**Microscopy and XEDS of Anti-Biofouling Treated Seismic Streamers**

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Seismic streamers are long arrays of sensors housed in a polyurethane (PU) jacket used in geophysical exploration for oil and gas. As they are deployed for months at a time, fouling by marine organisms is a substantial problem to performance longevity and product life. A new antifouling technology being developed sees antifouling particles, such as copper metal, deposited into the PU jacket using a high velocity spray process known as cold spray[1,2].The particles embed at or below the PU surface and remain in contact with the environment via the impact tunnel, giving effective broad spectrum antifouling control[3]. Optimising longevity requires an understanding of the fate of the copper which, interestingly, appears to have a diffusion front migrating through the PU. In this paper, we combine optical microscopy with backscattered and secondary electron Scanning Electron Microscopy (SEM) and X-ray Energy Dispersive Spectroscopy (XEDS) to examine the penetration of copper into the PU matrix.

A PU seismic streamer jacket (Colex International Ltd, Leicestershire, UK) was cold sprayed with copper and copper-based particles as described in Vucko using particle speeds of approximately 500 $ms^{-1}$, to give particle loadings in the range 50-300 $gm^{-2}$, determined by weighing the streamers pre- and post-cold spraying.

Figure 1 shows secondary (A) and backscattered (B) electron images of a sample ($Cu_2O$ particles embedded in polyurethane) with a particle loading of 67 $gm^{-2}$. From the images it is clear that the particles only penetrate approximately 10 - 20 µm into the polymer. The copper particles visible below the implantation zone in figures 1A and 1B are clearly not embedded in the polymer but have fallen out during sample preparation as shown in the secondary electron image. Loose copper particles are an issue environmentally by not containing to the specific device possibly leading to toxicity not controlled.

While preparing the samples it was noticed that there was a yellow band which extended some distance into the sample. This can be seen in the optical micrograph, Figure 2. This band was present at a depth far exceeding the depth which the copper penetrated the sample (0.5 - 1 mm). XEDS analysis of the samples showed that copper was present (at very low concentrations (~ 1%)) at a depth of 1 mm (Fig. 3). This indicates that there is diffusion occurring within the PU.

1. P.C. King, A.J. Poole, S. Horne, R. de Nys, S. Gulizia and M.Z. Jahedi, "Embedment of copper particles into polymers by cold spray," Surf. and Coat. Tech. vol 216, pp 60-67, 2013.
2. A.J. Poole, R. de Nys, P.C. King, S. Gulizia and M.Z. Jahedi, "Surface Treatment" World Intellectual Property Organization, International Bureau, Patent Number WO 2012/006687 A1, January 2012.
3. M.J. Vucko, P.C. King, A.J.Poole, M.Z. Jahedi, R. De Nys, "Polyurethane seismic streamer skins: an application of cold spray metal embedment," Biofouling, vol 29, no. 1, pp 1-9, 2013.

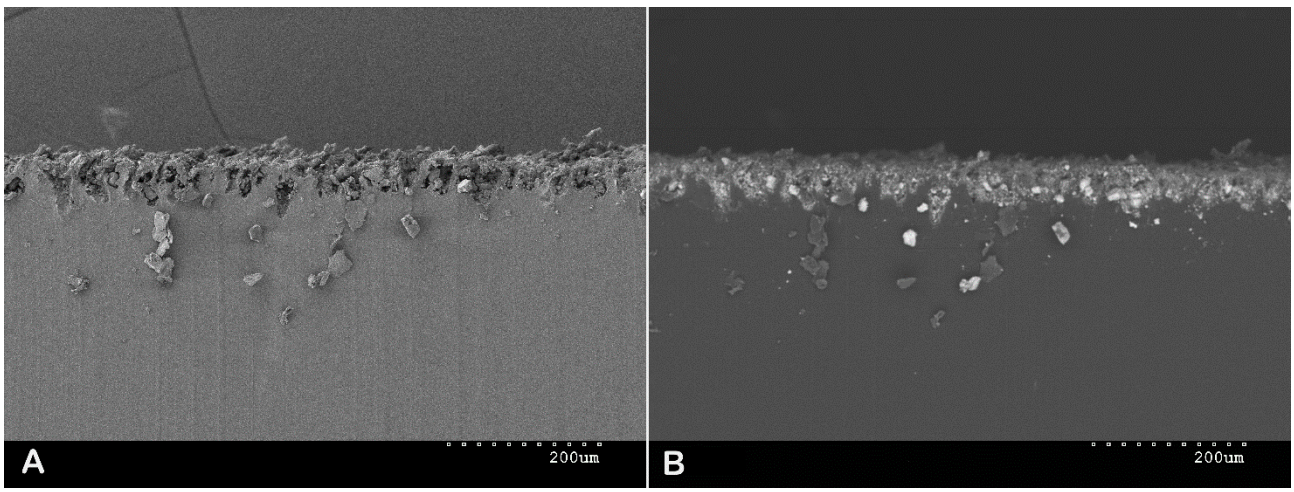

Fig. 1. Secondary electron image (A) and backscattered electron image (B) of a polymer jacket.