Supporting Information

on

Covalently Attached Graphene-Ionic Liquids Hybrid Nanomaterials: Synthesis, Characterization and Tribological Application

Rashi Gusain[1], Harshal P. Mungse[1], Niranjan Kumar[2], T.R. Ravindran[2], R. Pandian[2], Hiroyuki Sugimura[3], Om P. Khatri[1,]*

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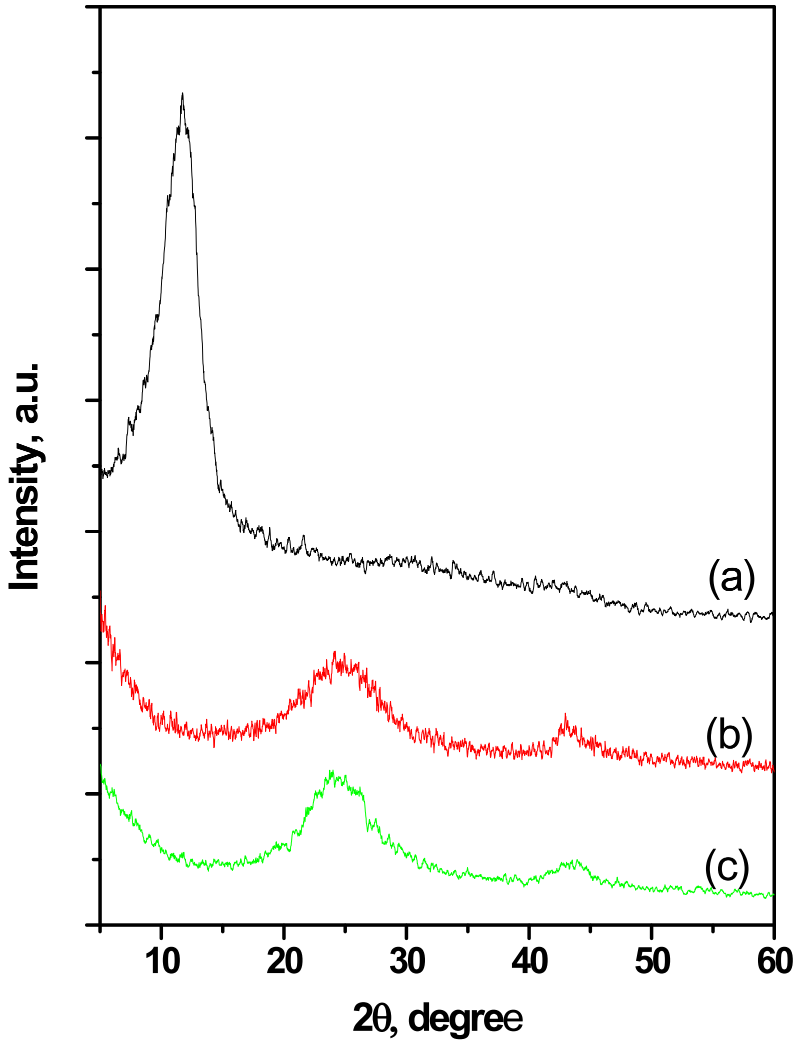
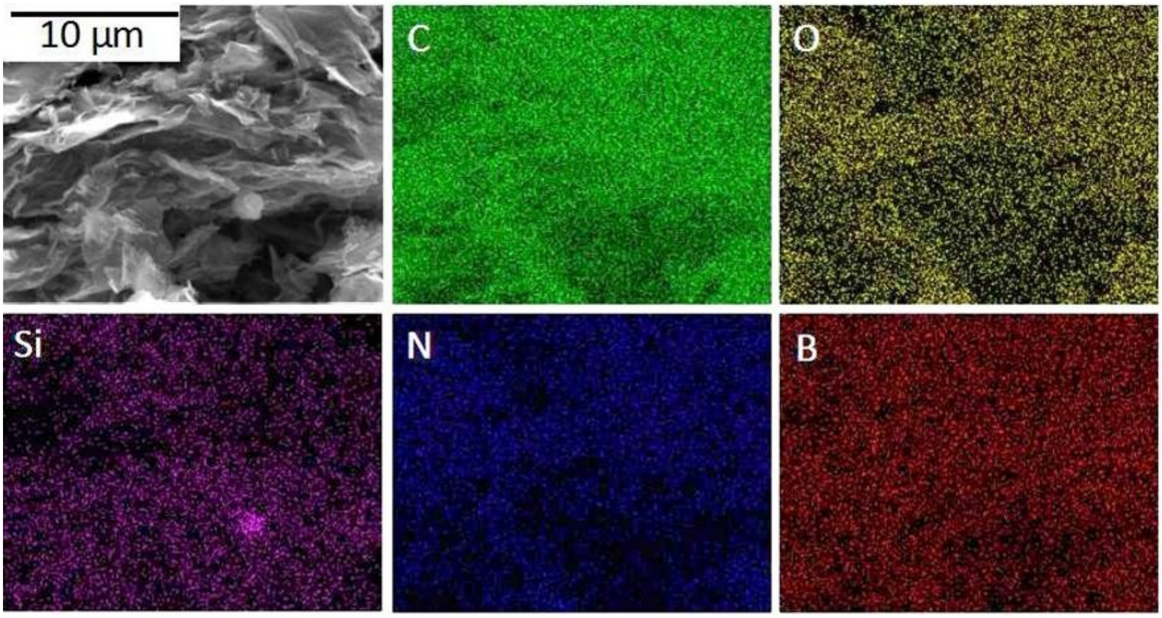


