Vasculoy® by MeKo

The Nickel Free Vascular Alloy for Implants

The name **Vasculoy®** is a composition of the words vascular and alloy. MeKo developed this alloy especially for vascular implants. **Vasculoy® is the only nickel free alloy for stents.**

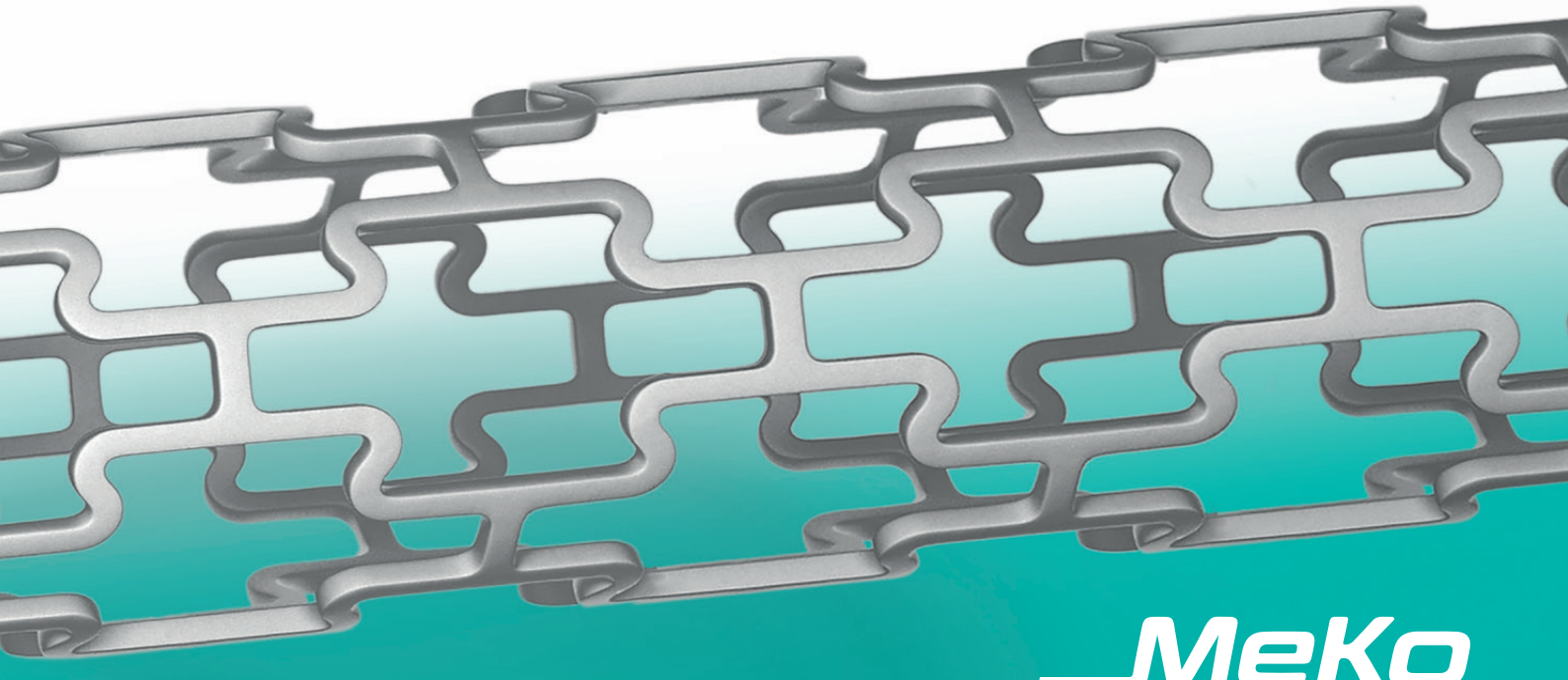
Motivation

Studies show that approximately 13 % of the population are allergic to nickel with a strong upward trend[1]. Individuals who are allergic to nickel, demonstrate a greater restenosis rate[2, 3]. Furthermore, the corrosion products of 316LVM are toxic to the primary culture of vascular smooth muscle cells when the nickel concentration is higher than 11.7 ppm[4].

