Tribological behaviour of DLC and Si-DLC films deposited on nitrile rubber for piston seals

Michael Lubwama

Supervisors: Dr. B. Corcoran, Mr. K. Sayers, Dr. J.B. Kirabira, Dr. A. Sebbit

Sustainable handpump technologies

Outline

Brief background

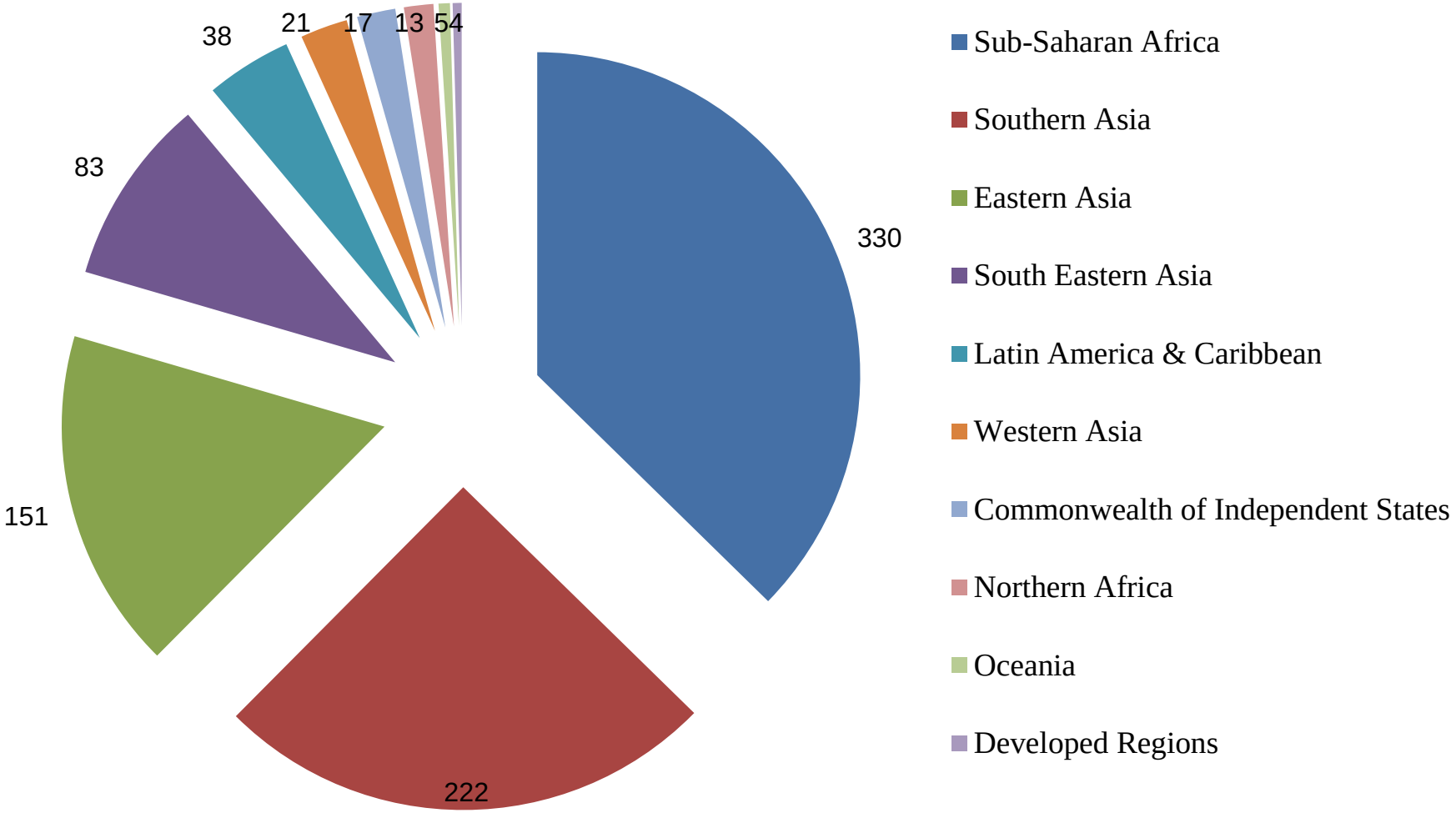