Figure S1: XRD patterns of (a) GO, (b) rGO, prepared by chemical reduction of GO. (c) Carboxylic group enriched graphene nanosheets, prepared by mild oxidation of rGO. XRD patterns reveals that during mild oxidation of rGO, the graphene characteristic interlayer distance remains intact.



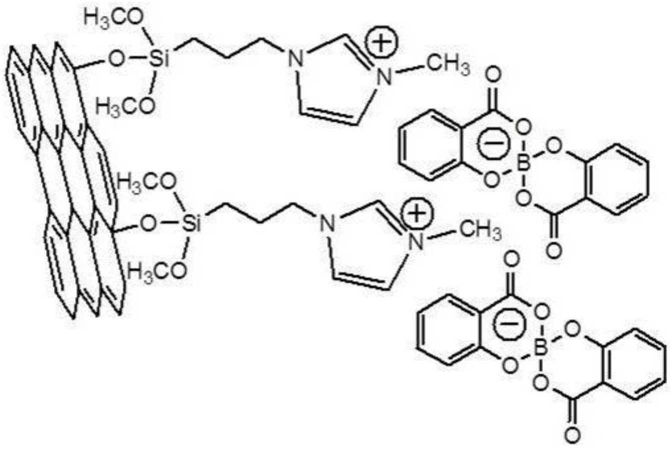


Figure S2. FESEM micrograph and corresponding element mapping images of Gr-BScB hybrid nanomaterial along with its representative molecular structure. The element symbol is mentioned on each image.

