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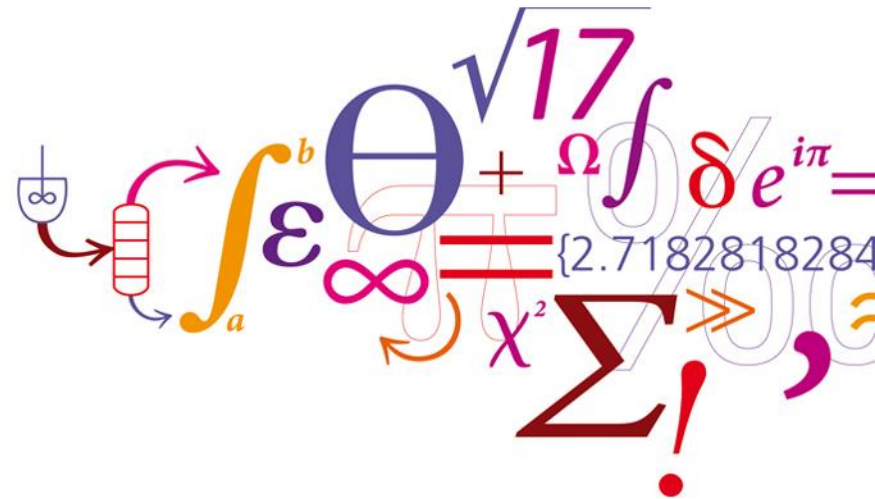
Improving dielectric permittivity by incorporating PDMS-PEG multi block copolymer into PDMS network

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Main supervisor: Anne Ladegaard Skov

