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Diamond Machinable Coating for Large R2R Rollers and Hydrostatic Bearings

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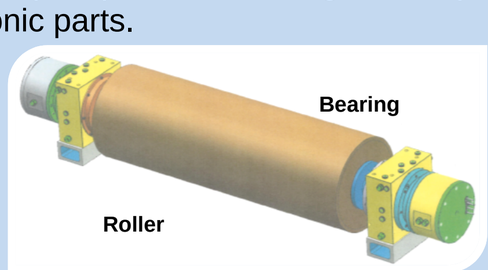
Single point diamond turning (SPDT) microstructures for R2R manufacturing

Exciting research and development is underway in large scale (1.4m wide), reel to reel (R2R) manufacturing techniques for the production of plastic and electronic parts.



Reel-to-Reel roller and bearing

Fresnel Lens on copper roller Image: UPS[2]

R2R involves the application of coatings, printing, or performing replication processes starting with a roll of a flexible material and re-reeling after the process to create an output roll.

Structured rollers and hydrostatic bearings are production machine components used in the R2R manufacturing system are typically made of **aluminium** and **steel** where as copper are used for micro-pattern machining programming.

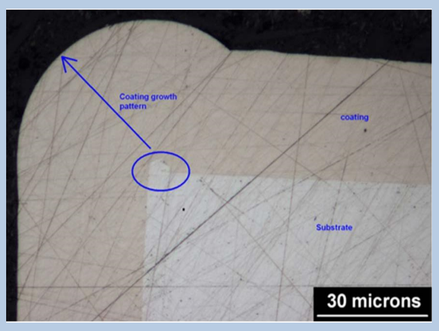
Autocatalytic (electroless) nickel coating

Electroless nickel phosphorus (P >10wt.%) coating has been identified to be suitable for diamond turning due to it's uniformity in the coating deposition and the low tool wear, which makes continuous machining of large workpiece possible and the deposits excellent physical and chemical properties such as hardness and corrosion resistance.

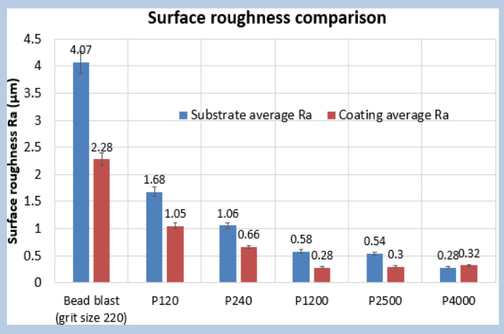
The challenge is to reach a **thicker deposit** (>100µm) to accommodate the multiple SPDT process in prepare surface, create micro-patterns and recondition existing components while achieve the minimum **defect rate**.

Understand the coating – steel substrate AISI 1080

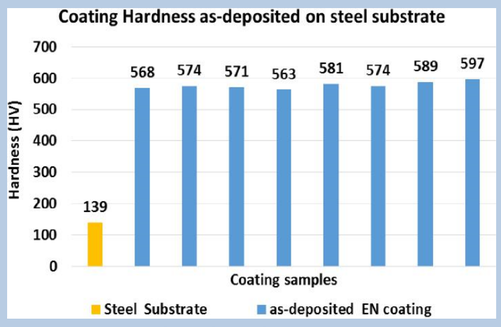
In-house plating shows that the coating can be easily deposited onto steel substrates. Coating surface exhibits identical topographical features as the substrate morphology. As the coating thickness increases, these features will amplifies and the eventually alters the coating growing pattern. Such features tends to occur at the edge of workpiece.



Coating amplifies the corner feature



Pre & post plating Ra comparison



Coating hardness test

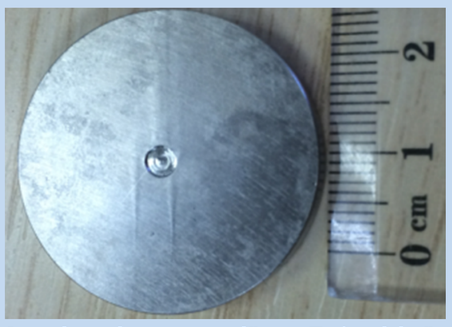
In other cases, as-plated coating can effectively reduce the substrate roughness by a maximum of near 50 percent. This indicates that if the substrate's initial surface feature size (or difference between surrounding and individual feature dimension) is smaller than 10µm, the coating is capable of reduce the surface Ra by 50 percent. This behaviour continues until the coating reaches a saturated value, where the initial Ra is less than 0.3µm. It appears that the maximum coating roughness of the as-plated surface is 0.3 microns Ra.

The Vickers hardness test shows that the coating is around 577 HV, that is 4 times harder than the low carbon steel substrate.