Aims and objectives

Methodology

Results

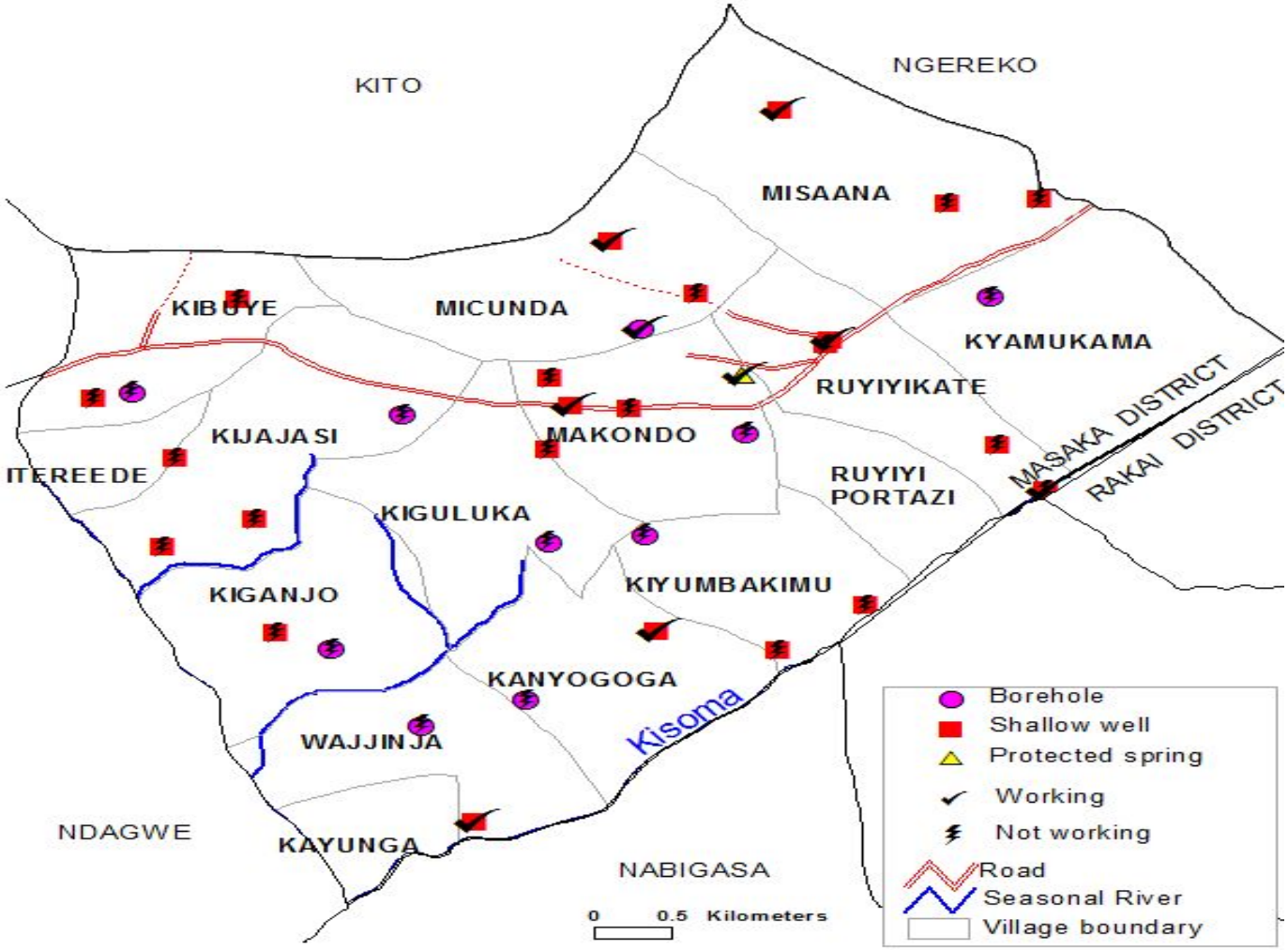
Conclusions

World Water Situation



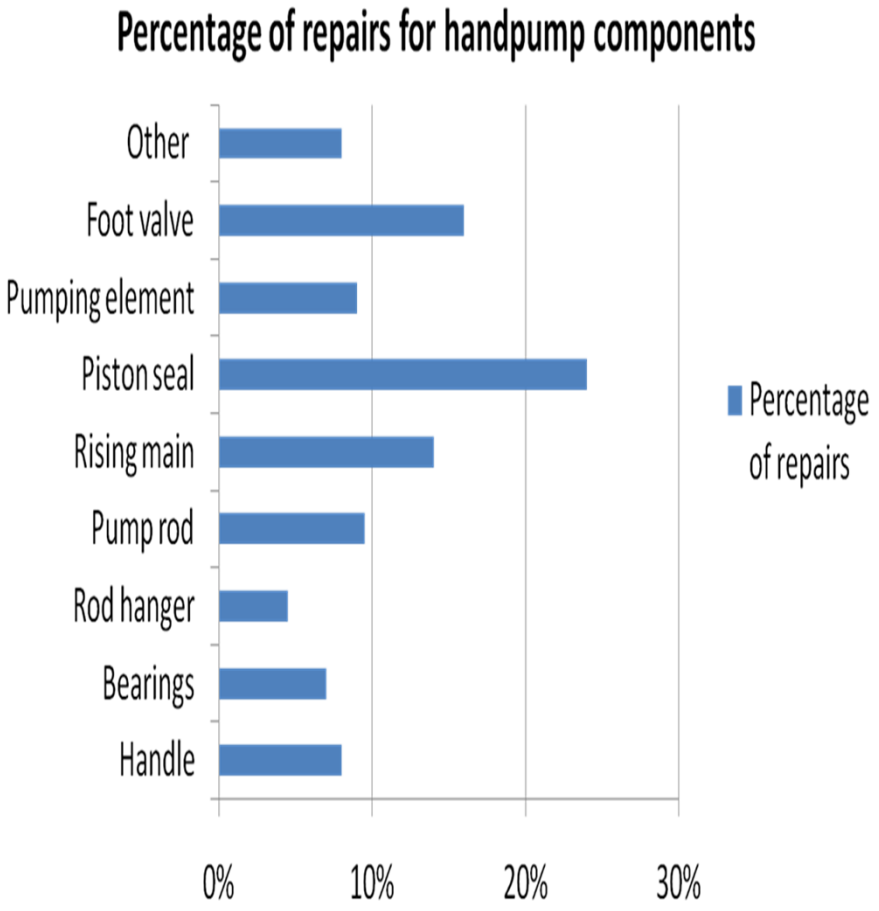
About 1 billion people do not have access to safe water; with sub-Saharan Africa accounting for about 33 % [JMP Report, 2010].