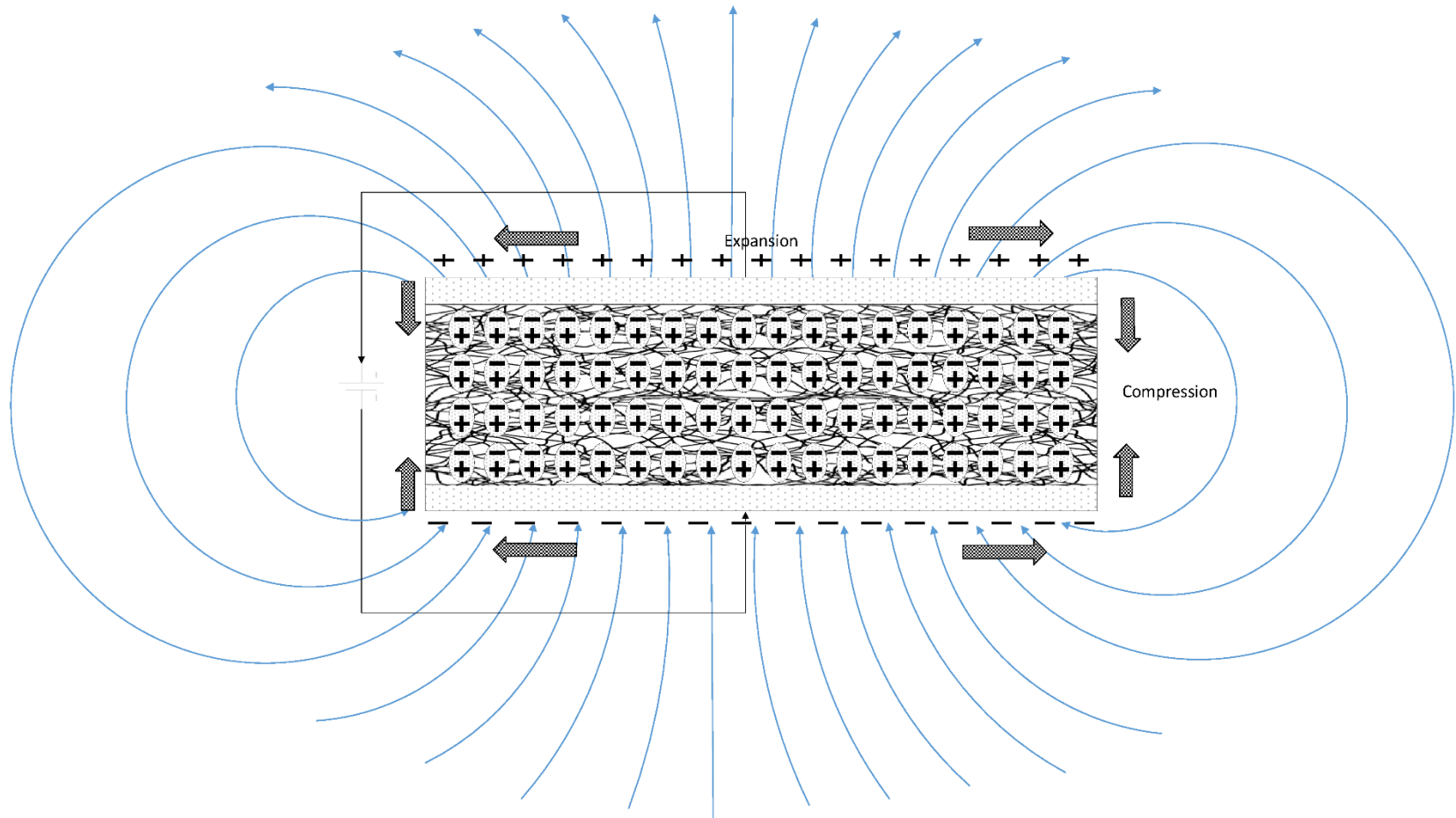
Co-supervisor: Peter Szabo



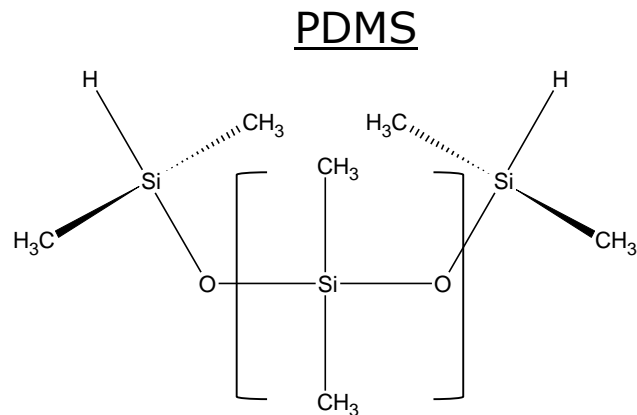
Outline

- INTRODUCTION:
 - Dielectric electroactive polymer (DEAP).
 - Poly(dimethylsiloxane) (PDMS) versus Poly(ethylene glycol) (PEG)
 - Morphology of block copolymer and phase continuity
 - Experimental setup and characterization methods
- RESULTS
 - Properties of PDMS-PEG multi block copolymer
 - Binary polymer blends of PDMS-PEG block copolymer and commercial PDMS elastomer
- CONCLUSION

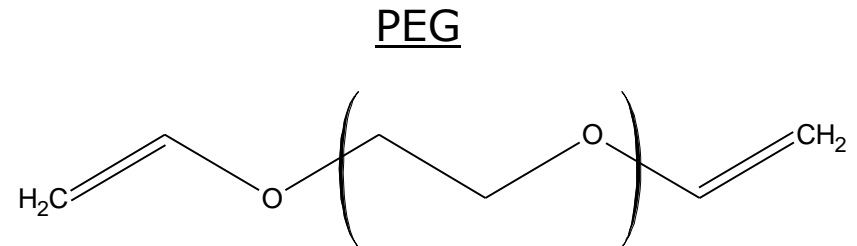
Principal of DEAP material



PDMS versus PEG

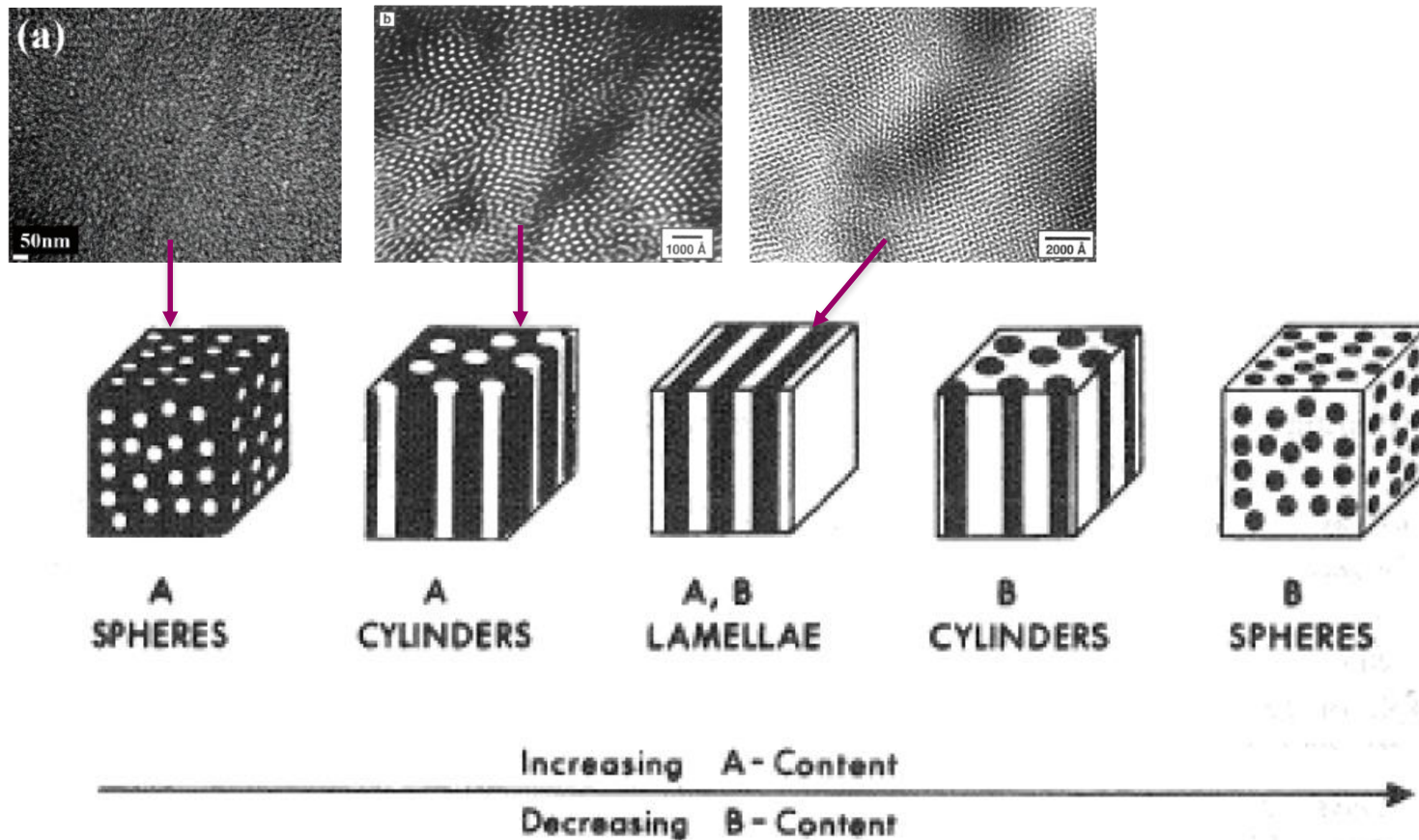


- Hydrophobic
- Low surface energy
- Low conductivity
- Wide temperature range
- High stability
- Low modulus
- Low permittivity