Due to this general negative effect of nickel, the European Parliament and Council passed the Nickel Directive. It limits the nickel content in products used for epithelialisation after piercing to 0,05 % and the nickel release from objects intended for use in direct and prolonged contact with skin to 0,5 µg cm-2 week-1.

Based on these facts, it is imperative for us to introduce a new nickel free alloy suitable for stents. **Vasculoy®** improves the biocompatibility through freedom of nickel (and freedom of cobalt).

In a superior manner, **Vasculoy®** offers further benefits using the new material for stents.



Mechanical properties of **Vasculoy®**

Mechanical properties including yield strength, ultimate tensile strength and break elongation of **Vasculoy®** are superior to stainless steel 316LVM and comparable to CoCr alloys (such as L605) as shown in diagram 1 and table 1. Thus, **Vasculoy®** facilitates stent designs with thin struts and high flexibility. Stent designs with thin struts show very positive results as proven in several clinical studies[5].

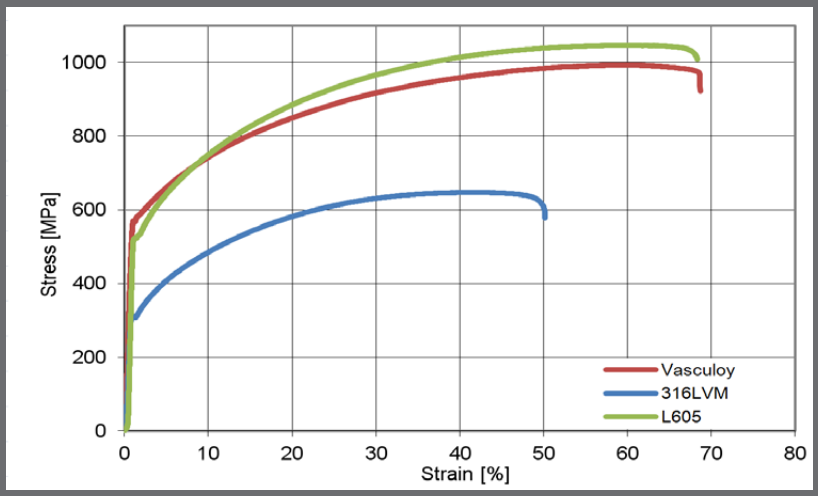


Diagram 1: Stress-Strain curve of **Vasculoy®**

Compared to other nickel free alloys like BioDur108® or P2000®, **Vasculoy®** shows key benefits in the **crimp and dilatation performance**.

The low **spring back** during crimping and low recoil during stent expansion are obtained by a reduced elasticity. With the given Young's modulus for the material the yield strength Rp0,2 has to be reasonably low. The heat treated **Vasculoy®** shows a yield strength of less than 600 MPa in comparison to BioDur108® which yields at approximately 800 MPa.

The recoil of **Vasculoy®** is equal to L605 proven by comparison tests of identical stents.

The **break elongation** At is extremely high for a Ni-free alloy (see table below).

	316LVM	**Vasculoy®**	CoCr - L605
Rp0,2 [MPa]	260 - 390	500 - 600	460 - 650
Rp0,2 [MPa]	570 - 650	920 - 1020	1000 - 1080
At [%]	50 - 60	60 - 65	65 - 70
Young's modulus [GPa]	190	190	240
Grain size [G] (EN ISO 643)	8 - 9	6 - 8	7,5 - 8,5

Table 1: Comparison of mechanical properties

Corrosion resistance of **Vasculoy®**

The chemical resistance (susceptibility to pitting corrosion according to ASTM F2129) of **Vasculoy®** is superior compared to L605 and comparable to 316LVM.

For the corrosion measurements exactly the same stent designs (length and tube dimensions) have been used for the different materials: 316LVM, **Vasculoy®**, L605. Conclusively the results in diagram 2 and table 2 are perfect comparisons 1 to 1.

The **Vasculoy®** curve shows a reduced electrical current (the curve is shifted further to the left side). This means that the metal ion discharge is lower and the vascular reaction will be minimized. Watch the scale - it is logarithmic!

