# Creation of nanoporous surface onto Co-Cr by selective plasma etching method for vascular stent application

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**Statement of Purpose**: Stents are intravascular prostheses which provide endoluminal scaffolding, effectively reducing elastic recoil and sealing local dissections. Despite the beneficial effects of stenting, persistent high rates of inflammation, thrombosis, fibromuscular proliferation and formation of restenosis caused by insufficient biocompatibility of metal stent materials remain as a significant clinical challenge [1]. A vascular stent having nanoporous surface was found to promote re-endothelialization to improve overall healing and to reduce inflammation and intimal disease progression at sites of stent [2]. This study was aimed to propose a novel method to create Co-Cr substrate by means of selective plasma etching (SPE).

**Methods:** In the SPE process, high energetic ions bombarded into the substrate by applying extremely high negative substrate bias**,** and selectively etched surface relative to less protective region during sputtering. Co-Cr substrates polished down to 1μm were placed in a vacuum chamber ($5x10^{-4}$ Pa) and cleaned with a argon-based plasma under a negative substrate bias voltage of 600 V for 10 min to remove any residual surface contamination. The Co-Cr substrate was etched with Ta ions by sputtering of a Ta target under extremely high negative substrate bias up to 800V. Fabricated nanoporous surfaces were characterized by SEM and FIB, and their *in vitro* cell attachment behavior using endothelial cell were also examined.

**Results:** The effect of the negative substrate bias on the surface morphology of Co-Cr substrate was examined, as shown in Fig. 1 (a)-(c).
A high negative substrate bias of 400 V allowed to create tiny nanopores with a diameter of ~50 nm. The formation of nanopores became more vigorous with increasing negative substrate bias to 600 V and 800 V with the pore size increased to ~200 nm and ~500 nm, respectively. The development of these nanoporous surfaces is presumably attributed to ion-induced diffusion, phase separation and composition difference leading to etching rate difference of the deposited film. This difference drives the self-organized nanoporous surface formation with a thickness of ~380 nm (Fig. 1(d)).

The chemical composition of the nanoporous Co-Cr surface was characterized by EDS, as shown in Fig. 2. Peaks corresponding to the Co, Cr and Ta elements were observed (Fig. 2), indicating the presence of the Ta in the nanoporous surface. In addition, the Ta element was uniformly distributed throughout the nanoporous surface.

The effect of the creation of the nanoporous Co-Cr surface on the cell behavior was examined by analyzing cell spreading on substrates. The SEM morphologies of endothelial cells adhesion behavior on bare Co-Cr and nanoporous Co-Cr are showed in Fig. 3(a) and (b). The endothelial cells on nanoporous surface were progressively grown and gradually formed a single layer keeping their natural original shape, as seen in Fig. 3(b).

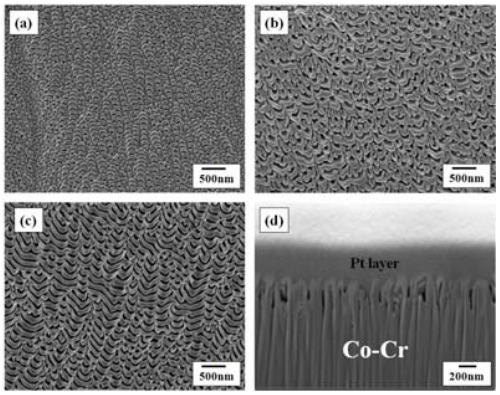


Fig. 1. SEM images showing the surface morphologies of the Co-Cr substrates created by applying various negative substrate bias of (a) 400V, (b) 600V, (c) 800V and (d) the cross-section of the nanoporous surface with 800V substrate bias.

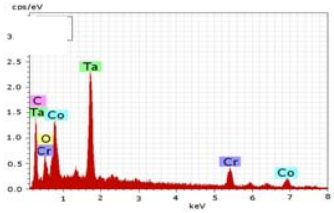


Fig. 2. Typical EDS spectrum of the nanoporous Co-Cr substrate surface.

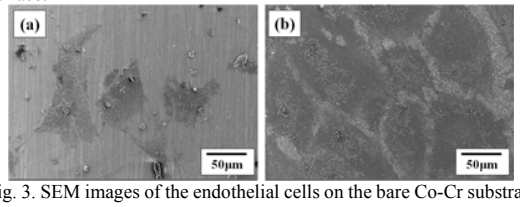


Fig. 3. SEM images of the endothelial cells on the bare Co-Cr substrate (a) and the Co-Cr substrate with the nano- porous surface (b) after 1 day

**Conclusions:** A highly nanoporous Ta-incorporated Co-Cr surfaces were successfully created onto the Co-Cr substrate by SPE process. The dimension and shape of nanoporous structures were varied by changing applied substrate bias voltage. This nanoporous surface remarkably improved endothelial cell adhesion behaviour, which was attributed to the nano-topographic feature and large surface area of the nanoporous surface. These results show that the SPE method is very useful to create nanoporous structure onto Co-Cr, which would possibly overcome current limitations of bare metal stent application.

**Reference**

1. A. Martinez et al. Nanomed Nanobiotec 2011;3:256-268
2. J. Palmaz et al. J Vasc Interv Radiol 1999;10:439-444