- Hydrophilic
- High surface energy
- Low toxicity
- High mobility in solution
- High permittivity
- High Conductivity

Morphology in block copolymer (AB) ^{1, 2}



¹ Bates, F. S., & Fredrickson, G. H. (1999). Block Copolymers—Designer Soft Materials. *Physics Today*, 52(2), 32. doi:10.1063/1.882522

² Khandpurj, A. K., et.al (1995). Diblock Copolymer Phase Diagram near the Order-Disorder Transition. *Macromolecules*, 28(26), 8796–8806.

Phases in polymer blend

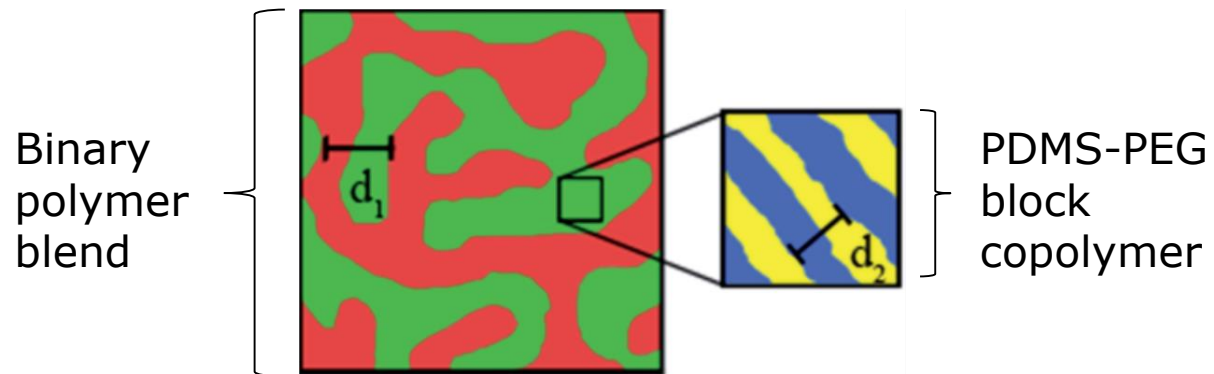
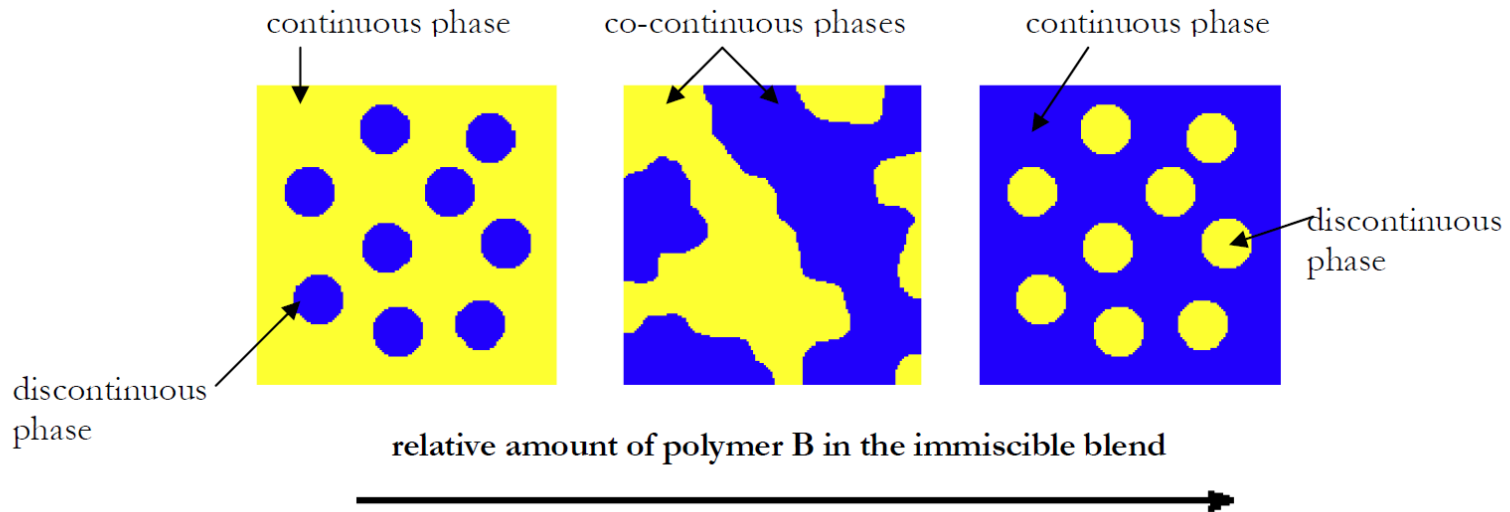


Illustration of PDMS: PDMS-PEG BC polymer blend

Habersberger, B. M.; Bates, F. S.; Lodge, T. P. *Soft Matter* 2012, 8, 3429–3441.

