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Significance of Established TEM Analysis for Industry-Related Research on Inhomogeneous and / or Inside Boundaries and Interfaces

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Micro analytical investigations are the backbone of many material driven technology innovations, helping to identify the right manufacturing parameters for the right material properties. While Focused Ion Beam (FIB) Technology has become a state-of-the-art tool for target-based and tailored preparation to characterize and analyze microstructures [1], it may not necessarily be the preferred choice when it comes up to studying very inhomogeneous, rough or inside boundaries and interfaces. In this case conventional techniques such as Precision Ion Polishing (PIP) can be a time- and cost-effective alternative to FIB lamellae preparation. This becomes effective in particular when a 2D analysis is sufficient to evaluate the production to microstructure correlation and large area analysis combined with high resolution TEM investigations are needed. Hence, this work will not focus on likely risks of FIB-induced damage [2] as a motivation to apply PIP. Rather, the examples described are intended to illustrate the potential of low-cost and time-saving preparation by means of PIP to support and evaluate different manufacturing processes and their influence on the reliability and reproducibility of different material systems. SEM and TEM analyses were carried out on ta-C coatings, Al-Cu joinings and on microthrough-holes produced by laser helical drilling technique. In particular the latter example gives interesting insights into likely defect generation, material degradation and microroughness effects due to the laser drilling – a topic which is of particular interest with respect to latest developments of laser assisted serial sectioning techniques used in 3D microstructure characterization (see e.g. [3]).

Due to new large volume plasma vapor deposition techniques hydrogen-free tetrahedral amorphous carbon (ta-C) can nowadays be applied as coatings in a wide range of applications, where high hardness, high chemical inertness and good dry-running behavior are needed [4]. However, the reliability of any such ta-C coating strongly depends on the stability of the process conditions and the bonding agent being used. Applying PIP preparation TEM lamellae were extracted from different areas of a geometrically complex coating to identify the interface compositions. Depending on the processing parameters, the amorphous nature of the ta-C coating could be realized along the overall coating area whereas in other cases columnar intermediate layers formed in certain areas, where process parameters where difficult to be kept constant due to geometrical discontinuities, see Fig. 1.

The second application example presented here is related to the joining of Al/Cu dissimilar welds - a material combination which has moved into the spotlight with the increasing market for electro-mobility. One of the major drawbacks of this particular material combination is to control the formation of the intermetallic layer which accounts for the material fusion on the one hand, while on the other hand has a negative impact on the ductility and the contact resistance of the dissimilar joint. Once again TEM analysis was the key method to study the microstructural changes depending on the process applied and its parameters. Friction stir welding, laser induction roll plating and electromagnetic pulse welding all achieved subcritical phase seam thickness of less than 1 micron, hence resulting in much lower electric resistance values compared to laser welding or conventional screw joining. TEM analysis allowed to identify the type of intermetallic phases formed during joining, as can be seen in Fig. 2.

The third example presented, is related to the characterization of the precision and quality of microthrough-holes produced in 0.4 mm-thick silicon wafers by applying pulsed laser helical drilling [5]. Extensive SEM and TEM analyses were carried out on systematically varied pulse widths from nanosecond to femtosecond range. It could be shown that smooth holes free of recast and free of thermally and mechanically driven structural damage were realized by using pulses with a width of 10 ps. However, laser helical drilling with ns pulses resulted in thick melt redeposition and microcrack formation, while fs pulses caused detrimental mechanical effects resulting in defect generation, material degradation and a pronounced microroughness.

References

[1] CA Volkert and AM Minor, MRS Bulletin **32** (2007) p. 389.

[2] J Mayer, LA Giannuzzi, T Kamino and J Michael, MRS Bulletin **32** (2007) p. 400.

[3] MP Echlin, MS Titus, M Straw, P Gumbsch, TM. Pollock, Acta Materialia **124** (2017) p. 37.

[4] S Makowski, V Weihnacht, F Schaller and A Leson, Triology International **71** (2014) p. 120.