Water Situation – Makondo Parish

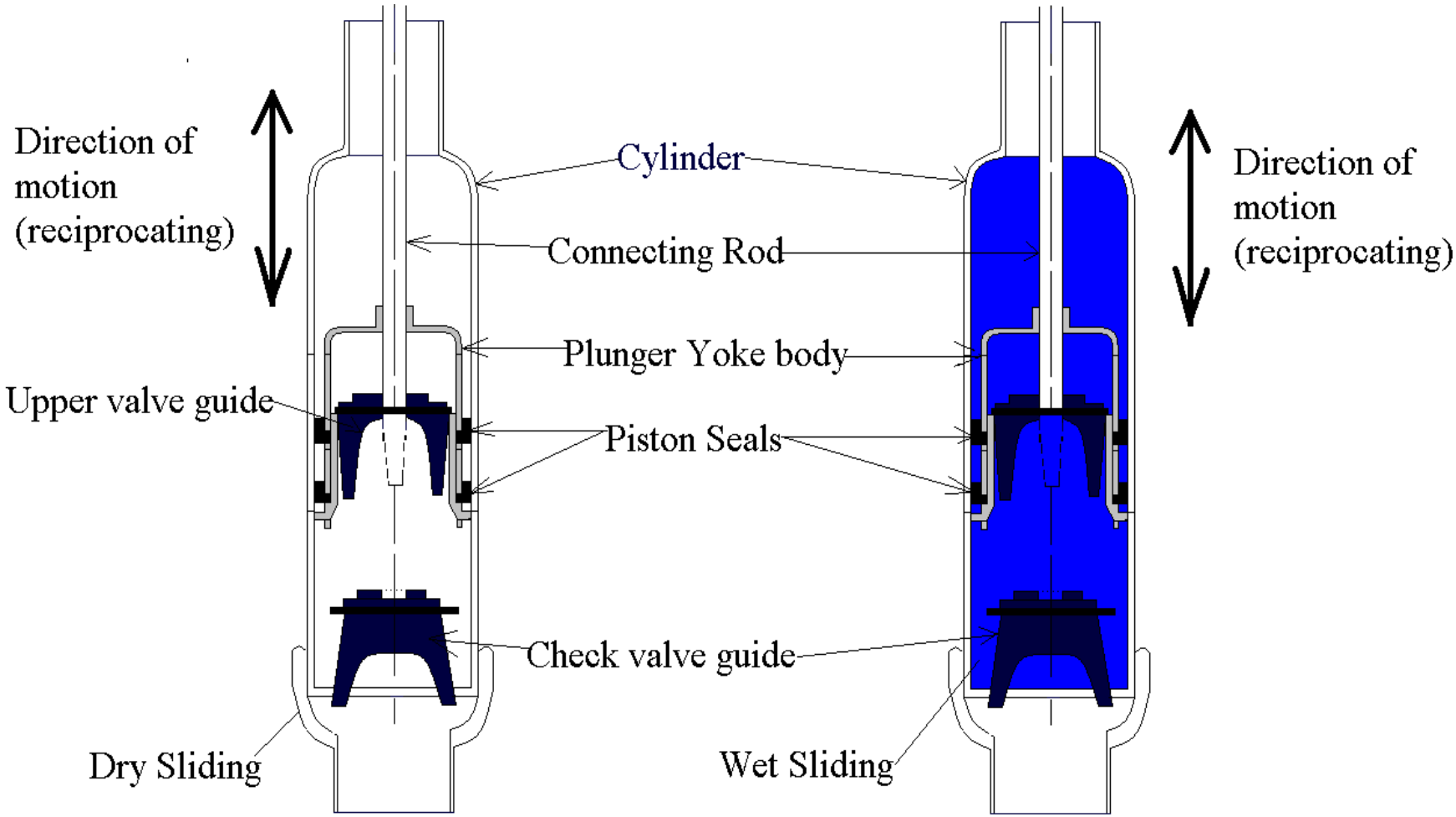


Less than one-third of the handpumps were functional

Handpump Component Repairs



Dry and Wet Sliding



Wear Mechanisms

$$V_{wear\_total} = V_{abrasive\_wear} + V_{adhesive\_wear} + V_{fatigue\_wear}$$

Functional Sustainability

- Handpump reliability is defined as mechanical availability [Reynolds, 1992]
- A trade off has to be made between reliability and maintainability
- Maximum pump functionality; minimal number of maintenance interventions
- Increased pump availability through longer operation time of the seal [Aspegren et al. 1987]

Surface Engineering Approach

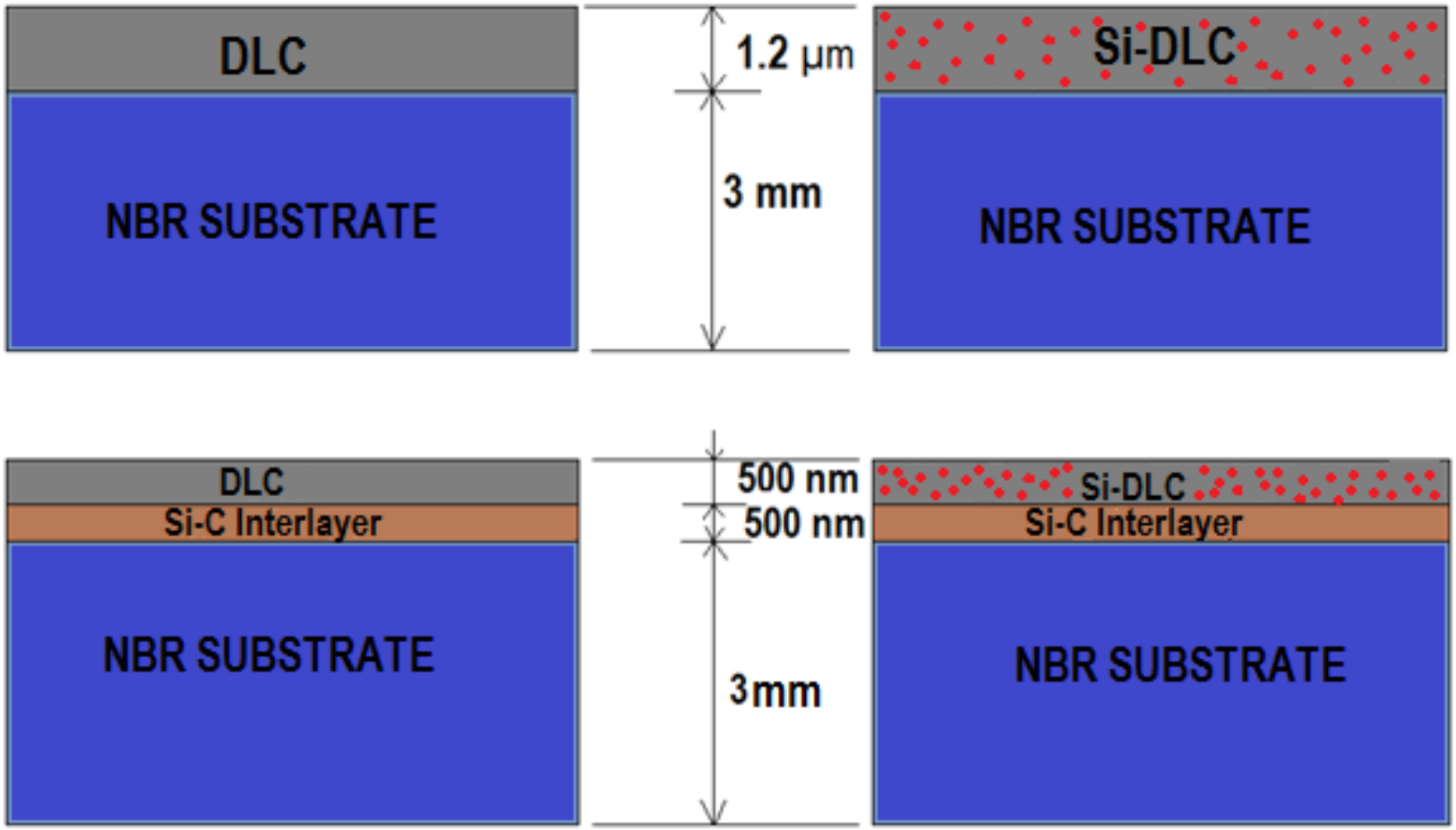
The systems in place are not altered:

1. Labour
2. Training
3. Design, development and manufacturing
4. Supply chain systems

Research Objectives

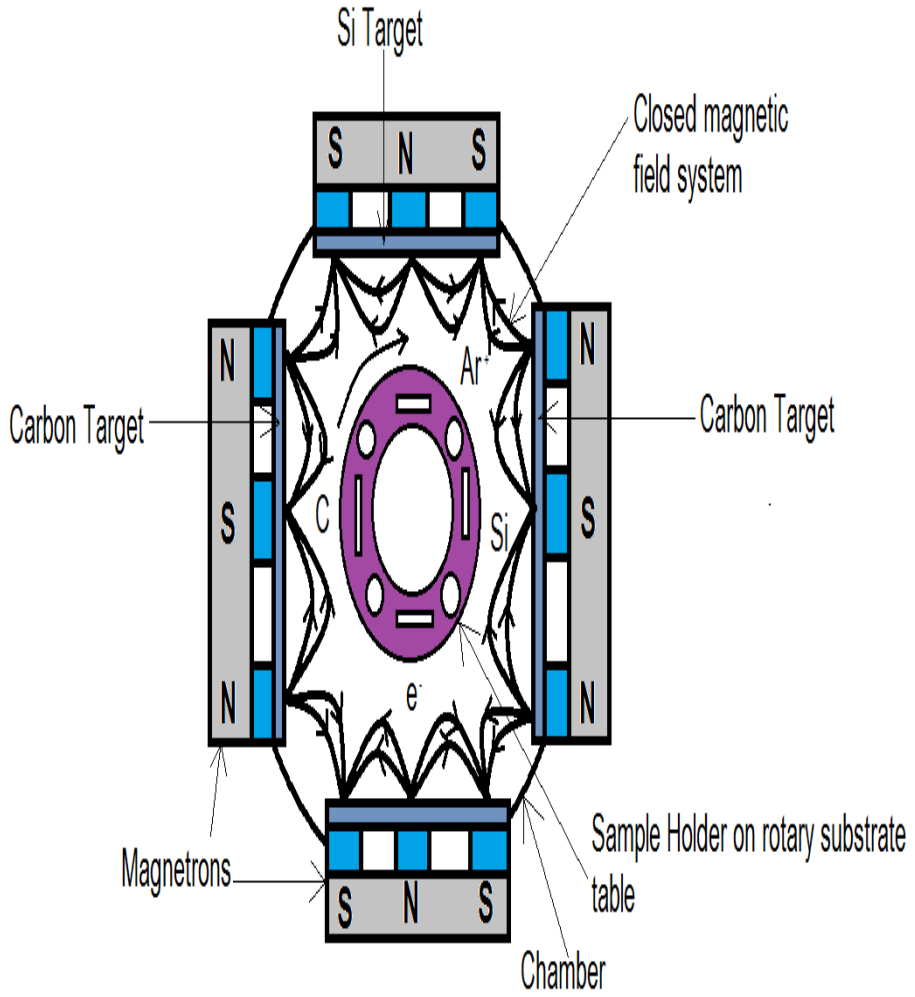
- To quantify field and user operating conditions relating directly and indirectly to piston seal failure
- To deposit DLC and Si-DLC films, with and without Si-C interlayers onto NBR substrates and actual piston seals using an industrial closed field unbalanced magnetron sputtering ion plating (CFUBMSIP) rig.
- To characterise the structural and mechanical properties; and tribological behaviour of DLC and Si-DLC films, with and without Si-C interlayers deposited on NBR substrates
- To determine the wear mechanisms of actual piston seals coated with DLC and Si-DLC films, with and without Si-C interlayers, using a purposely designed and developed test rig.

Coating Process Design

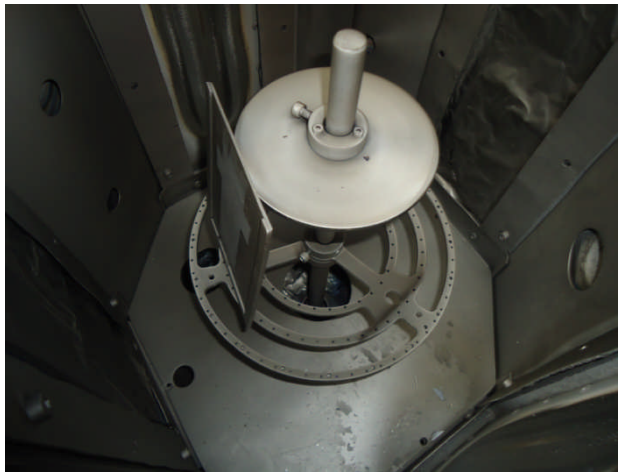


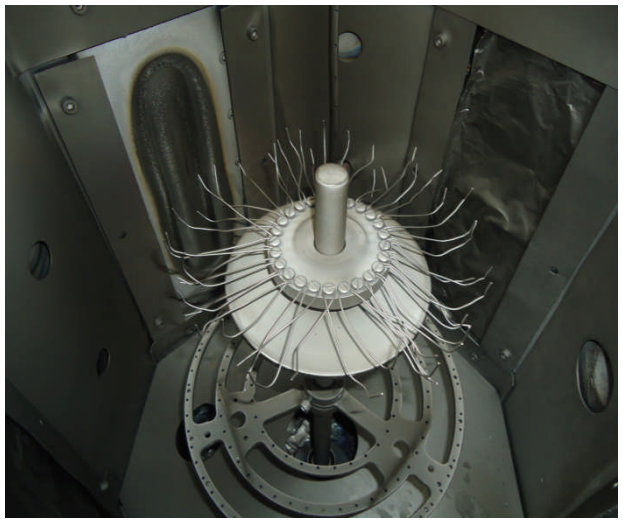
CFUBMSIP

- Field lines “closed” with another magnetron
- Plasma confined around substrates
- Electrons and ion loss to chamber walls minimised
- Possibility to produce low temperature coatings
- Dense, non-columnar , adherent coatings
- Coating deposition is carried out using a high density of low energy bombarding ions
- Teer Coatings UK (Miba coating group)