Sequence(s) of project

1st step - synthesize PDMS-PEG prepolymer

2nd step - Blending PDMS-PEG block copolymer with commercial PDMS elastomer

3rd step - crosslinking with methylhydrosiloxane-dimethylsiloxane copolymer (HMS-501)

Experimental setup

PDMS Hydride-terminated	Reactant	Average number of molecular weight M_n [g/mol]	No. of repeating units -reactant- (N)	No. of repeating units -block copolymer- (X)	Stoichiometry ratio (r)	Volume fraction of PDMS (f_A)
H21	PEG-DE	250,00	4	6	1,21	0,94
	PDMS Hydride-terminated	6000,00	81	5		
H11	PEG-DE	250,00	4	24	1,04	0,75
	PDMS Hydride-terminated	1050,00	14	23		
H03	PEG-DE	250,00	4	38	1,03	0,62
	PDMS Hydride-terminated	550,00	7	37		
SIH	PEG-DE	250,00	4	57	1,02	0,45
	PDMS Hydride-terminated	208,00	3	56		

Characterization

1. Chemical reaction
 - NMR (Si-H \sim 4.70ppm)
2. Mechanical properties
 - LVE properties.
 - Parallel plate (25 mm)
3. Electrical properties
 - Dielectric properties
 - 20 mm electrode
4. Contact angle
 - Sessile method
 - Static contact angle