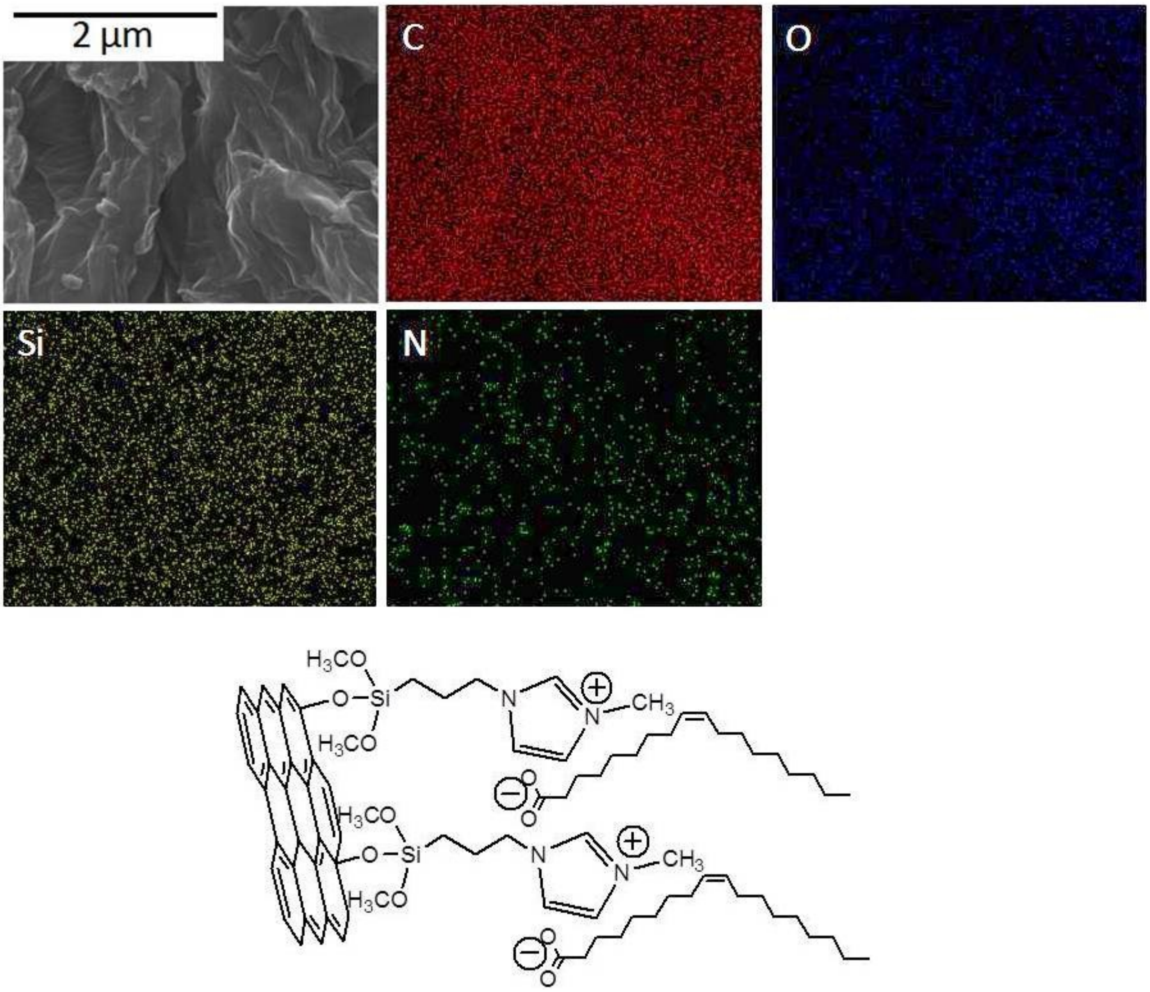


Figure S3. FESEM micrograph and corresponding element mapping images of Gr-OL hybrid nanomaterial along with its representative molecular structure. The element symbol is mentioned on each image.

