Smooth crack-free targets for nuclear applications produced by molecular plating*

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Within the TRAKULA project (**Tra**nsmutationsrelevante **k**ernphysikalische **U**ntersuchungen **l**anglebiger **A**ktinide) high-quality α sources are required for the precise half-life ($t_{1/2}$) measurement of the very long-lived low energy α-emitter ^{144}Nd ($t_{1/2}$ = (2.65 ± 0.37) · 10^{15} y, E_α = 1.85 MeV).

Using a Nd salt, i.e., [$Nd(NO_3)_3 \cdot 6H_2O$], as model electrolyte several constant current density molecular plating (MP) experiments were carried out to investigate the effects of parameters like the plating solvent (isopropanol and isobutanol mixed together -hereafter referred to as IP+IB- and N,N-dimethylformamide -DMF-) and the surface roughness of the deposition substrates (~13 and ~24 nm) on the quality of the produced layers. One of the deposition substrates (Ti-A, average roughness 24 ± 7 nm) was a circular 50 µm-thick Ti foil cut from a bigger foil (Goodfellow), the other (Ti-B, average roughness 12.8 ± 0.7 nm) was produced by coating a 300-µm thick mechanically-polished Si wafer onto which 100 nm of metallic Ti were sputtered. For the MP, 0.338 g of $Nd(NO_3)_3 \cdot 6H_2O$ were dissolved in 20 mL 0.1 M HNO_3. From the solution an aliquot of 100 µL was added to a mixture of 1 mL isopropanol (Fisher Chemical) and 34 mL isobutanol (Applichem), or to 35 mL DMF (Merck), finally yielding 0.22 mM solutions of Nd^{3+} in the deposition cell. The plating solutions were stirred by means of a quartz tip ultrasonic stirrer (Bandelin Sonopuls HD 2070) operated at 30% power pulse. MP experiments were always carried out for 3 h by applying a constant current of 6 mA, corresponding to a current density of 0.7 mA/cm^2 [1].

Gamma-ray spectroscopy was performed after MP of Nd solution containing radioactive ^{147}Nd tracer. The tracer was produced in a (n,γ) reaction on ^{146}Nd present in the used Nd of natural isotopic composition (^{nat}Nd) by irradiating an aliquot of 100 µL of the stock solution with thermal neutrons in the TRIGA Mainz research reactor. A high-purity germanium detector (GEM series HPGe Detector Model No. GEM 23158 P-Plus, ORTEC Company) was used to determine the Nd deposition yield. To obtain quantitative data, reference sources with known amounts of the tracer were prepared. They consisted of filter papers with the same geometry as the targets, soaked with the tracer-containing solution. The yield values were always obtained as the average value calculated from three distinct γ-ray measurements. The measurements always gave quantitative deposition yields: (99.2 ± 1.4)% for targets produced on Ti-B using IP+IB, (98.7 ± 2.8)% and (99.1 ± 2.2)% for targets produced with DMF using Ti-A and Ti-B as deposition substrates, respectively.

The surface roughness of the inactive Nd targets was investigated by using an Atomic Force Microscope (AFM) (MFP 3D, Asylum Research) in tapping mode. Fig. 1a shows the AFM image of the Nd target produced on Ti-B using IP+IB (mean roughness 22 ± 13 nm). Figs. 1b and c show insted the images of the targets produced on Ti-A (b, mean roughness 130 ± 40 nm) and on Ti-B (c, mean roughness 18 ± 9 nm) using DMF. The smoothest deposition substrate grows the smoothest layers even if heavily cracked in the case of IP+IB. DMF is superior to IP+IB as there are fewer cracks present. They are even completely absent when the smoother Ti-B substrate is applied. Substrate roughness and plating solvent are thus key factors for the production of smooth, crack-free targets .

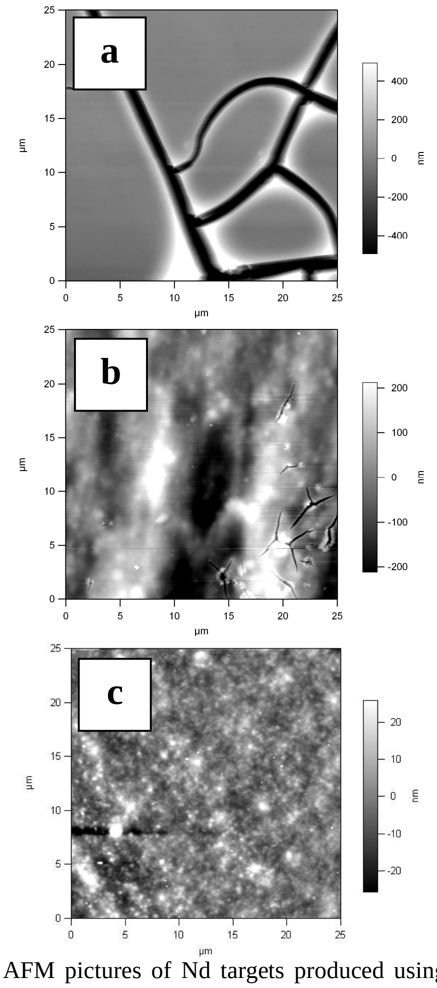

Figure 1: AFM pictures of Nd targets produced using Ti-B and IP+IB (a), Ti-A and DMF (b), and Ti-B and DMF (c).

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References

[1] A.Vascon et al., Nucl. Instrum. Meth. A (2013) accepted