CFUBMSIP Sputtering Rig and Interior Set-up

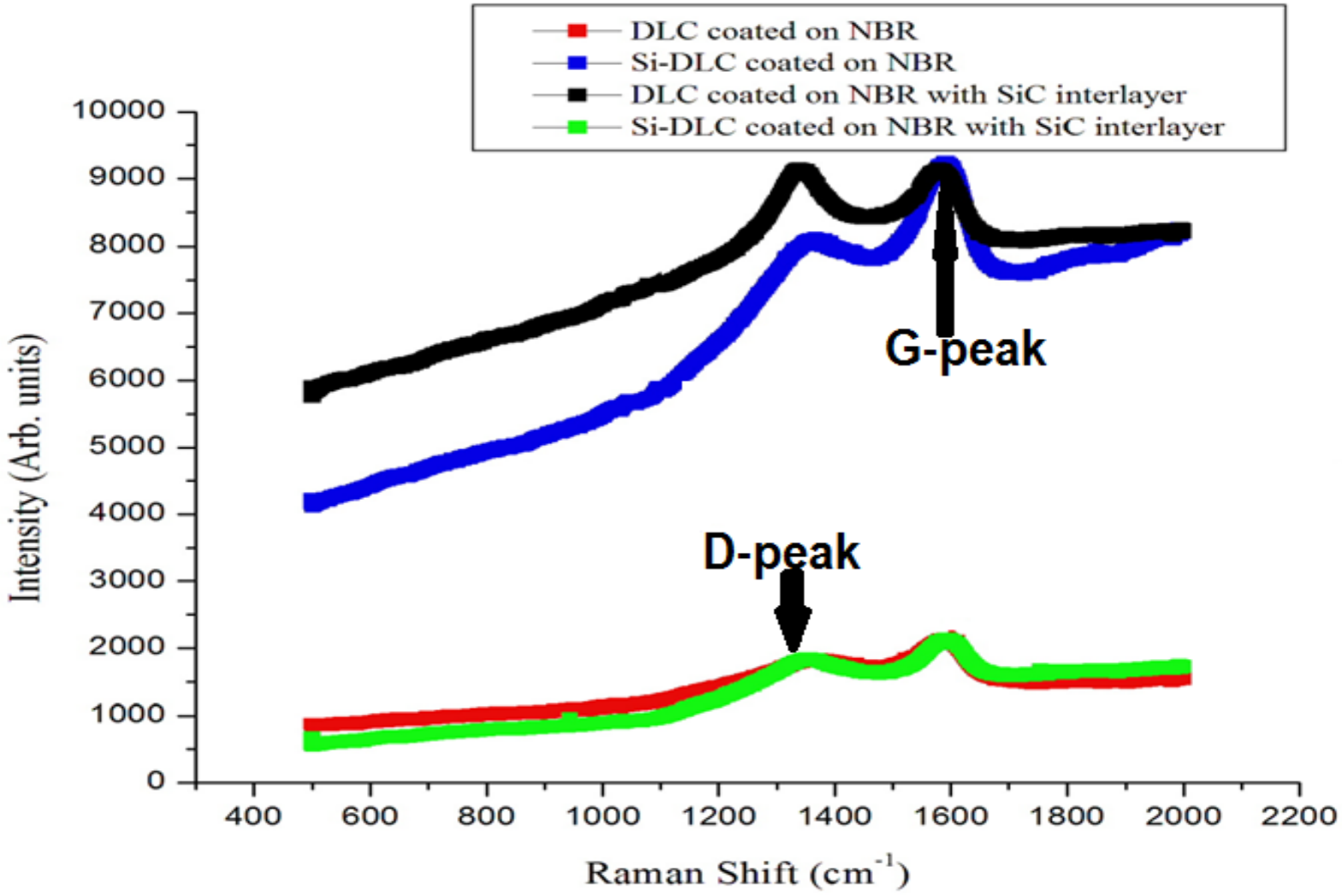




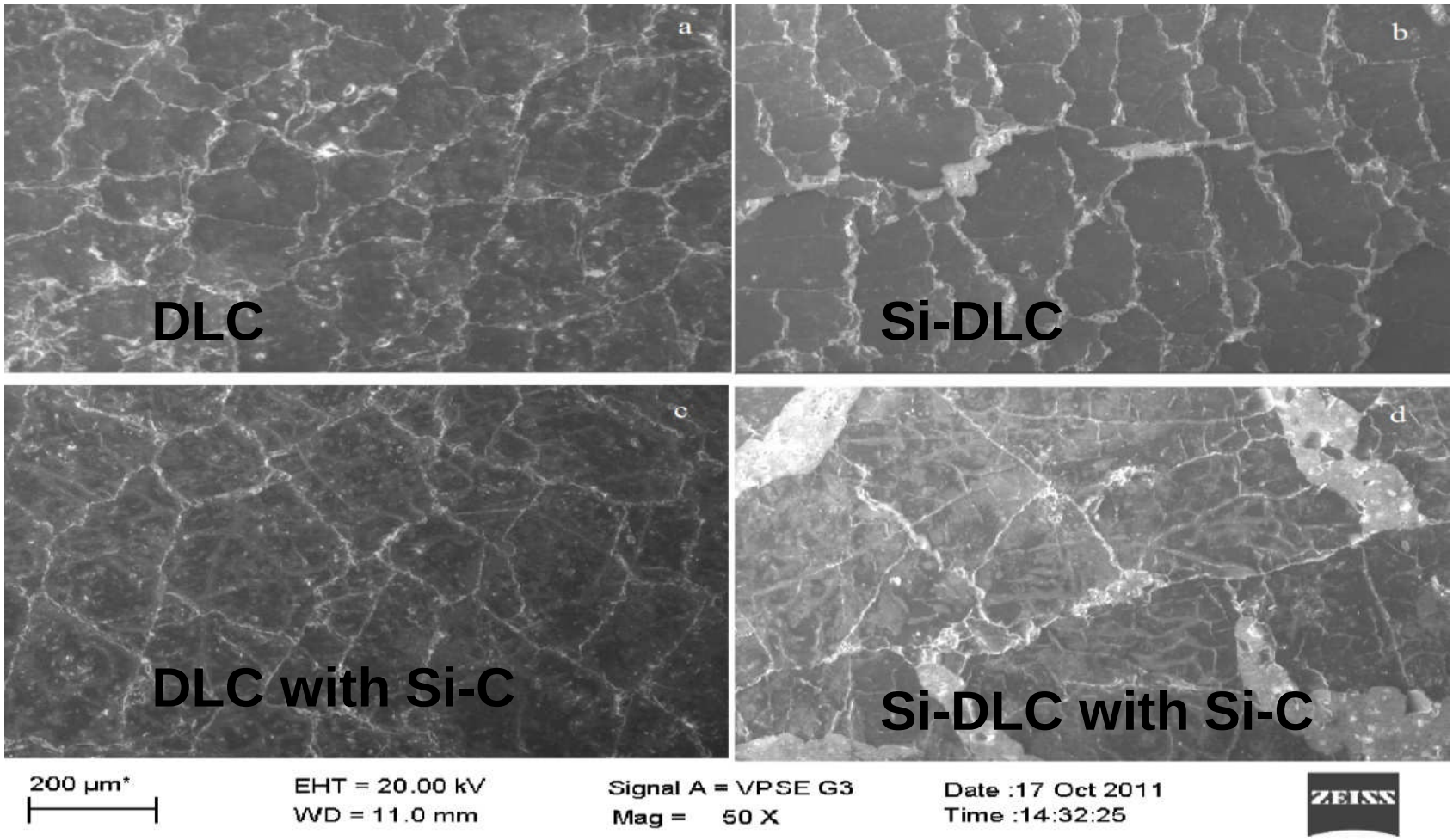
Coating Deposition Parameters

Coating Type	Ion Clean process	Ar (sccm)	C_4H_{10} (sccm)	C (A)	Si (A)	Bias (V)	Coating time (min)
DLC	200V for 10 min	12	8	2	0	30	60
Si-DLC	200V for 10 min	12	8	2	0.5	30	60
Si-DLC with Si-C interlayer	200V for 10 min	12	8	2	0.5	30	35 for Si-C/ 40 for DLC
DLC with Si-C interlayer	200V for 10 min	12	8	2	0	30	35 for Si-C/ 40 for DLC