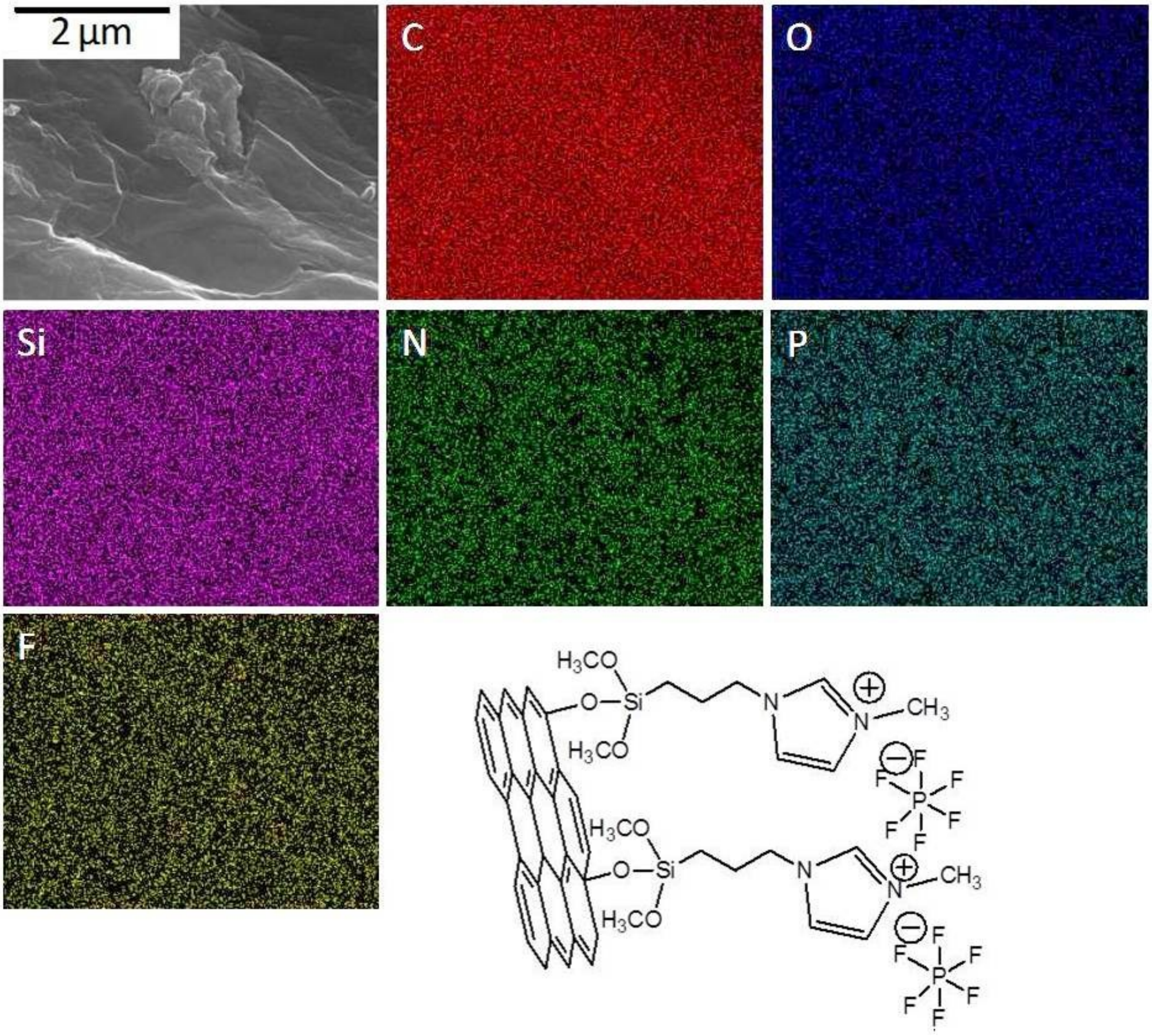


Figure S4. FESEM micrograph and corresponding element mapping images of Gr-PF_6 hybrid nanomaterial along with its representative molecular structure. The element symbol is mentioned on each image.

