INTRODUCTION
The use of non-reflective surfaces in consumer and commercial applications has become increasingly popular. Whether they are used to reduce reflection on a monitor or increase the efficiency of photovoltaic solar cells, the advantages are being recognized and the demand for inexpensive coatings is high. The limitation of these nanostructured surfaces is the length of time required to produce a useable quantity, usually by deposition techniques. This paper describes an improvements made to the nanocoining procedure which increase the quality of indented areas.

The concept is to create non-reflective surfaces through a process called nanocoining. Nanocoining uses a nanostructured diamond die to imprint a structure on to a mold surface. This type of manufacturing requires a high speed actuator to be useful.

A process for creating areas of nanofeatures has been successfully developed. Areas of precisely indexed nano-indents have been created with nanofeatures exhibiting high fidelity. An elliptical tool-path has been developed to match indenter and work-piece velocity and avoid smearing the nanofeatures. However, refinements in this procedure are needed to improve the quality of each indent and thus the overall surface.

INITIAL INDENTATION PROCEDURE
The nanocoining process uses a diamond indenter which has a 20 x 20 µm nanostructured area. The nanostructured area is composed of 1600 250 x 250 x 300 nm (length x width x height) semi-pyramidal features which have 250 nm spacing. The indenter is attached to a PZT driven elliptical actuator whose motion, seen in Figure 1, is a function of the indenter dimensions [1]. The critical dimension is the horizontal amplitude, a, which is a function of the indenter length only.
It was determined through experimentation that materials with high Vickers hardness such as hard plated copper and electroless nickel were less susceptible to sticking to the indenter. The issue of material sticking in the indenter was examined from a geometry point of view as well. The original indenter had square post features which meant the sides of the features were normal to the face of the indenter. A second indenter was created with features which more resembled a pyramid. This introduced a relief angle between the features and the indenter face. Both material and geometry effects were studied to eliminate the detrimental effect of material sticking in-between the nanofeatures resulting in indents as shown in Figure 3.

Indenter Alignment
The second issue is the angular alignment of the indenter face with respect to the work-piece surface. Because the length of the nanostructured surface is 20 µm and the height of the nanofeatures is 300 nm, the indenter must be parallel to within 0.01° so that the depth of the features is constant. An alignment fixture which can rotate the actuator about two axes has been designed and used to create indents. The actuator mounted to the alignment fixture can be seen in Figure 4.

CONCLUSIONS
The use of a diamond indenter to nanocoins sub-micrometer features could be an efficient way to produce large scale quantities of non-reflective, hydrophobic or hydrophilic surfaces. A procedure has shown that indents with well-formed nanostructures can be created at 1 KHz. The indents are indexed precisely in both directions to completely cover the target area. Material sticking to the indenter, depth control and indenter alignment are all issues which have been addressed to create seamless areas of nanostructures.

ACKNOWLEDGEMENT
Principle funding for this research is through the NSF Grant NM-1000055 monitored by Haris Doumanidis.

REFERENCES