The Effect of Ultrasonic Spot Welding on the Piezoelectric β-Phase of PVDF

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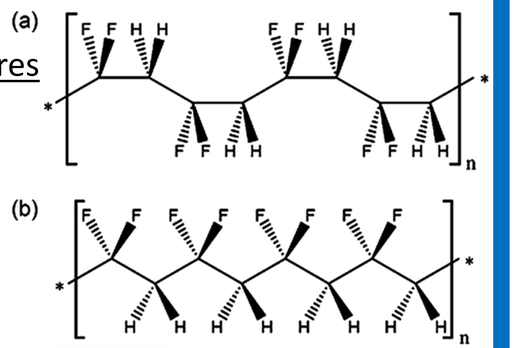
Introduction

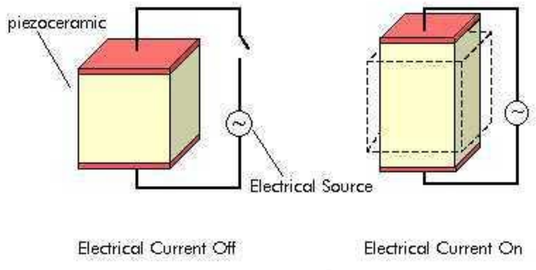
- Polyvinylidene Fluoride (PVDF)
  - A thermoplastic with four crystalline phases: alpha (α), beta (β), gamma (γ), delta (δ)
  - The β-phase is piezoelectric
  - A piezoelectric material accumulates an electrical charge from mechanical stress and vice versa

PVDF Crystal Structures

a) α-phase

b) β-phase





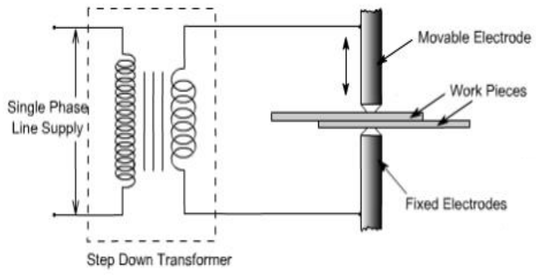
Images taken from http://pubs.rsc.org/services/images/RSCpubs.ePlatform.Service.FreeContent.ImageService.svc/ImageService/Articleimage/2014/RA/c3ra45134h/c3ra45134h-f1_hi-res.gif and http://webdocs.cs.ualberta.ca/~database/MEMS/sma_mems/img/piezoeffect.jpg

Objectives

- To transform α-phase PVDF samples into the β-phase
- Characterize the crystalline structure before and after welding

Procedure

- Step 1: Obtain β-phase by drawing
  - Use an 810 material testing system (MTS) to draw samples of PVDF at set rates and temperatures
- Step 2: Characterize (before welding)
  - Use x-ray diffraction (XRD) to asses the crystalline phases
- Step 3: Ultrasonic spot weld
  - Use a 20 kHz Dukane welder to join samples together using ultrasonic vibrations that cause friction, thus creating a weld



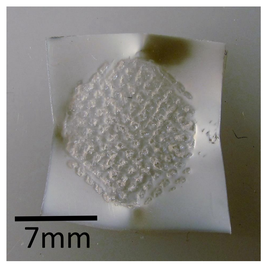


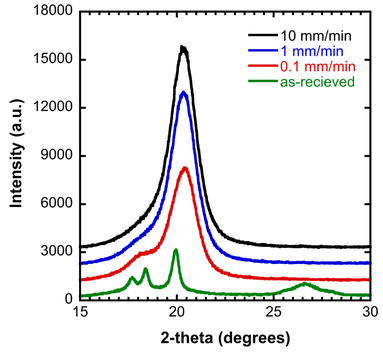
Image taken from http://nptel.ac.in/courses/112107144/welding/image/fig%2011.2.jpg

- Step 4: Characterize (after welding)
  - Use XRD to asses the crystalline phases

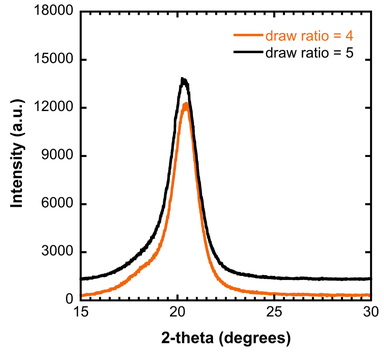
Results

- Drawing
  - The α to β transition was observed by noticing that the peaks at 17, 18, and 26 degrees flatten out and the major peak at 20 degrees shifts slightly to the right

Draw Ratio of 5



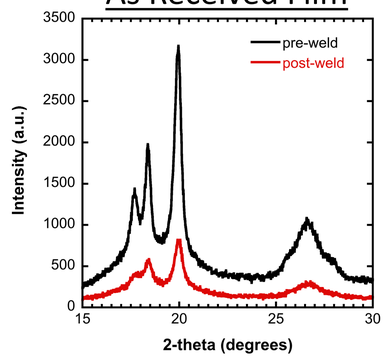
Draw Rate of 10 mm/min



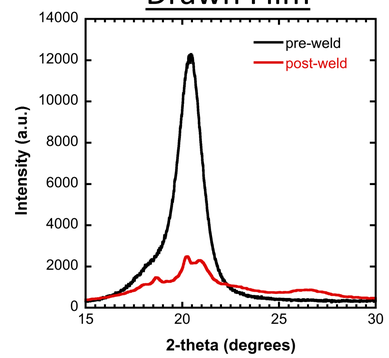
  - The β-phase was most defined when drawn at a temperature of 80˚C with a draw rate of 10 mm/min and a draw ratio of 5

- Welding

As Received Film



Drawn Film



  - The welded drawn film shows increasing peaks at 17, 18, and 26 degrees, indicating that the welding has transformed the PVDF back into the α-phase

Conclusion

- β-phase PVDF was obtained by a drawing and heat treatment
- Ultrasonic spot welding causes β-phase PVDF to partially transition to α-phase in the bonded area

Future Work

- Ongoing work is focused on the development of an in-house experimental setup to measure the piezoelectric constants of PVDF

Acknowledgments

This work was made possible by the National Science Foundation REU Back to the Future Site DMR-1460912. Special thanks to Dr. Michael West, Dr. Cassandra Degen, and Dr. Alfred Boysen. Other thanks to Navaneethaa Krishnan Pollachi Veluswamy, Bert Mannhalter, Todd Curtis, Russ Lingenfelter, and Austin Steffen.