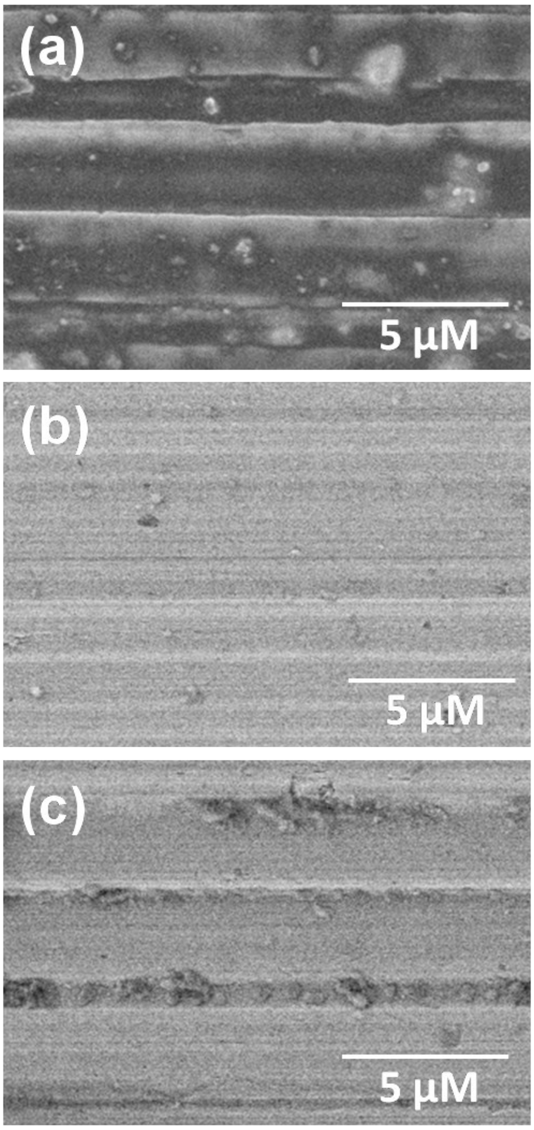


Figure S5: FESEM micrograph images of worn track of steel disc lubricated with (a) PEG and variable dose of Gr-BScB (b) 0.02 and (c) 0.05 mg.mL^{-1} blended samples.

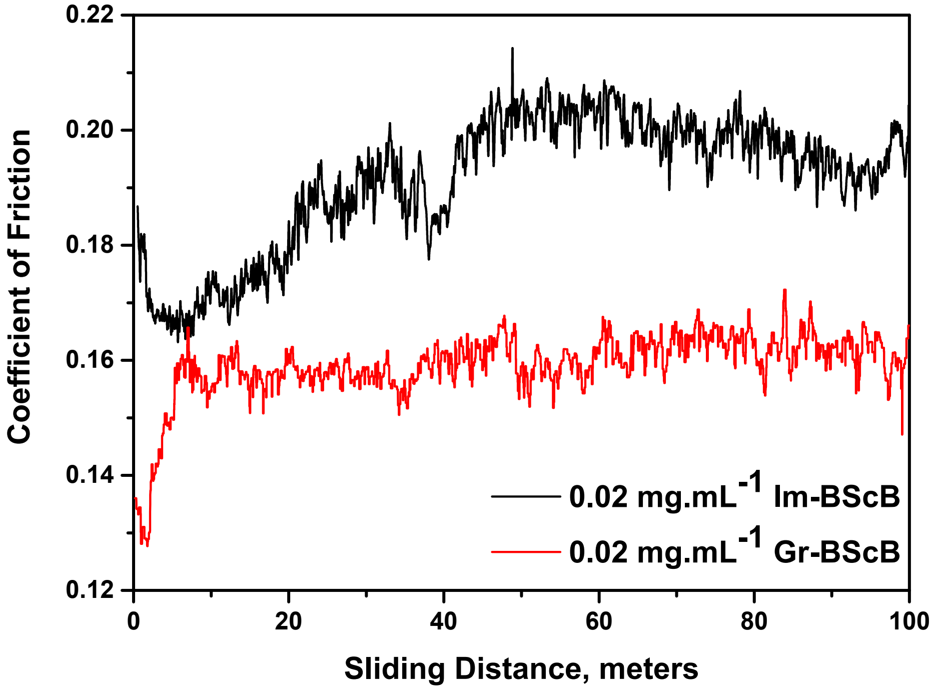


Figure S6: Changes in coefficient of friction as a function of individual blends of Im-BScB ionic liquid and Gr-BScB hybrid nanomaterial in PEG 200 (0.02 mg.mL^{-1}) under reciprocating sliding contact of steel tribo-pair. Load: 2 N, speed: 3 cm.s^{-1}, mean Hertzian contact pressure: 810 MPa

