NANOCELLULOSE REINFORCED PVDF SPEAKER

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Background

- Piezoelectric materials generate mechanical strain proportional to applied electric charge
- PVDF is a piezoelectric polymer when it is in the β-phase (See Figure 1)
- PVDF film exhibits piezoelectric behavior in specific planes relative to an applied electric field (See Figure 2)
- Crystalline nanocellulose (CNC) filler provides electrical and mechanical properties and potential cost savings
- Piezoelectric PVDF films can serve as an audio speaker
- The range of human hearing is approximately 20 Hz – 20,000 Hz

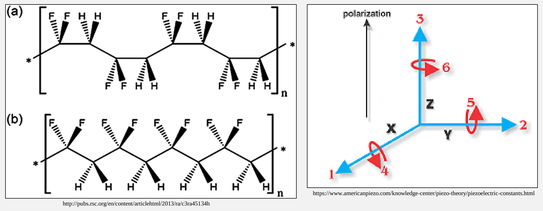

Figure 1(a): α-phase of PVDF
Figure 1 (b): β-phase of PVDF where the fluorine atoms are aligned on one side and hydrogen on the other.

Figure 2: Different strains that a piezoelectric film can experience for an electric field in a given direction

Methods

•PVDF film is cast in a solution of nanocellulose and DMAC for four hours

•Thickness is measured with a micrometer

•Film is coated with silver ink on both sides to evenly distribute charge across the film

•Frequency of electricity is applied at discrete intervals and increased by 100 Hz using a waveform generator

Figure 3: Solution of CNC and DMAC is left in rotary caster with a heat gun applied to maintain 60 ºC for four hours

Objective

Investigate the use of crystalline nanocellulose (CNC) as a filler in polyvinylidene fluoride (PVDF) films for use in two-dimensional audio speakers.

Tests were performed to investigate the effect of:

- Filler content (% CNC)
- Thickness of films (µm)

The effect of these parameters were analyzed by looking at

- Volume and sound quality of speaker
- Frequency range of produced sound

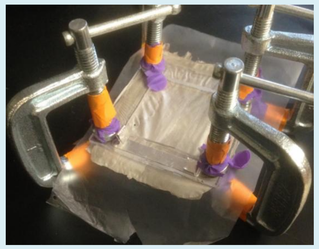

Figure 4: Original frame design made of polycarbonate with the use of four c-clamps to secure film

Results

Comparison of frequency vs. audio volume for different filler contents of nanocellulose in PVDF films and film coatings are summarized in the plots below. All films were tested over a frequency range of 800-16,000 Hz.

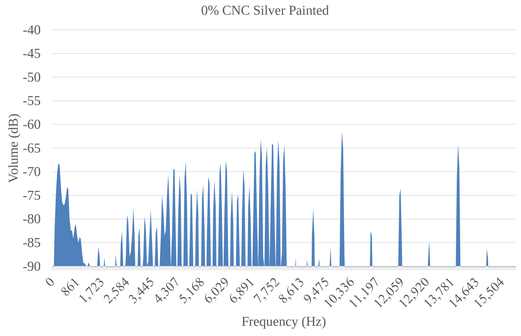

Figure 5: Volume produced by a 0% CNC film that was 30 µm thick. The film has been metalized with silver ink and tested using the polycarbonate frame. Large peaks below 1000 Hz are due to background noise.

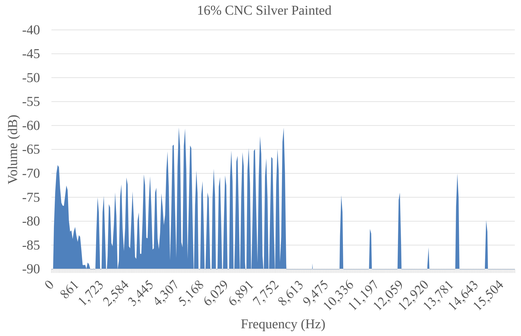

Figure 6: Volume produced by a 16% CNC film that was 37 µm thick. The film has been metalized with silver ink and tested using the polycarbonate frame. The CNC filled film has more peaks that pass -65 dB than the 0% film.

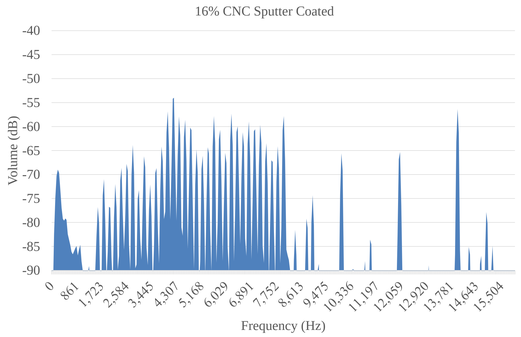

Figure 7: Volume produced by the same 16% CNC film as before. The film has been metalized by sputter coating with gold instead of silver ink and tested using the polycarbonate frame. Large peaks below 1000 Hz are due to both background noise and noise produced by the film.

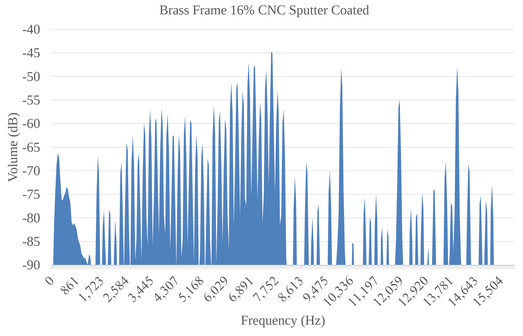

Figure 8: Volume produced by the sputter coated 16% CNC film and tested using the brass frame. Volume produced with this frame was substantially higher than the polycarbonate frame. Large peaks below 1000 Hz are due to both background noise and noise produced by the film.

Future Work

- Compare effect of different size and conductivity design on volume produced
- Poling the PVDF films by subjecting to large electric field
- Perform tests to determine mechanical robustness
- Cast with other methods to get wrinkle free PVDF films, to improve speaker sound quality
- Explore relationship between manufacturing geometry and optimal speaker orientation
- Compare thickness and sound results at same content filler of nanocellulose

Conclusion

- PVDF films filled with nanocellulose has greater volume compared to non-filled films
- Sputter coated PVDF films produce higher volume compared to films coated with silver ink
- Ring-shaped brass frame produced substantial higher volume compared to square polycarbonate frame

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