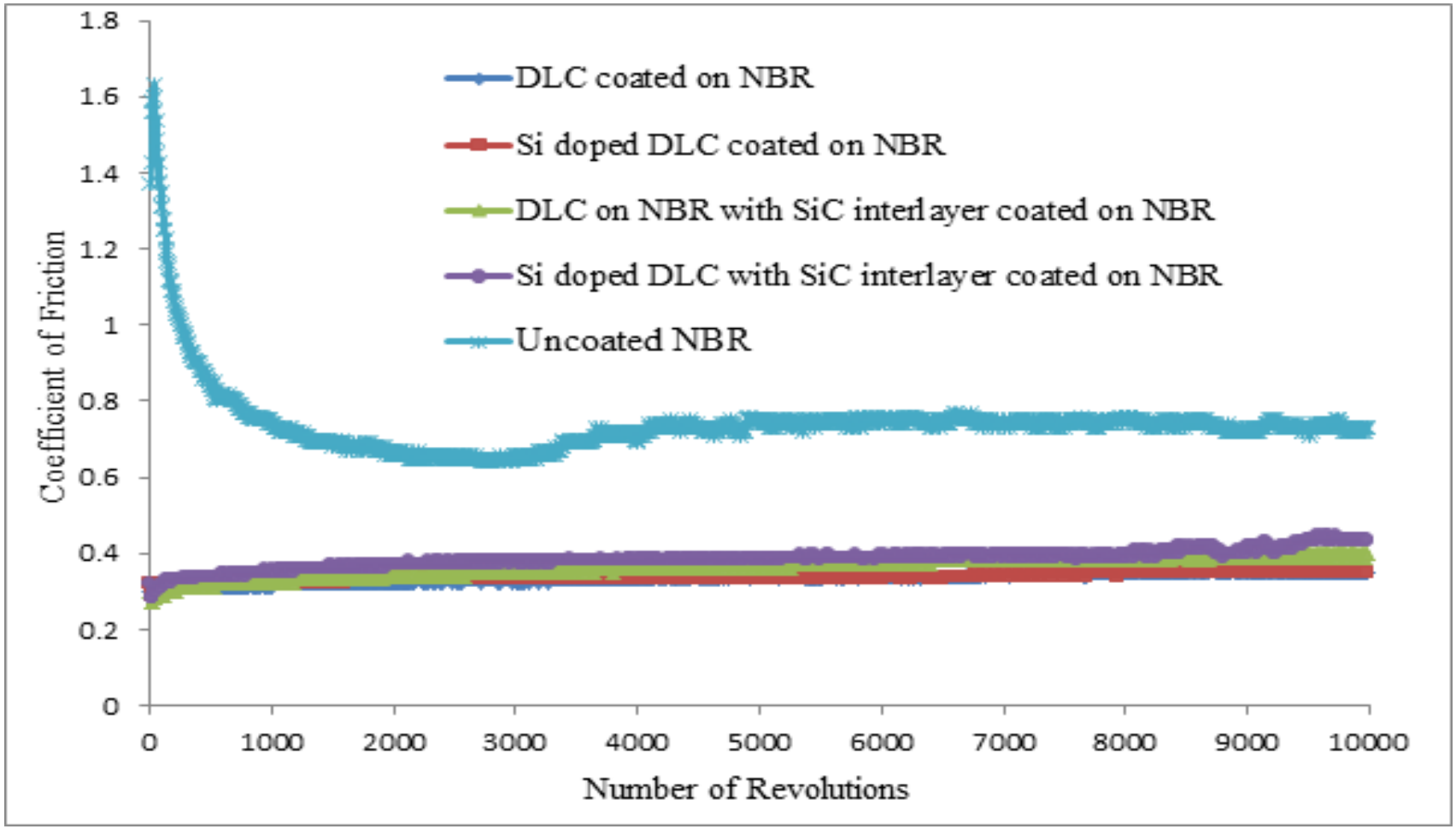
Raman Spectra



Surface Morphology



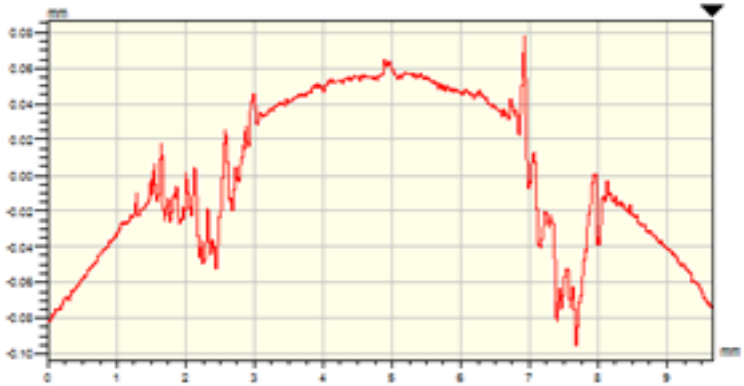
Coefficient of Friction – Dry Sliding, 1 N