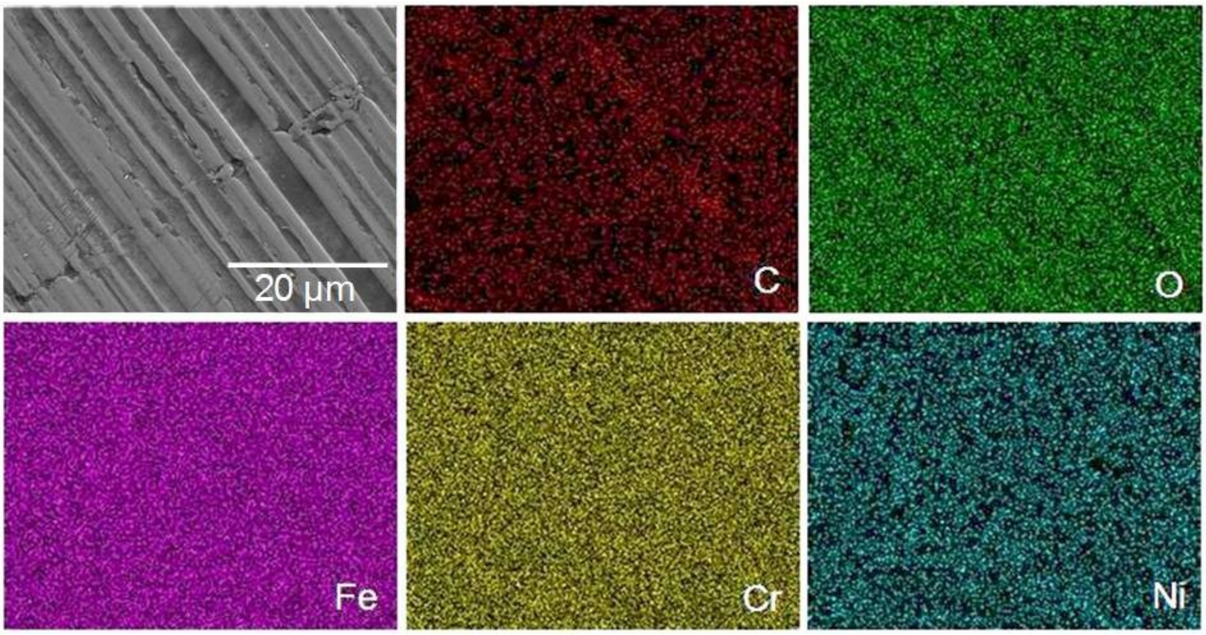


Figure S7. FESEM micrograph and corresponding element mapping images on the worn track of steel disc lubricated with PEG 200 lube base oil. Load: 2 N, speed: 1 $cm.s^{-1}$, sliding distance: 100 meter.