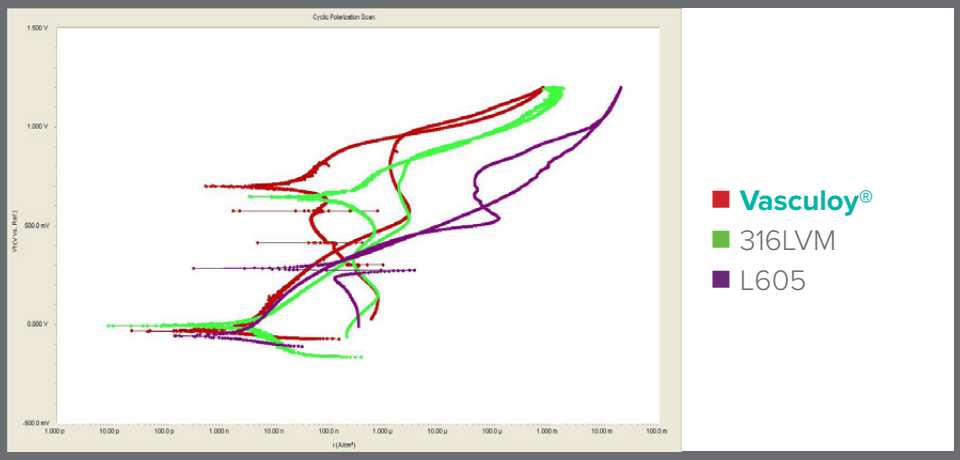


Diagram 2: Cyclic Potentiodynamic Polarisation curves

The **protection potential** is of specific interest for stents. The passive layer of a stent can break during dilatation and has to repassivate in the oxygen free environment of the patient. A high protection potential enables a fast repassivation. For **Vasculoy®** it is even better than 316LVM and superior to L605!

The **break-down potential** of **Vasculoy®** is also better than 316LVM and L605.

The **passive range** determines the electrochemical conditions where the stent shows a passive behaviour. The range is the difference between rest and breakdown potential.

	316LVM	**Vasculoy®**	CoCr - L605
Protection Potential Ep [mV]	859	1040	591
Breakdown Potential Eb [mV]	823	842	769
Passive range [mV]	825	1058	802

Table 2: Comparison of corrosion resistance

MRI compatibility of Vasculoy®

Vasculoy® is tested as MRI safe and MRI compatible according to ASTM.

An implant is **MRI safe** when no risks exist by strong static or alternating magnetic fields. Possible negative impacts are high forces through static magnetic fields or induction heating by alternating magnetic fields.

In addition to being MRI safe, **MRI compatible** implants exhibit no significant affect on the quality of the diagnostic information and the MRI operations. Imaging artifacts should be marginally. Following the ASTM standard F2119 artifacts were measured as “the maximum distance (in mm) from the edge of the implant to the fringe of the resulting image artifact found in the entire set of images acquired using this test method”.

As before, identical stents of 316LVM, **Vasculoy®** and L605 were crimped, dilated and tested per the ASTM standard. The MRI testing results are summarized in Table 3.

According to ASTM F2052 the magnetically induced displacement **force** has to be lower than the gravitational force. The force is measured as the deflection angel of the device in the magnetic field. If the deflection angle is less than 45° the magnetically induced deflection force Fm is less than the force on the device due to gravity. For **Vasculoy®** the force is only 7° and nearly half that of 316LVM.

The radio frequency induced **heating** of all stents was as low as the heating of the phantom (reference part). The measured data even show a lower temperature at the stents. Thus **Vasculoy®** is MRI safe accordingly to ASTM F2182.

The MR Image **Artifacts** were investigated for field strengths of 1.5 Tesla and 3 Tesla in regard to the spin echo artifacts and gradient echo artifacts. The artifacts of **Vasculoy®** are essentially lower in comparison to 316LVM. Although 316LVM stents are known as MRI compatible, the artifacts are reduced up to 55 % by **Vasculoy®**.

The MRI compatibility of **Vasculoy®** is superior to 316LVM and comparable to L605.