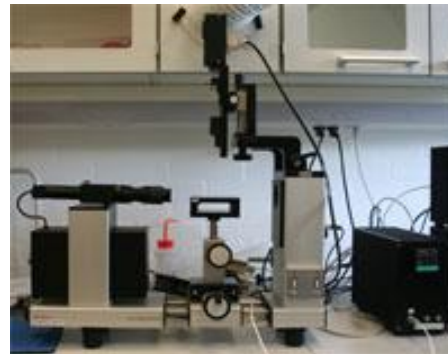
1. Bruker 300 MHz NMR



2. Rheometer (ARES-G2)



4. Dataphysics OCA20



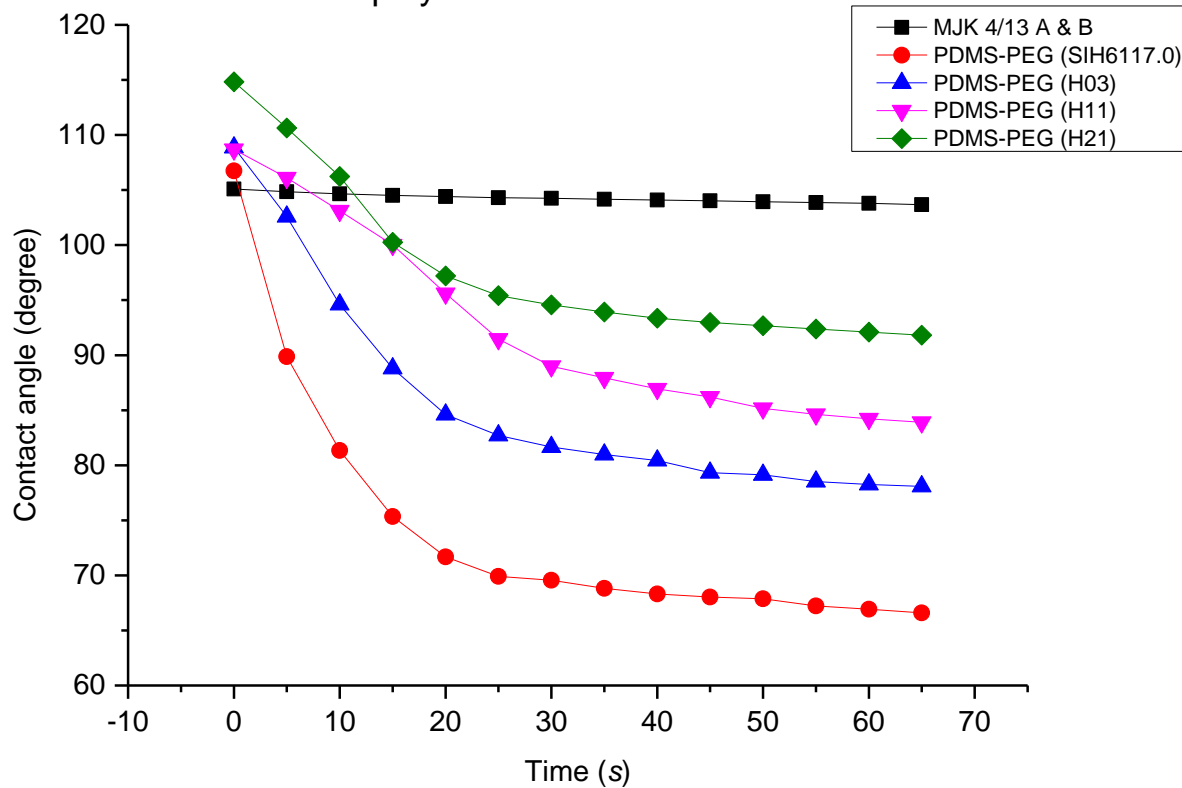
3. Novocontrol GmbH



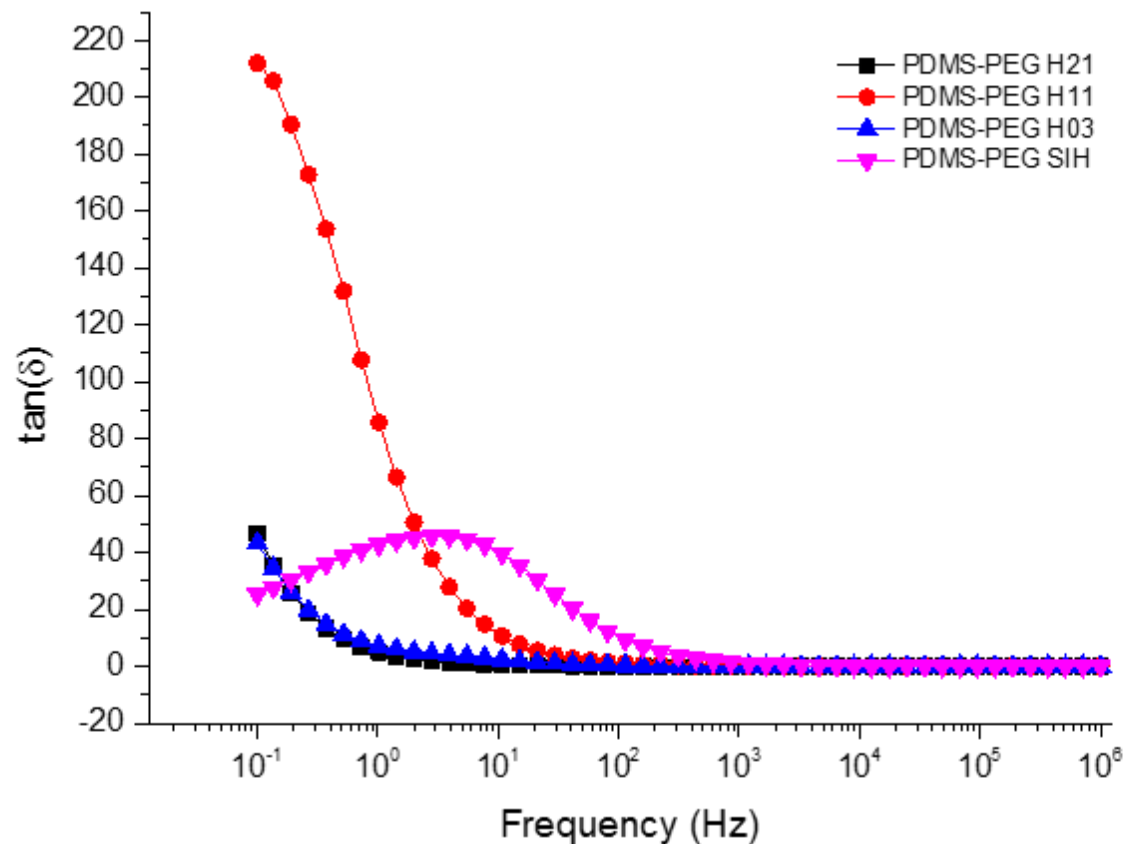
**Result: Block copolymer (H21, H11, H03,
SIH)**

Contact angle for all block copolymer

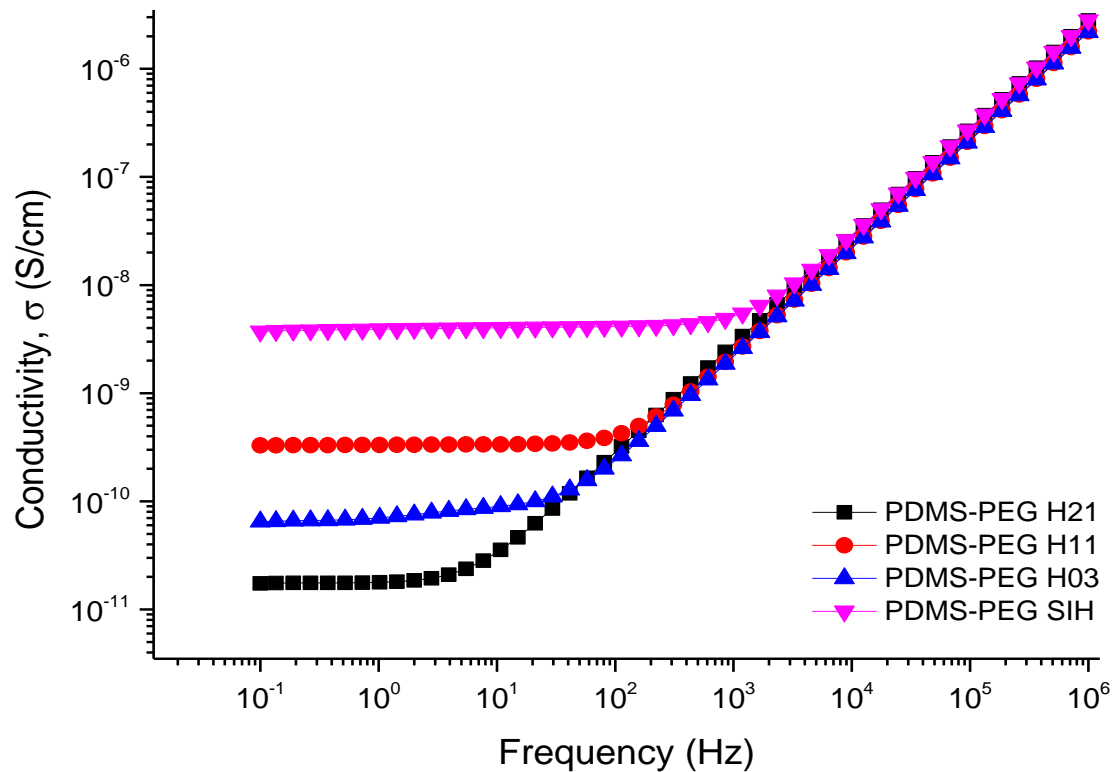
Comparison of contact angle between pure PDMS (Wacker) and PDMS-PEG block copolymers