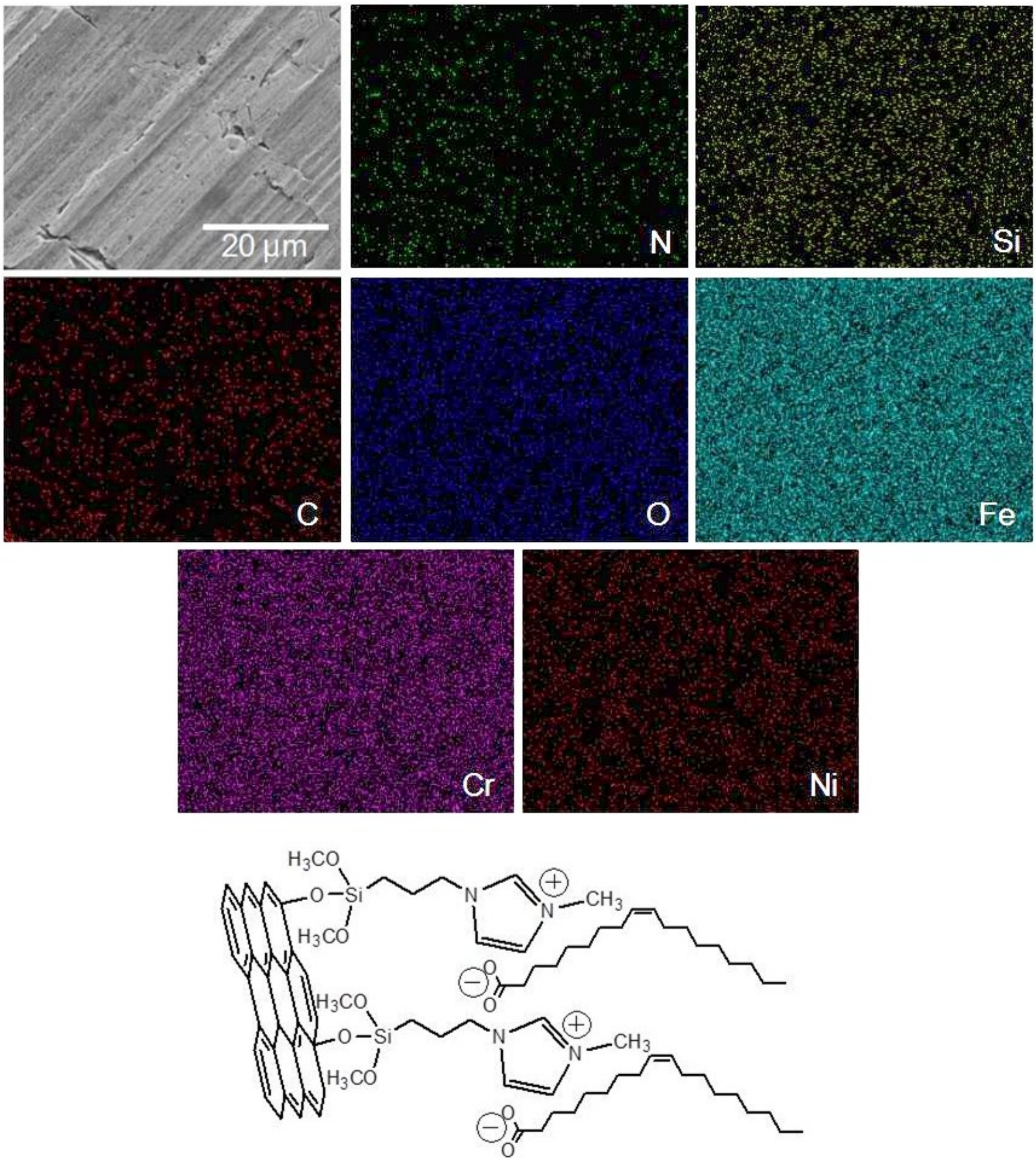


Figure S8. FESEM micrograph and corresponding element mapping images on the worn track of steel disc lubricated with Gr-OL blended with PEG 200 lube base oil (dose: 0.02 mg.mL^{-1}). The uniform distribution of nitrogen and silicon on the worn track of steel disc revealed the contribution of Gr-OL hybrid nanomaterial in formation of tribo-thin film, which reduces the friction and wear. The representative molecular structure of Gr-OL is shown separately.