Simulating the diamond turning workpiece – aluminium substrate Al6061-T6

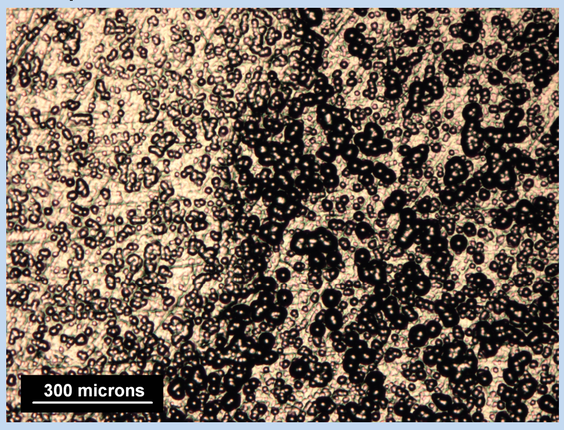
To simulate the diamond turning process over the electroless nickel coating, identical aluminium substrate has been used to replicate the plating scenario.

Al6061 coupon for diamond turning

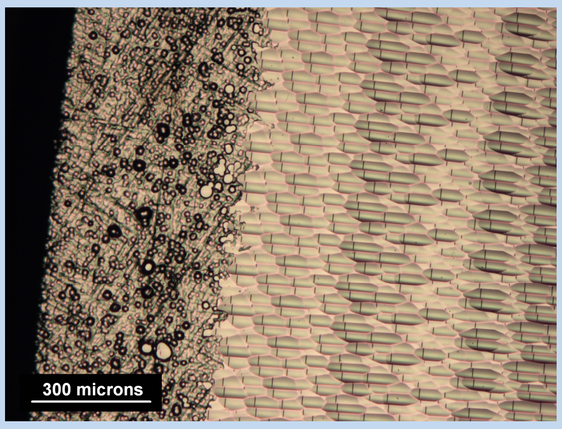


As-plated coupon (8µm Ra) with 2 visible striation line

The pre-treatment of (b)alkaline etching, acid pickling and (c)zincation was applied and the coated deposit presents uniform coverage over the entire sample surface. Important features such as the agglomerate micro-nodules that forms in patches and the macro-features such as the striation has been noted and trial diamond turning has been conducted to investigate the feature size towards turning performance as well as increasing coating thickness from 85µm to 300µm.



As-plated surface with micro-nodules



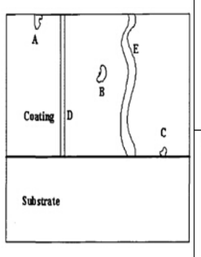
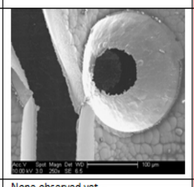
SPDT 5µm turning trial over micro-nodule-rich surface

Current Work

In-house refurbished sample with coating delamination (Left) vs. as plated sample with higher substrate Ra (Right)

Visible pitting on diamond turned spindle sample with 75µm electroless nickel coating, Image: Poeton

Coating feature compendium

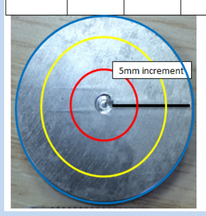
Micro Features	Feature name	Feature size	Feature description	Example image	Possible cause	Quality rating	Acceptability	Method of recovery	Chance of recovery
Category A: Chemical reactants induced features.									
	A. Near surface pit	Ø:1 µm - 150 µm; Depth: 0.5 µm - 30 µm	A small, sunken area that forms on a coating surface.		Continues rupture of bubbles at the near end of the plating session.	2	Diamond turning: only coating with depth of pit less than 5 µm is acceptable.	1. Remove adequate amount of thickness to reach pit free. 2. Polish pitted area to smear surrounding excess coating into the pit.	95%
	B. Submerged void	Ø:1 µm - 100µm; Depth: unpredictable .	A small, none-coating that is formed within the coating as part of the Ni-P coating without any significant change towards the final coating surface and difficult to detect unless the substrate is ferrous material.	None observed yet.	Entrapment of the bubbles during the plating which was recovered by solution agitation.	2	Diamond turning:		50%
Note:									

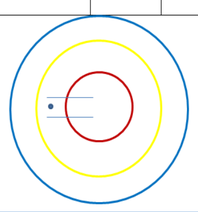
Current work

1. Coating feature compendium.
2. As-deposited coating assessment.
3. Diamond turning trial of known defects and dimensions.
4. Phosphorus content control.
5. 300µm coating thickness goal and subsequent diamond turning.

Coating assessment

Sample name	Substrate Ra	As-plated Ra	Coating thickness	Specific surface feature (describe in words)	Feature dimensions	Number of features	Feature distribution (refer to image below: zone red, zone yellow, zone blue)	Please indicate on graph the location of significant features in dots. (Draw if necessary)
							R	Notes:
							Y	
							B	





Future work

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