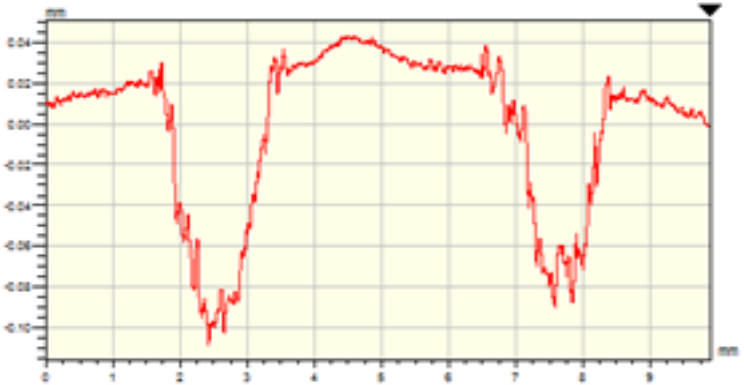
Wear Analysis

DLC

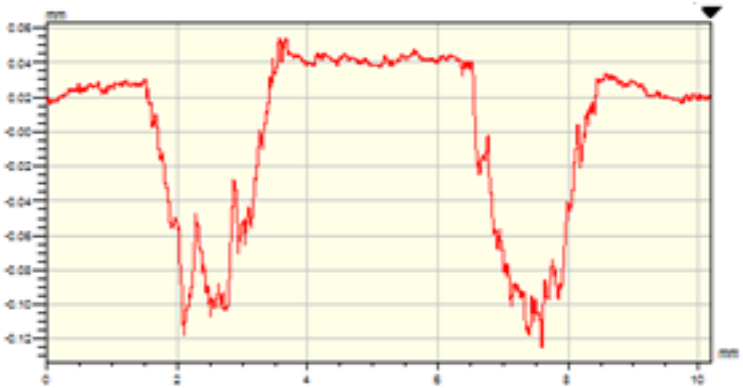
Si-DLC



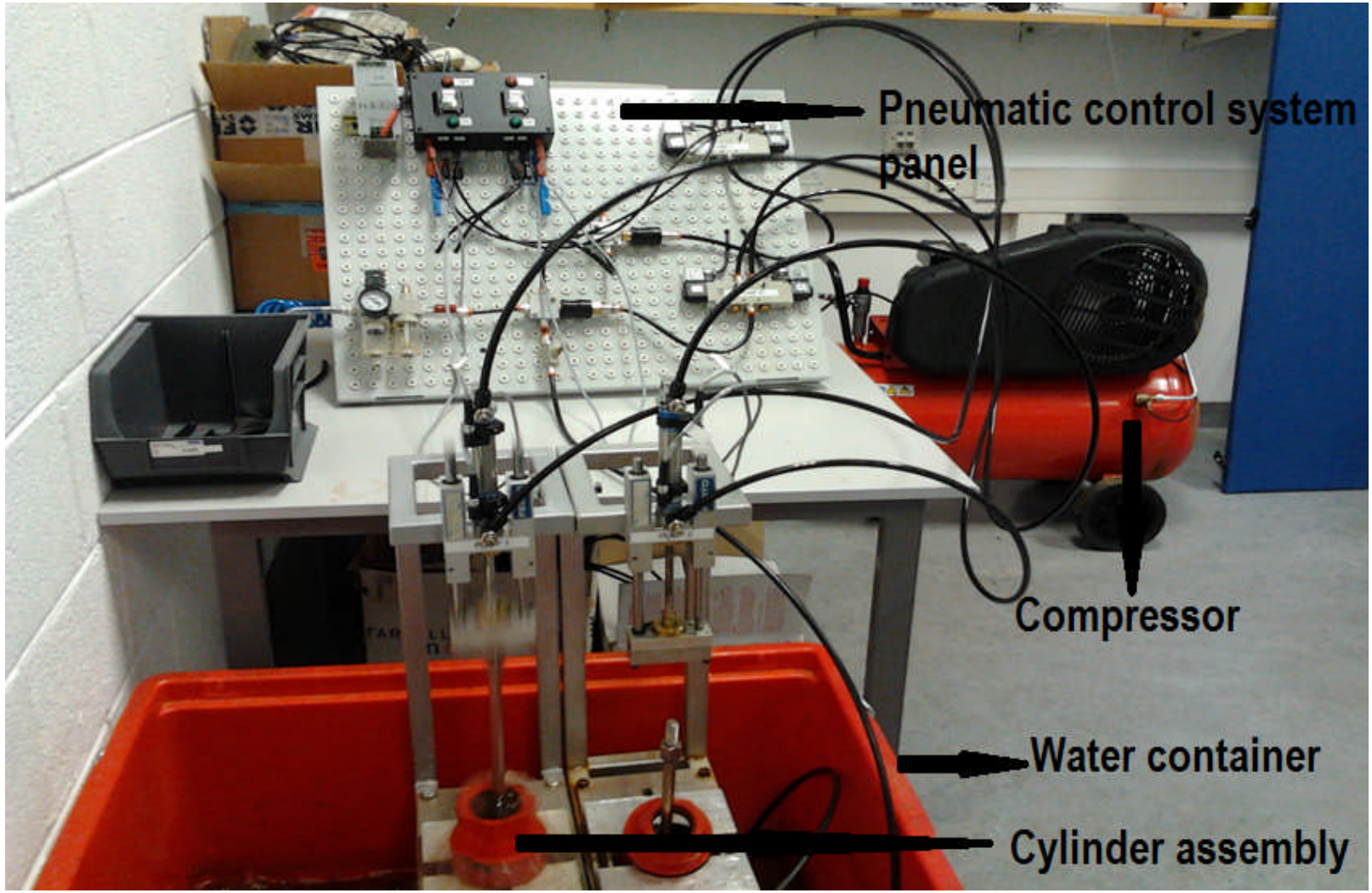
DLC with Si-C



Si-DLC with Si-C



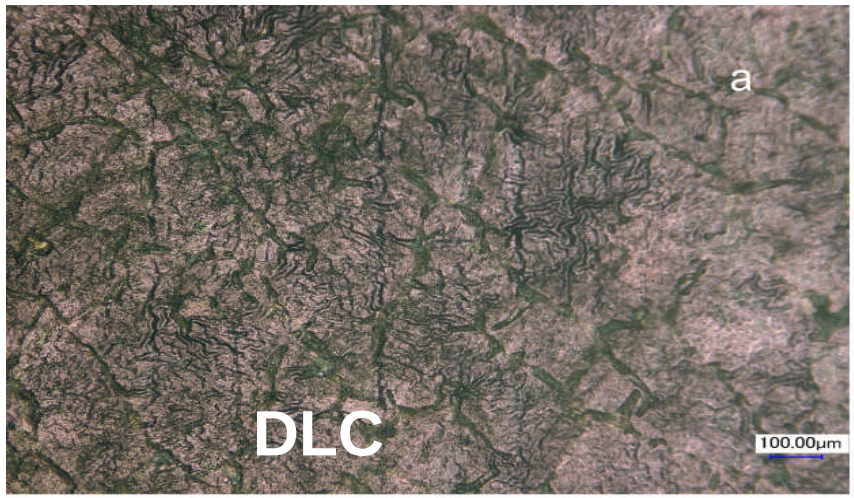
Piston Seal Wear Test Rig

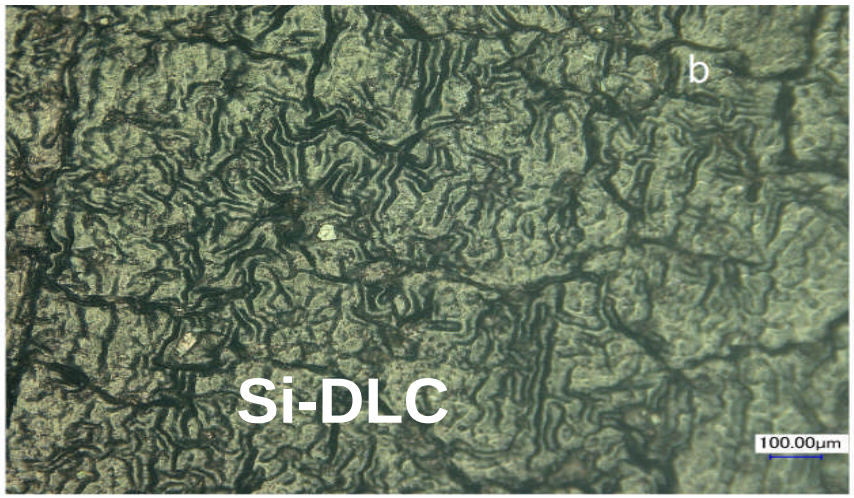


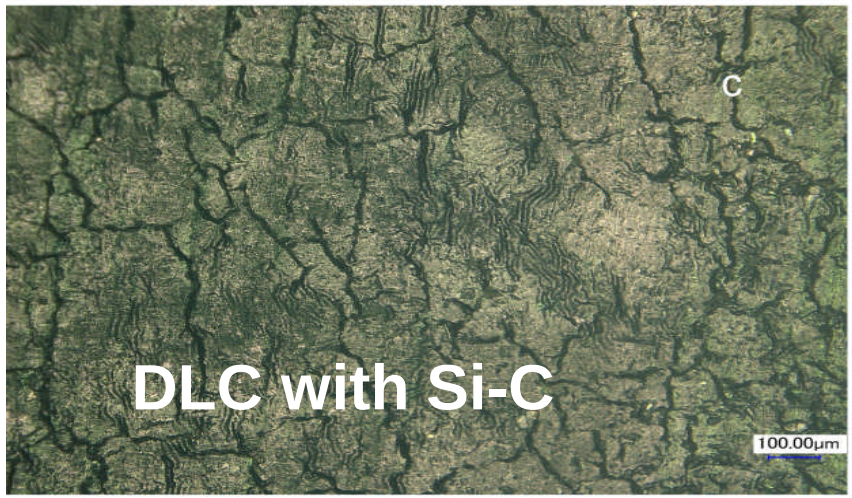
Piston seal testing - context

- Average number of strokes to fill 20 l container = 115 strokes
- Test rig set up to fill a 20 l container in 113 strokes
- Water delivered during one half of stroke = 57 mm in test rig design
- For 100000 strokes (24 hour testing regime), 17768 l delivered
- This test period covers 1776 10 l containers