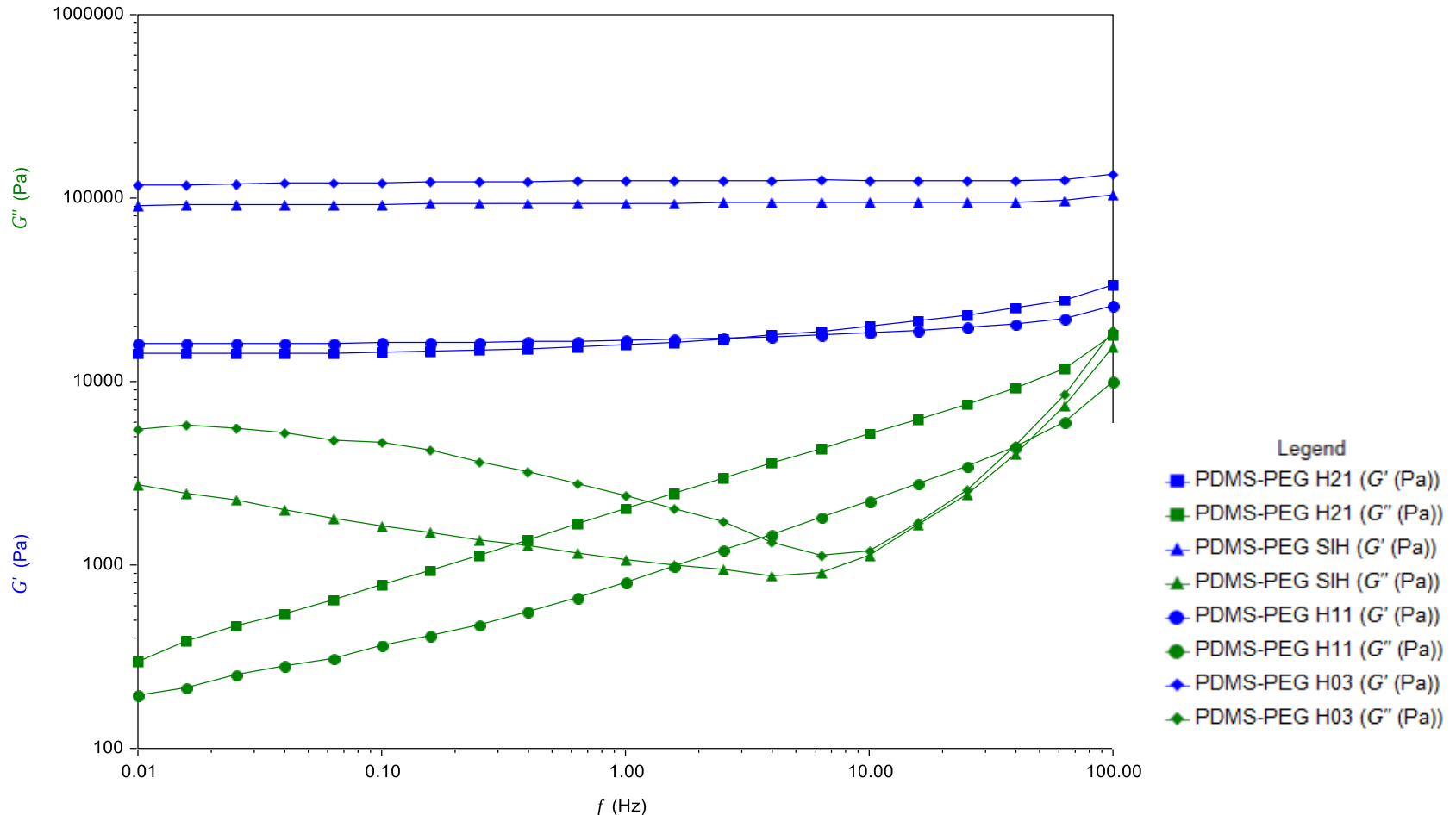
Comparison of **Permittivity** among H21, H11, H03 and SIH



