric performance was improved on these new samples compared to the previous results [3,4]. This new process allows to manufacture at low cost, and in any fablab, of biodegradable piezoelectric resonators with quality factor up to 110. There is a nice potential for these elements to be implemented in smart objects for energy harvesting or sensing applications with eco-friendly considerations. In facts, the energy budget needed to manufacture such RS/PLA composite piezoelectric disk is extremely low and performances obtained are being acceptable. Finally, this manufacturing technique is applicable for any crystalline piezoelectric salt.

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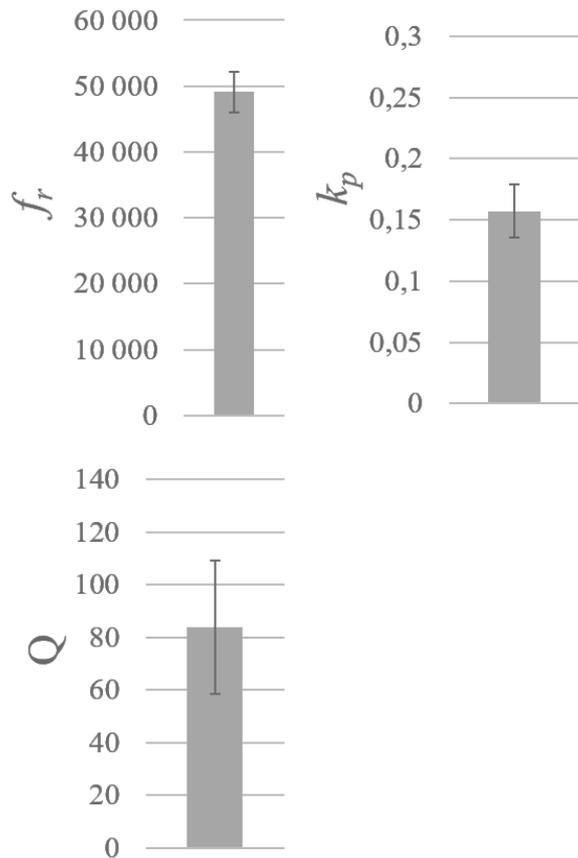


FIGURE 3. Resonant frequencies ( $f_r$  [Hz]), quality factors ( $Q$ ) and coupling