[5] J Kaspar, A Luft, S Nolte, M Will, E Beyer, Journal of Laser Applications 18/2 (2006) p.85.

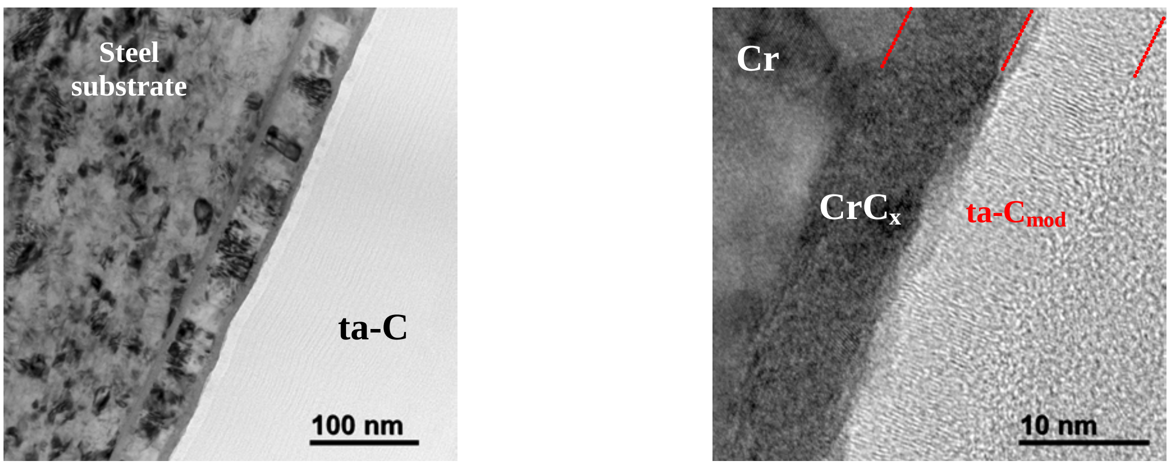

Figure 1. TEM analysis of ta-C coating, revealing transition from substrate to functional ta-C coating: Note the nano-periodic ta-C substructure and the oriented graphen-like structure of the ta-C_{mod} layer.

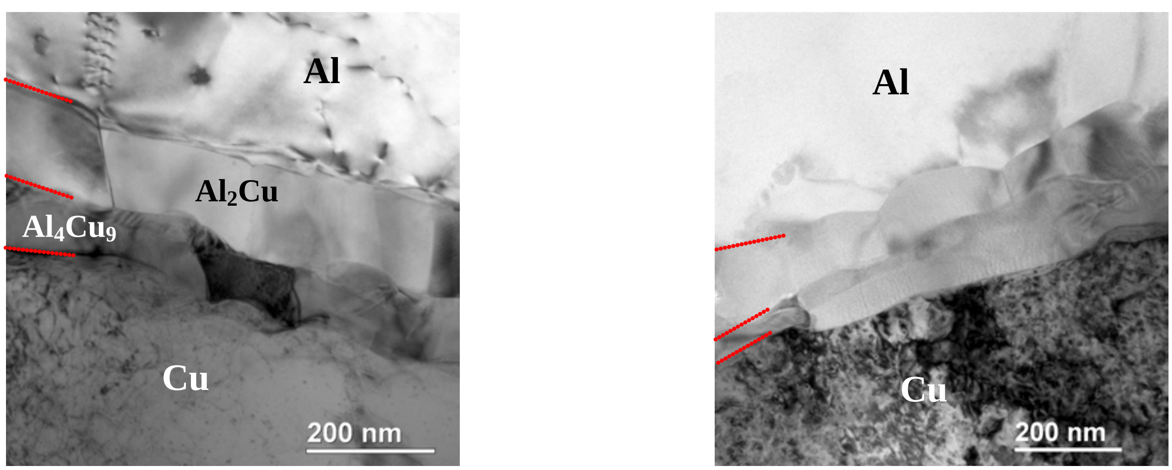

Figure 2. Formation of intermetallic phases in the welding seam a) friction stir welding, b) laser induced roll plating.