Comparison of **Conductivity** among H21, H11, H03 and SIH

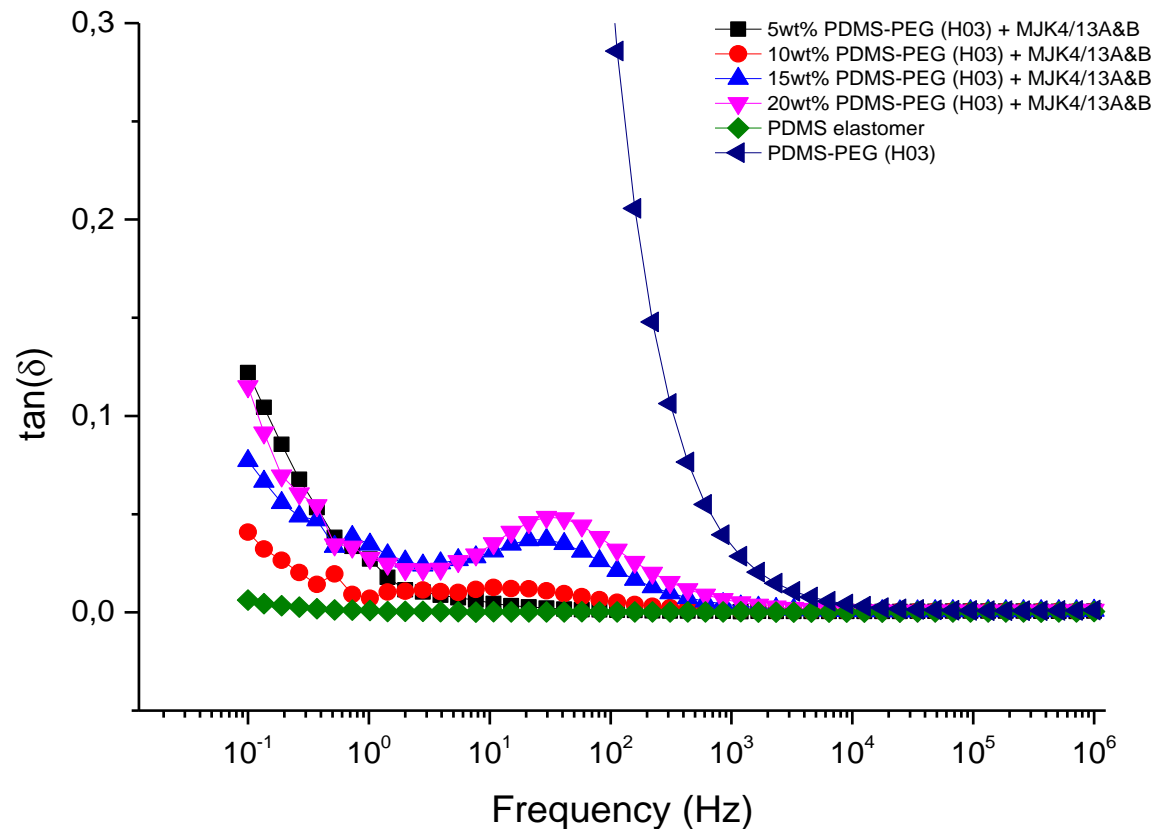


Comparison of **modulus** among H21, H11, H03 and SIH

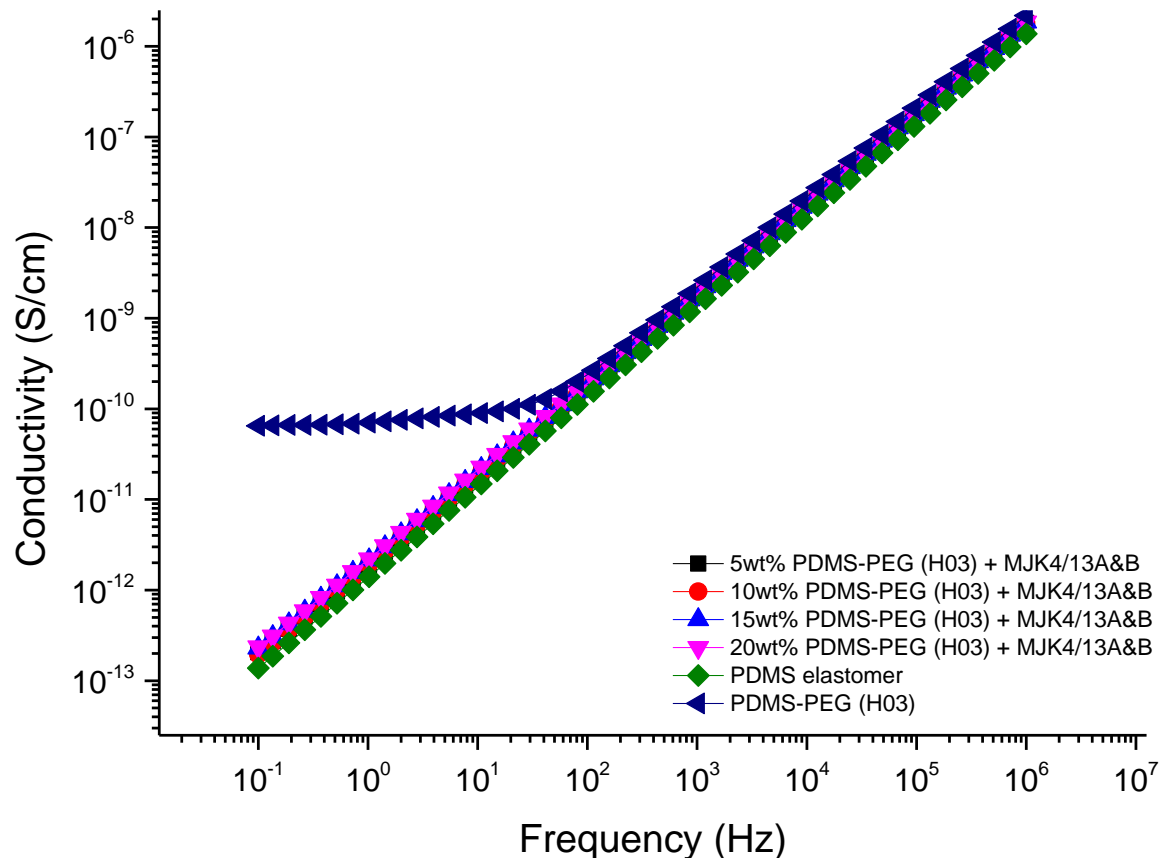


Result: Binary polymer blend of PDMS-PEG block copolymer and commercial PDMS elastomer