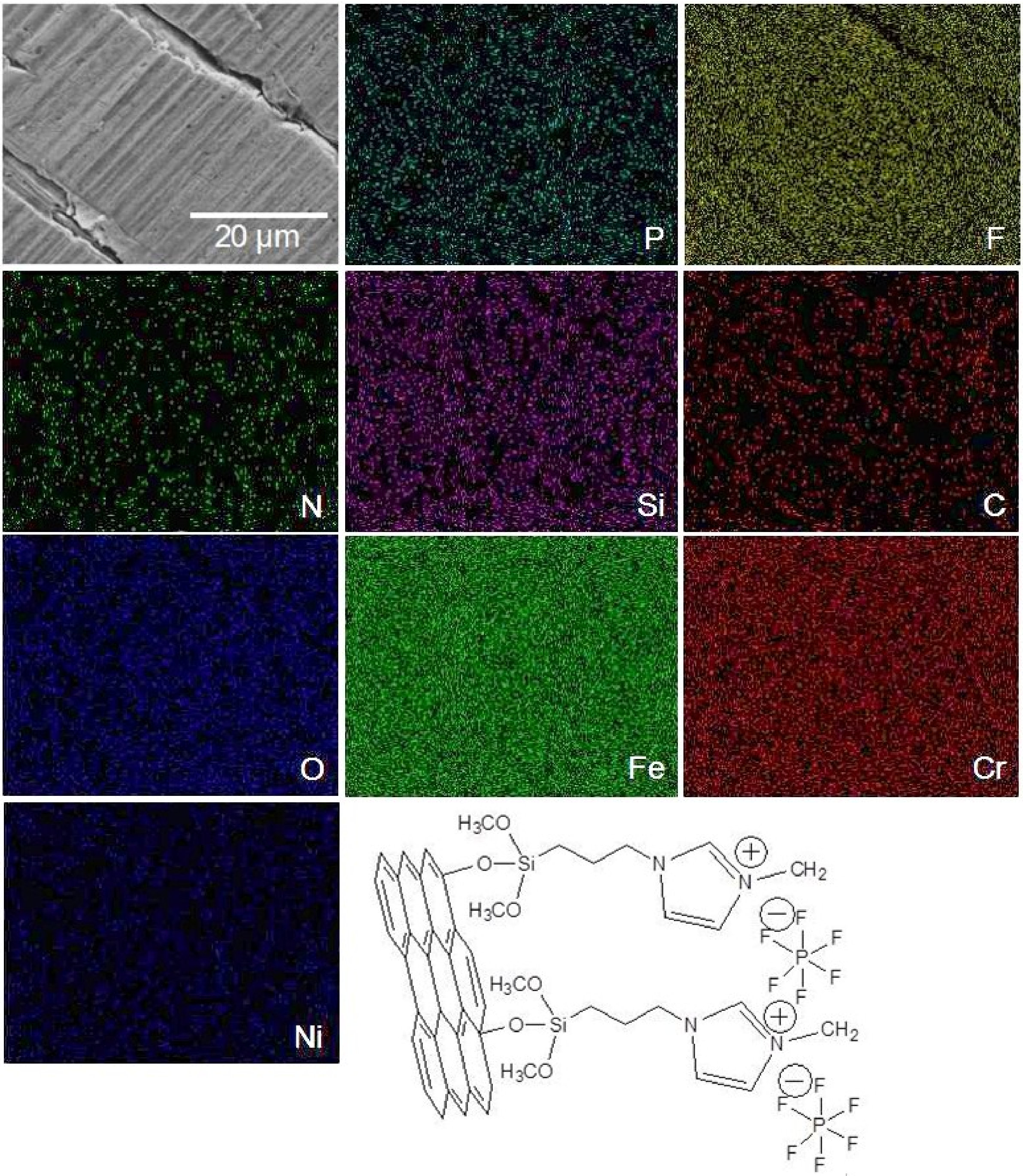


Figure S9. FESEM micrograph and corresponding element mapping images on the worn track of steel disc lubricated with Gr-PF_6 blended with PEG 200 lube base oil (dose: 0.02 mg.mL^{-1}). The uniform distribution of phosphorus, fluorine, nitrogen and silicon on the worn track of steel disc revealed the contribution of Gr-PF_6 hybrid nanomaterial in formation of tribo-thin film, which reduces the friction and wear. The representative molecular structure of Gr- PF_6 is shown separately.

Table S1. Chemical composition of tribo-pair (Cr6 steel ball and 316 LN disc) used for friction measurement

Element	Elemental %	
	Cr6 Steel Ball	316LN Steel Disc
Carbon	0.98	0.03
Silicon	0.2	1.0
Nitrogen	-	0.2
Nickel	-	12.6
Mangnese	0.32	2.0
Phosphorus	0.025	0.045
Sulphur	0.015	0.03
Chromium	1.43	17.2
Molybdenum	0.1	2.8
Aluminium	0.05	-
Copper	0.3	-
Iron	Balance	Balance

Table S2. Mechanical properties of Cr6 steel ball and 316 LN disc used for friction measurement

Specimen	Tensile Strength, GPa	Yield Strength, GPa	Elasticity Modulus, GPa	Poisson's ratio
Cr6 Steel Ball	0.76	0.45	200	0.3
316LN Steel Disc	0.51	0.20	210	0.28

Table S3. Physicochemical properties of PEG 200 and Gr-ILs blended samples#

Sample Description	Kinematic Viscosity, $mm^2.s^{-1}$		Viscosity Index	Density at 40 °C, $g.mL^{-1}$
	At 40 °C	At 40 °C		
PEG 200	22.204	4.138	76	1.1105
Gr-BScB Blend with PEG 200	22.215	4.1406	76	1.1103
Gr-OL Blend with PEG 200	22.214	4.1434	76	1.1102
Gr-PF_6 Blend with PEG 200	22.211	4.4384	76	1.1102

#Concentration of each ionic liquid in the PEG 200 is 0.02 $mg.mL^{-1}$

Table S4: Thermal % weight loss of GO, Gr-BScB, Gr-OL, and Gr-PF_6 as deduced from thermogravimetric pattern of respective sample.

Sample Description	TGA Temperature for % Weight Loss, °C		
	10%	20%	35%
GO	90.7	195.9	221.4
Gr-BScB	296.4	378.1	463.3
Gr-OL	247.3	321.0	409.3
Gr-PF_6	200.7	290.6	302.6