	316LVM	**Vasculoy®**	CoCr - L605
Deflection angle [°] by Magnetical Force (3 Tesla)	13	7	5
Radio frequency induced heating [°C] Probe / Reference Probe	0,8 / 0,9	0,7 / 0,8	1,3 / 1,1
MR Image Artifacts 1,5 Tesla Spin - / Gradient echo artifact [mm]	4,7 / 6,4	2,6 / 5,5	3,4 / 4,6
MR Image Artifacts 3,0 Tesla Spin - / Gradient echo artifact [mm]	5,5 / 8,2	4,4 / 6,4	3,8 / 6,0

Table 3: Comparison of the MRI properties

Biocompatibility of Vasculoy®

The biocompatibility of **Vasculoy®** was tested by an accredited institute according to ISO 10993. The investigations included cytotoxicity as well as hemolysis tests and chemical analysis. **Vasculoy®** passed all tests with superior results.

The **cytotoxicity** test was performed with an extract of **Vasculoy®**. In the extract and a control medium, cells of the type L929 were seeded. After incubation, no proliferation inhibition by **Vasculoy®** could be observed.

The **hemolysis** test was also performed with an extract of **Vasculoy®**. In the extract and a control medium, an erythrocyte-suspension was added. No increased hemoglobin release after incubation for 4 hours was induced in presence of the extract.

The **hemocompatibility** was tested under dynamic conditions (modified resonance thrombography). Human blood was incubated in a simulated blood flow in a container with **Vasculoy®** stents and without stents. Afterwards the clotting time of the blood was measured without differences between incubation with or without stents.

Furthermore, the fibrin amplitude and the platelet amplitude were identified for **Vasculoy®** and in comparison for 316LVM stents. There are only little differences between the reference control without stents and the test materials. Rather than a negative effect of the materials, the difference is attributed to turbulences in the blood flow caused by the structure of the stents. The results for both materials are equal.

For the **chemical analyses**, an extract of inorganic leachables of **Vasculoy®** was generated. This extract was analyzed with inductively coupled plasma mass spectrometry (ICP-MS) for all relevant elements. All elements like chrome, manganese and molybdenum were under the limit of quantification.

Chemical analyses of an extract of organic substances was also generated. This extract was analyzed with gas chromatography-mass spectrometry. No organic substances were detectable.

Cytotoxicity test (EN ISO 10993-5)	No Proliferation inhibition
Hemolysis – elution method (EN ISO 10993-4)	No hemolytic effects
Hemocompatibility – dynamic conditions (EN ISO 10993-1)	No activation of the coagulation system
Chemical analysis – quantification of inorganic leachables (EN ISO 10993-1)	No quantificational leachables
Chemical analysis – detection of organic substances (EN ISO 10993-12)	No detectable substances

Table 4: Biocompatibility

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Vasculoy® | For Reduced Restenosis Rates

The **mechanical properties** of **Vasculoy®** offer enhancements over the properties of 316LVM and are comparable to L605. As a matter of principle the recent L605 stent designs can be switched to Vasculoy®. Therefore, stent designs with thin struts, high flexibility and positive clinical results are ensured.

The **corrosion resistance** of **Vasculoy®** is superior to L605 and 316LVM. The Protection Potential, an important attribute for stents, is significantly higher. The reduced ion release of **Vasculoy®** is highly recommended for stents.

Vasculoy® is **MRI compatible.** Compared to 316LVM, the artifacts are reduced by 55%.

The biocompatibility of **Vasculoy®** has been proven with no limitation or restrictions.

Truly nickel free, Vasculoy® is superior to all commonly used implant materials. For nickel-allergic persons the restenosis rate will be reduced.

Vasculoy® is produced utilizing high quality melting processes to assure microstructural integrity and cleanliness. These features facilitate brilliant products with a high-quality surface finish. In combination with the excellent mechanical properties, superior corrosion resistance, MRI-compatibility and unrestricted biocompatibility, outstanding stent performances are ensured, differentiating **Vasculoy®** from other stent materials.

References

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PRECISION IS OUR PROFESSION

MeKo MEDTECH

MeKo Manufacturing e.K.
Im Kirchenfelde 12-14
31157 Sarstedt / Hannover
Germany

+49 5066 7079-0
+49 5066 7079-99
laser@meko.de
www.meko.de