Comparison of **permittivity** for PDMS-PEG (H03) with commercial PDMS elastomer

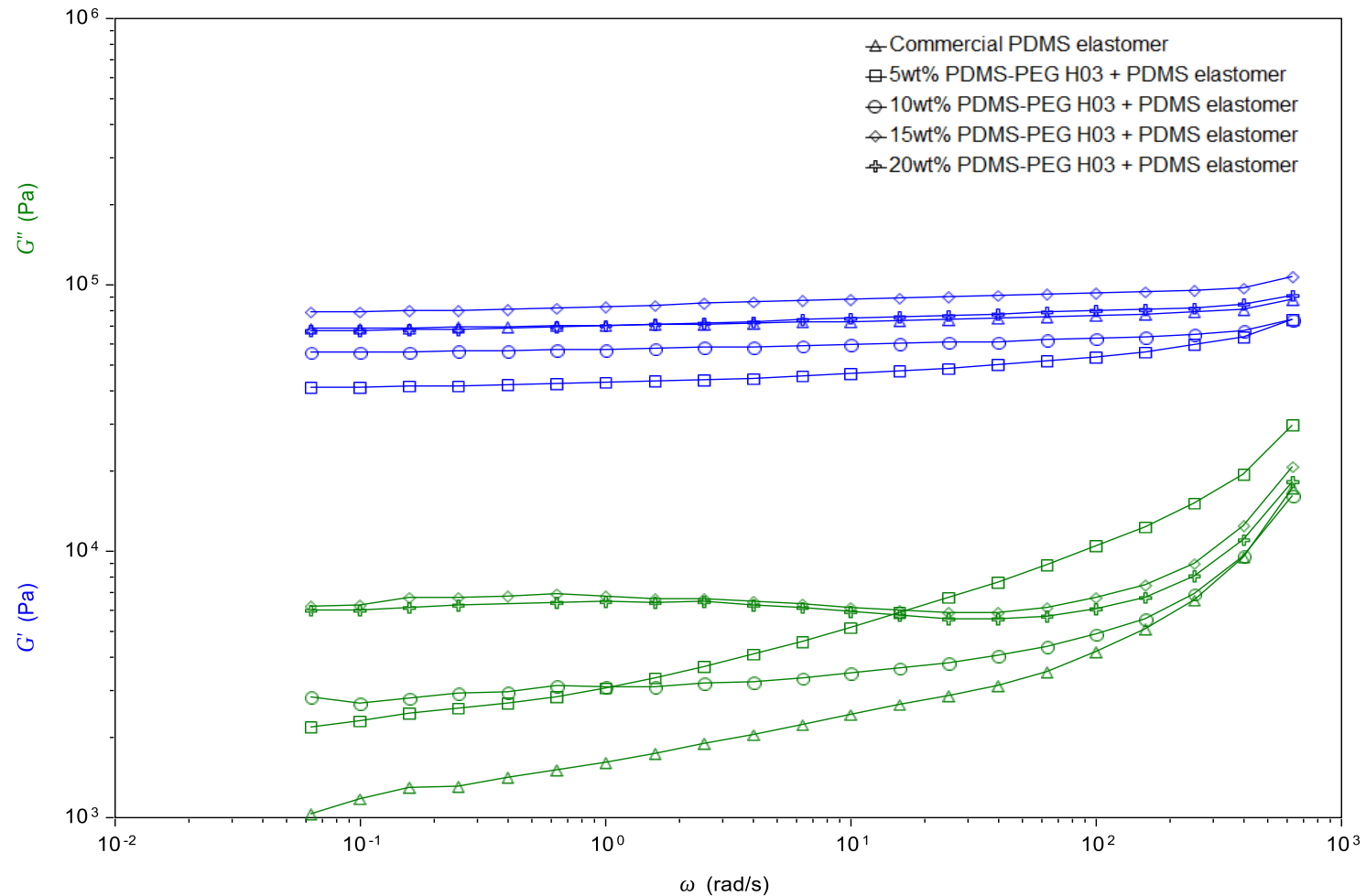


Comparison of **conductivity** for PDMS-PEG (H03) with commercial PDMS elastomer



Comparison of **modulus** for PDMS-PEG (H03) with commercial PDMS elastomer

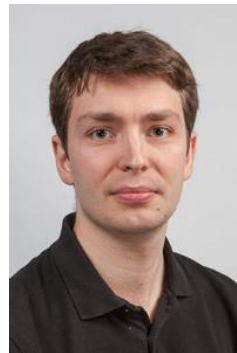
Overlay 2



Conclusion

- PDMS-PEG is a conductive block copolymer (10^{-8} S/cm) with amphiphilic behaviour.
- Incorporating PDMS-PEG (H03) with commercial PDMS elastomer:
 - Improve storage permittivity up to 60% with low loss permittivity.
 - Maintain LVE properties compared to the commercial.
 - Has amphiphilic behaviour (contrast with PDMS elastomer).

Thank you



DPP Group