Coated Piston Seals Before Wear Testing (side)



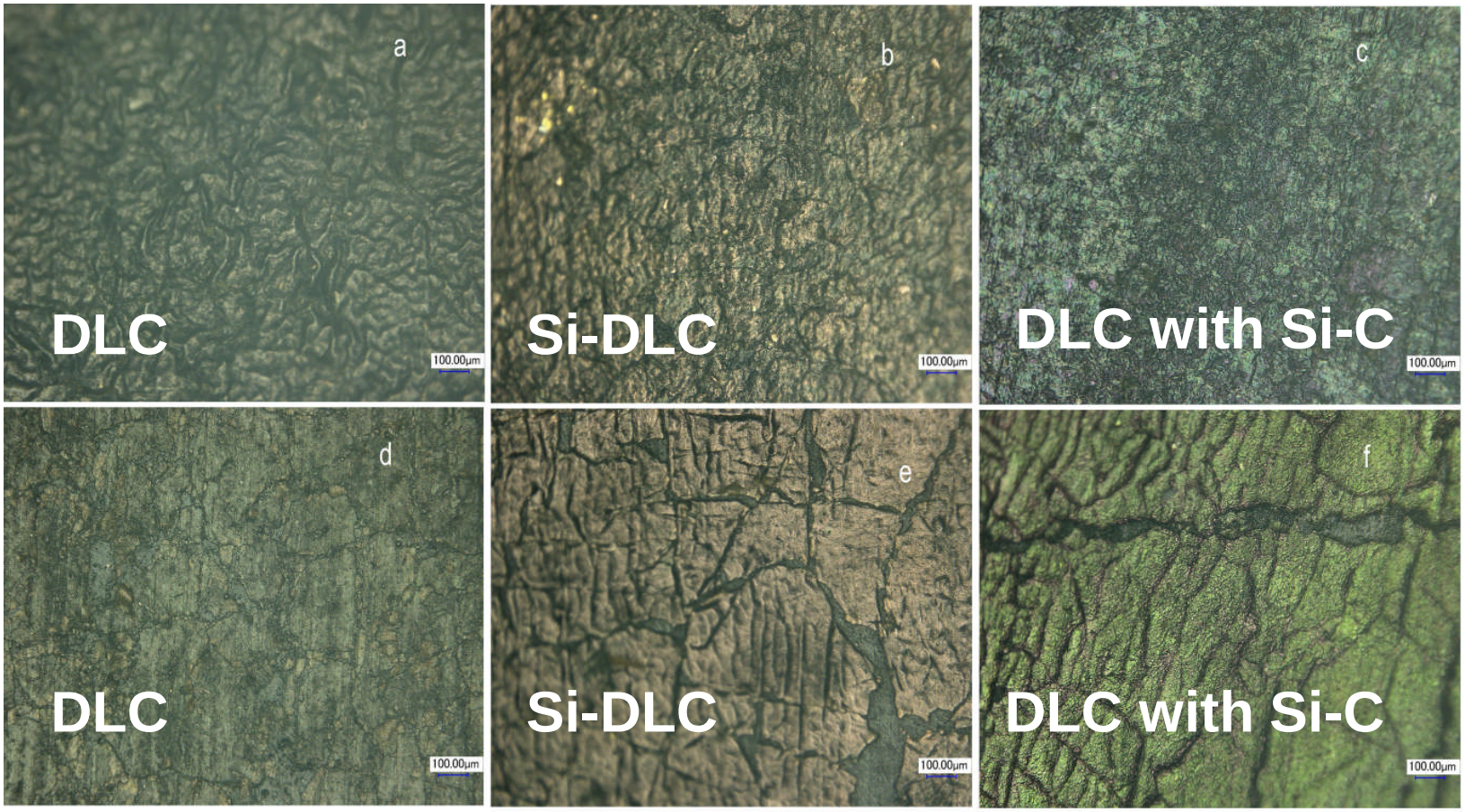




Coated Piston Seals After Wear Testing

Top

Lower



Conclusion

- DLC and Si-DLC films with and without Si-C interlayers were deposited onto nitrile rubber and actual piston seals using CFUBMSIP.
- This Surface Engineering approach offers a method for reducing the wear rate of piston seals
- Various characterisation techniques have been successfully applied
- Wear testing on actual coated piston seals on-going

Acknowledgement

- Water is Life Project
- Irish Aid
- HEA
- Dublin City University
- Makerere University

Publications

1. M. Lubwama, K. A. McDonnell, J. B. Kirabira, A. Sebbit, K. Sayers, D. Dowling, B. Corcoran, *Characteristics and Tribological Performance of DLC and Si-DLC Films Deposited on Nitrile Rubber*, Surf. Coat. Technol. 206 (2012) 4585-4593
2. M. Lubwama, B. Corcoran, K. Sayers, J. B. Kirabira, A. Sebbit, K. A. McDonnell, D. Dowling, *Adhesion and Composite Micro-hardness of DLC and Si-DLC films Deposited on Nitrile Rubber*, Surf. Coat. Technol. 206 (2012) 4881-4886
3. M. Lubwama, B. Corcoran, K. Sayers, J. B. Kirabira, A. Sebbit, K. A. McDonnell, D. Dowling, *Role of Si-C Interlayer on the Properties of DLC and Si-DLC Films Deposited on Nitrile Rubber*, under review in Thin Solid Films Journal
4. M. Lubwama, B. Corcoran, K.A. McDonnell, D. Dowling, J.B. Kirabira, A. Sebbit, K. Sayers, *Flexibility and tribological behaviour of DLC and Si-DLC films deposited on nitrile rubber*, under review in Surface and Coatings Technology Journal
5. M. Lubwama, B. Corcoran, K. Sayers, J. B. Kirabira, A. Sebbit, *Closed Field Unbalanced Magnetron Sputtering Ion Plating of DLC and Si-DLC Films onto Nitrile Rubber*, Proceedings of the 29th International Manufacturer's Conference, Belfast, UK
6. M. Lubwama, B. Corcoran, K. Sayers, J. B. Kirabira, A. Sebbit, K. A. McDonnell, D. Dowling, *Role of Si-C Interlayer on the Properties of DLC and Si-DLC Films Deposited on Nitrile Rubber*, Proceedings of the 15th International Conference on Advances in Manufacturing and Processing Technologies Conference, Wollongong, Australia, 23rd to 26th September, 2012.
7. M. Lubwama, K. Sayers, J. B. Kirabira, B. Corcoran, *Wear Mechanisms of Piston Seals for reciprocating handpumps for rural water supply*, Proceedings of the Second international Conference on Advances in Engineering and Technology, Macmillan Africa, pp. 612 – 618

Questions

Thank You